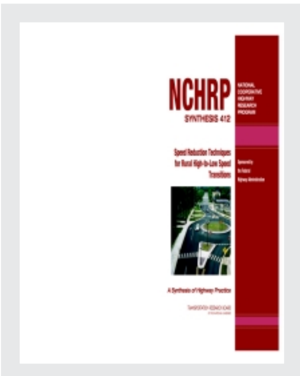


# Speed Reduction Techniques for Rural High-to-Low Speed Transitions

**DETAILS**

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## SYNTHESIS 412

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

# Speed Reduction Techniques for Rural High-to-Low Speed Transitions

Sponsored by the Federal Highway Administration

*A Synthesis of Highway Practice*

TRANSPORTATION RESEARCH BOARD
*OF THE NATIONAL ACADEMIES*

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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# Speed Reduction Techniques for Rural High-to-Low Speed Transitions

## *A Synthesis of Highway Practice*

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**SUBSCRIBER CATEGORIES**
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TRANSPORTATION RESEARCH BOARD

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**Cover figure:** Traffic circle with chicane.

# FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

# PREFACE

*By Jon M. Williams*
*Program Director*
*Transportation*
*Research Board*

Rural settlements may be located on high speed roads. A high-speed road section that approaches the settlement will have lower posted speeds to slow traffic. This road section is known as a *transition zone*. The subject of this study is effective techniques for lowering traffic speeds in rural transition zones. The scope of the study is limited to engineering practices, such as signing, pavement markings, and horizontal and vertical roadway deflections. The study includes North American and European experience.

Information was gathered through a literature review, and surveys of U.S. state and Canadian provincial transportation agencies.

Gerry J. Forbes, Intus Road Safety Engineering, Inc., Milton, Ontario, Canada, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

# CONTENTS

# SPEED REDUCTION TECHNIQUES FOR RURAL HIGH-TO-LOW SPEED TRANSITIONS


## SUMMARY

North America's rural landscape is dotted with isolated settlements, villages, and small towns that are typically located on rural roads where the general speed limit is 55 to 60 mph (90 to 100 km/h). Motorists are expected to slow down as they pass through these settlement areas, reducing their operating speed to 30 or 40 mph (50 or 65 km/h) in sections of road known as *transition zones.* In designating and designing transition zones, the ultimate goal is for motorists to reduce their speed in the transition zone to the point where they reach the lower speed limit at the start of the settled area. However, several factors thwart the goal of using transition zones to reduce driver speeds in settlement areas, including speed adaptation (the tendency for motorists to underestimate their travel speeds after having driven at a higher speed for a prolonged period) and the generally abrupt change from the rural road to the town or village streetscape. As a result, state departments of transportation (DOTs) and other agencies are interested in developing more effective speed reduction techniques for transition zones.

At present, there are no national North American design guidelines for rural speed transitions, except for the general guidance provided on reduced speed ahead signing in the 2003 *Manual on Uniform Traffic Control Devices* (MUTCD). However, most existing transition zone design guidelines from the literature reviewed for this study are generally consistent in providing the following information:

- More extensive and aggressive measures tend to produce greater reductions in speed and crash occurrence than less extensive and passive measures.
- There needs to be a distinct relationship between a settlement speed limit and a change in the roadway character.
- No one particular measure is appropriate for all situations. Each settlement must be assessed and treated based on its own characteristics and merits.
- To maintain a speed reduction downstream of the transition zone, it is necessary to provide additional measures through the village. Otherwise, speeds may rebound to previous levels as soon as 820 ft (250 m) from the start of the lower speed zone.

There is clearly a need for better and more information concerning rural high-to-low speed transitions. This synthesis report is a preliminary step in that direction.

This synthesis is a state-of-the-practice report concerning effective and ineffective rural high-to-low speed transition treatments that have been tried by state DOTs and some overseas agencies. The scope of this research was limited to engineering measures that are used to transition motorists from high-to-low speed areas, and does not include the broader topics of speed management or the more specialized techniques and methods required for areas such as work zones, toll plazas, and school zones.

Literature in the subject of rural speed transition zones is not extensive. It is sometimes difficult to identify measures that are specific to transition zones, as researchers do not always distinguish between speed changing measures and speed maintaining measures. In general, research has shown that although engineering measures are effective at reduc-

ing speeds and crashes, and public acceptance of rural traffic calming measures is high, the effects of transition zone treatments are not sustained beyond the urban-rural threshold without additional downstream measures. The reported crash reduction factors have been quite significant, although methodological shortcomings with some of the studies may lead researchers to overestimate their effectiveness. With respect to the design of transition zones, there needs to be greater attention to treating the transition zone as the length of road rather than a specific point of speed change.

Current information on high-to-low speed transitions was compiled through a literature review and a 42-question survey that was distributed to United States and Canadian traffic engineering personnel. Together, the practitioner survey and the literature review provide a comprehensive snapshot of the state of the practice concerning rural high-to-low speed transitions. Thirty-six U.S. state DOTs responded to the survey, a 72% response rate. The survey of practice revealed that most jurisdictions do not have a set or standard approach to transition zone treatment. Those that do are typically applying traffic control devices according to the state *MUTCD*, which involves advance signing of a lower speed limit and/or posting of a stepped-down or intermediate speed limit to mitigate an abrupt change in speeds. The most frequently mentioned conditions that would prompt consideration of enhanced transition zone measures are a poor crash record, public opinion, access density, and a significant drop in the posted speed limit. Most state and provincial respondents agree that vertical deflections (e.g., speed humps and raised intersections) and removal of traffic control devices are inappropriate measures for speed transition zones. Between 40% and 50% of state/provincial respondents have never tried any geometric design, surface treatment, or roadside measures outside of what might be considered the standard approach. Although practitioners generally recognize that traffic signing alone is an ineffective method of managing speed, respondents are reluctant to experiment with more aggressive and physical measures.

At present, there is an interesting bifurcation between the North American and European approaches to speed management and road safety in small towns, settlements, and villages. Most effectiveness studies on transition zone treatments and traffic calming in rural areas have been conducted in Europe, and several European countries are currently experimenting with minimizing and removing traffic control and adding design features that physically separate road user types. These approaches attempt to create a measure of uncertainty in the driving environment that reduces operating speeds and requires motorists to pay closer attention to the driving task. This approach has not been specifically linked to transition zones, but it is in stark contrast to the North American approach to speed management, which has been to add measures. The results of these experiments are very preliminary, but should be monitored. The lessons learned from foreign testing might be used as a starting point for a North American effort into this important area of research.

CHAPTER ONE

# INTRODUCTION

## BACKGROUND

Speeding—either exceeding the posted speed limit or traveling too fast for ambient conditions—is a major contributing factor to traffic crashes in North America. In 2008, speeding was a contributing factor in 31% of all fatal crashes, and 11,674 lives were lost in speeding-related crashes. The National Highway Traffic Safety Administration (NHTSA) estimates that the economic cost to society of speeding-related crashes is $40.4 billion per year (NHTSA 2009).

Speeding in urban areas, towns, villages, and other settlements is both a safety and a quality of life issue. It is well documented that higher speeds increase the severity of crashes, particularly in crashes with pedestrians and cyclists, and conventional wisdom also suggests that increased speed increases the likelihood of a crash (SWOV 2009). This latter observation is at least in part the result of longer distances traveled during perception-reaction times and the narrowing of the visual field at higher speeds, which makes detection of objects in the periphery more difficult.

One of the areas where speeding may be particularly problematic is on the approaches to urban areas from rural areas, where motorists are expected to lower their operating speed from 55 or 60 mph (90 or 100 km/h) to 30 or 40 mph (50 or 65 km/h). These approaches are often called transition zones. A transition zone is a section of road that is continuous with and connects a road section with a high posted speed to a road section with a lower posted speed limit. The transition zones limits are usually defined in the field by either the limits of the intermediate speed limit(s), or the location of the reduced-speed-ahead sign (if an intermediate speed limit is not present from the location of the first lower speed limit).

The phenomenon known as speed adaptation—the tendency for motorists to underestimate their travel speeds after having driven for a long time at a significantly higher speed—may cause motorists to travel faster than they should upon entering the urban area. Researchers have confirmed that during any trip, previous driving at a higher speed for an extended period results in motorists having difficulty in adjusting to a lower speed (Schmidt and Tiffin 1969; Denton 1976; and Matthews 1978). In fact, in an examination of transition zones in Australia, Tziotis (1992) found that the injury-producing crash rates on these approaches are significantly greater than those of rural roads. Similarly, Ossenbruggen et al. (2001) studied speeds in rural settlements and concluded that a lack of respect for posted speed limits appears to translate into high multivehicle crash rates on posted “low-speed sections” of road.

North America’s rural landscape is dotted with isolated villages, settlements, and small towns that are typically located on high-speed rural roads. As traffic enters the settlement area a conflict is created, whereby the mobility function of the road is shared with the need to provide access to adjacent lands. A similar concern is present when a highway transitions from a rural to an urban/suburban area. The safety issues respecting rural settlements are at least threefold:

- Speed—Motorists traveling at high speeds on the rural roads that lead to rural settlements often do not slow down in the settlement area.
- Access Density—The access density (intersections and driveways) in rural settlements is higher than the surrounding rural area and increases crash risk.
- Road users—Pedestrian and cyclist activity is increased in the rural settlements.

Separately and collectively, speed, access density, and vulnerable road users significantly increase crash risk in rural settlements, and are therefore worthy of consideration. This report addresses the speed concern, and in particular engineering and infrastructure solutions to the speed concern, at rural-urban transitions. Physical changes to the roadway and its ancillary devices are favored methods of treatment because they typically have permanent and lasting effects, as opposed to enforcement and education, which are typically transient and less effective.

In addition to the speed adaptation phenomenon, inadvertent speeding in villages may also be exacerbated by the generally abrupt change from the adjoining rural zone to the town or village streetscape. The urban zone is typically differentiated from the rural zone by changes in land use and in the physical features of the road. Until relatively recently, the transition zone has not usually been thought of as a distinct zone and has not been consciously designed. In most instances, the transition zone is simply a length of rural roadway that is immediately upstream of and adjoining the urban area where the speed transition is expected to occur.

Speeds on the approaches to villages and urban areas could be better managed if a properly constructed transition zone was introduced. A rural high-to-low speed transition may be defined as a section of road on the approach to a village, settlement, or urban area from a rural area, over which it is expected that motorists will slow down from the higher speeds associated with rural travel to a speed that is commensurate with the urban area. These transitions are also known as urban/rural thresholds.

At present, there are no design guidelines for rural speed transitions except for the general guidance provided on reduced-speed-ahead signing in the *Manual on Uniform Traffic Control Devices (MUTCD)* (FHWA 2003). Figure 1 shows images of the suggested signing. The *MUTCD* also mentions that a stepped-down speed limit may be more appropriate than a sudden more significant speed reduction.


FIGURE 1 Reduced speed ahead signs [*Source*: FHWA (2003)].

The lack of guidance for practitioners on speed transition zone design is echoed in a recent document that states "[o]ne type of corridor segment that is too often not given the attention it deserves is the 'transition area' between the town center and its rural surroundings" (Puget Sound Regional Council 2004).

Various road authorities have attempted to manage travel speeds through these settlements by implementing a variety of traffic calming techniques and transitional highway designs. Although states such as Iowa, Minnesota, and Oregon have researched some of their speed transition experiences, the success of the various schemes is largely unpublicized; therefore, the traffic engineering community in North America is still uncertain about the efficacy and applicability of engineering measures to transition speed. The European and United Kingdom (U.K.) experiences are better documented, but are largely unknown to North American practitioners. There is clearly a need for more and better information concerning rural high-to-low speed transitions.

## SYNTHESIS OBJECTIVES

This synthesis is a state-of-the-practice report concerning effective and ineffective treatments that state departments of transportation (DOTs) and some overseas agencies have tried for rural high-to-low speed transitions. This report provides information on the state of the practice concerning engineering measures that are used to successfully transition motorists from high-to-low speed areas, identifies unfulfilled needs and knowledge gaps, and identifies design guidance from leading practitioners in the field. The primary audience for this synthesis is DOT personnel involved in speed management, and highway design and traffic operations personnel who have a role in managing speed on the approaches to villages. However, as speed management is a multiple stakeholder activity, policymakers and practitioners from other government agencies and organizations, as well as interest groups and volunteers, may also be interested in this synthesis.

## STUDY APPROACH

The scope of this research was limited specifically to engineering measures that are used to transition motorists from high-to-low speed areas. It therefore focused primarily on DOTs and county governments that design and operate high-speed rural road systems. It does not include the broader topic of speed management as it pertains to enforcement, education, and awareness initiatives, or selecting a target speed. Nor does it include techniques and methods used to transition motorists from high-to-low speed conditions in specialized areas such as work zones, toll plazas, and school zones.

A 42-question survey was distributed to U.S. and Canadian traffic engineering personnel. The questions were designed to gather information on standard engineering approaches to treating rural high-to-low speed transitions, to obtain information on enhanced or innovative engineering methods, and to obtain case study information including effectiveness measures. The survey also sought to identify techniques that had been used and found ineffective in transitioning speeds. All the states, the District of Columbia, Puerto Rico, and the 10 provinces and three territories of Canada were invited to participate in the survey. The survey was available as a web survey hosted on the TRB website, as an MS-Word™ template, and as a paper copy. Each nonresponding jurisdiction was sent a reminder note 2 days before the specified deadline for responses. Subsequent to the deadline for submissions, all nonresponding jurisdictions were contacted by telephone in an effort to obtain a survey response, and deadline extensions were permitted to increase the response rate. The survey was also made available to county road agencies through the National Association of County Engineers.

A comprehensive literature review of American and international sources was also conducted to assist in establishing practices that have been and are being pursued with respect to speed management at high-to-low speed transitions in rural areas. The literature review encompassed engineering and infrastructure techniques and measures including guidelines and manuals, evaluations of effectiveness, and documented case studies.

The practitioner survey and the literature review provide a comprehensive snapshot of the state of the practice concerning rural high-to-low speed transitions, and identify both knowledge gaps and trends and patterns concerning successful practices.

## REPORT ORGANIZATION

The first chapter of this synthesis report contains introductory information, including background, objectives, and scope. Chapter two is a literature review, which was conducted to identify available techniques, guidelines, and evaluations concerning rural high-to-low speed transition areas. Chapter three documents the survey process and results obtained. Chapter four highlights the existing engineering measures for treating high-to-low speed transitions in a toolbox format. Chapter five summarizes the synthesis findings and conclusions, including future research that may be considered to understand the extent and usefulness of speed management strategies performed by state DOTs in rural high-to-low speed transition areas.

CHAPTER TWO

# LITERATURE REVIEW

Literature in the field of speed and speed management is abundant. However, the applicability of this literature to rural speed transition areas is limited. Even in the literature about rural traffic calming or traffic calming in small towns and villages, it is sometimes difficult to identify measures that are specific to transition zones as researchers do not always distinguish between speed maintaining measures (located in the village) and speed changing measures (located in the transition zone).

The literature may be broken down into the following broad categories: effectiveness/evaluation studies and guidance/standards/recommended practices. The literature research focused on the former category but includes some important documents from the latter category as well. In this section, the effectiveness/evaluation studies are presented first, followed by the recommended practices and guidelines. The effectiveness studies are organized by measure of effectiveness (i.e., effect on operating speed or crash risk). The manuals and guidelines are organized by continent.

## EFFECTIVENESS STUDIES

### Speed Studies

*Van Houten and Van Houten (1987)*

Van Houten and Van Houten (1987) conducted an experiment to examine the efficacy of a roadside sign with the legend "BEGIN SLOWING HERE" on vehicle speeds at the start of a new speed zone. The study site was an approach to an urban area where a four-lane facility with a speed limit of 50 mph (80 km/h) transitioned to a two-lane facility with a speed limit of 30 mph (50 km/h). Speeds were recorded at the start of the 30 mph (50 km/h) speed zone.

The test sign was a rectangular sign with a white background and black lettering, and a black arrow that pointed down at 45 degrees to the roadway. The sign was placed 280 ft (86 m) upstream of the start of the 30 mph (50 km/h) speed zone. The standard advance warning sign for a reduced speed limit was also present, upstream of the experimental sign.

The measures of effectiveness included the percentage of vehicles traveling above 35 mph (60 km/h). The study employed baseline speed measurements, followed by speed measurements with the subject sign in place, followed by speed measurements with the experimental sign removed, and finally a fourth measurement when the sign was reintroduced. The results were as follows:

- During the baseline measurement, the percentage of vehicles exceeding 35 mph (60 km/h) was 45.8%.
- After implementing the sign for the first trial, the above percentage dropped to 37.4%.
- During the interim baseline, the percentage of vehicles exceeding 35 mph (60 km/h) rebounded to pretest levels.
- During the second implementation of the sign, the subject percentage dropped to 33.8%.

The researchers concluded that the effectiveness of the sign is the result of the clear direction provided to the motorist, whereas the standard reduced-speed-ahead sign simply provides nonspecific advice on where to slow down.

*Herrstedt et al. (1993)*

Herrstedt et al. (1993) examined and documented the effects of a wide variety of traffic calming measures on operating speeds in Denmark, France, and Germany. The examples that are presented refer to several locations where measures were used on a highway that runs "through a town," with associated data provided. Table 1 presents examples where the text mentioned a "gateway" or "portal" of a highway traversing a town, suggesting some treatment at the high-to-low speed transition.

The measures that were implemented clearly demonstrated effectiveness in managing speeds—an 11% reduction in mean speeds, and a 15% reduction in the percentage of motorists traveling faster than 35 mph (60 km/h). However, although the data showed impressive improvements in speed management, the information is of limited value. First, it is uncertain where the speed measurements were taken. Second, it is not possible to tease out the effects of the high-to-low speed transition treatment from the effects of the "in town" measures that were also employed. However, these examples underscore the effectiveness of providing a complete solution to the speed management issues of small towns—that is, providing a well-designed rural-urban transition and carrying the measures through the town for a sustained speed reduction.

TABLE 1
TRAFFIC CALMING EFFECTS FOR TRANSITION ZONES IN DENMARK, FRANCE, AND GERMANY

| Town | Before | | | | | After | | | | | Change | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Speed Limit | Speed | | Crash Rate+ | | Speed Limit | Speed | | Crash Rate | | Speed | | Crash Rate | |
| | mph (km/h) | Mean mph (km/h) | % > 35* | Injury | All | mph (km/h) | Mean mph (km/h) | % > 35* | Injury | All | Mean | % > 35* | Injury | All |
| Åbenrå | 30 (50) | 35 (58) | 41 | 1.64 | 4.48 | 30 (50) | 32 (54) | 21 | 1.21 | 2.40 | –7% | 20 | –26% | –46% |
| Vinderup | 35 (60) | 31 (51) | 20 | 1.87 | 3.46 | 25 (40) | 25 (42) | 3 | 0.56 | 1.83 | –18% | 17 | –70% | –47% |
| Tinglev | 35 (60) | 44 (73) | 92 | 1.48 | 3.11 | 30 (50) | 35 (58) | 80 | 1.40 | 2.46 | –21% | 12 | –5% | –21% |
| Vipperød | 35 (60) | — | — | 1.02 | 1.17 | 30 (50) | — | — | 0.50 | 0.76 | — | — | –51% | –35% |
| Tarm | 30 (50) | 23 (39) | — | 0.60 | 0.80 | 20 (30) | 22 (36) | | 0.50 | 1.00 | –8% | — | –17% | 25% |
| Skægkær | 35 (60) | 38 (63) | 26 | 1.32 | 1.93 | 30 (50) | 35 (59) | 14 | 0.76 | 1.03 | –6% | 12 | –42% | –46% |
| Nøvling | 30 (50) | 32 (54) | — | 0.70 | 1.00 | 25 (40) | 29 (49) | — | 0.00 | 0.50 | –9% | — | –100% | –50% |
| Arnage (France) | — | — | — | — | 0.63 | 25 (40) | — | — | — | 0.21 | — | — | — | –67% |
| Average | | | | | | | | | | | –11% | 15 | –44% | –36% |

*% > 35 = Percentage of vehicles traveling faster than 35 mph (60 km/h).
+Crash rates are reported as annual crashes per million vehicles.

*County Surveyors' Society (1994a)*

The County Surveyors' Society (1994a) of the U.K. reported the results of an investigation into the costs, benefits, and effectiveness of measures for managing vehicular speeds in villages. The analysis consisted of before-after studies in 24 villages, using 85th percentile speed and resident opinion surveys as measures of effectiveness. The number of sites was limited by the project budget, and sites were selected to provide a range of village size, road classification, traffic volume, and calming measures. Of the 24 sites, 11 sites had traffic calming on the approach to the village, four sites had traffic calming within the village, and nine sites had traffic calming on the approach and within the village. Ten of the sites were on roads of "high" priority.

The researchers did not collect crash data, as the small numbers available in the short after period were thought to be unreliable indicators of effectiveness. Instead, they collected data on speed, volume, and public opinion as measures of effectiveness. Speed and volume measurements were taken continuously for at least 1 week in the before and after periods; the after period was generally 1 or 2 months after installation.

The results indicated that small expenditures (i.e., simple gateways) provide small reductions in speed [about 3 mph (5 km/h) or less], whereas significant speed reductions [6 mph to 10 mph (10 to 16 km/h)] accompanied more comprehensive/expensive treatments (i.e., gateways and measures in the village). Table 2 shows the results presented by the researchers. One of the main conclusions on effectiveness was that there needs to be a distinct and evident relationship between the change to the village speed limit and a change in the road environment.

TABLE 2
TRAFFIC CALMING EFFECTS ON 85TH PERCENTILE SPEED IN THE UNITED KINGDOM

| Inbound at Gateway | | In Village | |
|---|---|---|---|
| No Measures in the Village | Measures in the Village | No Measures in the Village | Measures in the Village |
| a) Up to 3 mph (4.8 km/h) | — | a) Up to 4 mph (6.4 km/h) | d) Up to 3 mph (4.8 km/h) |
| b) Up to 7 mph (11.2 km/h) | e) Up to 9 mph (14.4 km/h) | b) Up to 5 mph (8.0 km/h) | e) Up to 10 mph (16 km/h) |
| c) Up to 10 mph (16 km/h) | f) Up to 12 mph (19.2 km/h) | c) Up to 6 mph (9.6 km/h) | f) Up to 12 mph (20.8 km/h) |

a. Gateway signing, minor marking.
b. Gateway signing with significant marking/colored surface and minor narrowing.
c. Significant physical restriction at gateway.
d. No gateway treatment.
e. Gateway with significant signing/marking at it or in advance of it.
f. Significant physical restriction at gateway.

With respect to resident opinions, the five surveys revealed generally strong support for the speed management measures. One-third to one-half of the residents believed that traffic had slowed down. The majority of residents wanted more to be done.

The study concluded that there is no inexpensive and singular device that will have a significant and lasting effect on speeds, and that traffic calming measures and other engineering changes to encourage speed compliance are appropriate for villages.

*County Surveyors' Society (1994b)*

The County Surveyors' Society (1994b) of the U.K. also collected and summarized data on numerous traffic calming installations in the U.K. The intentions of this effort were to provide practitioners with a snapshot of traffic calming in the U.K., and to detail a number of case studies so that practitioners might better understand what plans and measures work and do not work in different situations. In all, 85 case studies were documented in the report, with 25 cases classified as traffic calming on rural roads/areas.

Table 3 summarizes the effects of traffic calming on the 25 rural case studies. It is noted that all of the traffic calming was implemented for one or more of the following objectives: reduce speed, reduce crash occurrence, and reduce through traffic. However, the measures implemented at each of the sites were not implemented for the same reasons and are not of the same form (i.e., humps versus narrowings). Therefore, this analysis is necessarily general.

This research indicated that traffic calming on rural roads has a positive impact on speeds. The average speed reduction was almost 5.4 mph (9 km/h). Twenty-three of the 25 sites reported before-after speed data, and all sites experienced a speed reduction following the introduction of traffic calming. However, the speed limit at each site was not reported, so it is perhaps more appropriate to indicate that there was a 21% reduction in speeds.

The data contained in the report do not indicate whether the rural road is a primary route or a local road. If the "before" traffic volume is used as a surrogate for road classification, for the eight sites with daily traffic volumes greater than 10,000 (which are assumed to be primary routes or arterial roads) the average speed was reduced by 4.5 mph (7.5 km/h) or 16%. These data indicate that traffic calming on the higher volume roads was effective at speed control, but not as effective as traffic calming placed on lower volume roads.

*Pyne et al. (1995)*

Pyne et al. (1995) conducted driving simulator experiments to test the effectiveness of a variety of measures for reducing speeds on undivided, rural, arterial roads, including on the approaches to villages. The measures of effectiveness included effect on speed (at the start, in the middle, and at the end of the village) and lateral position. The experiment was conducted in two phases: Phase 1 tested a variety of transition area measures, and Phase 2 examined variations on and combinations of the most effective treatments. Figure 2 shows the high-to-low speed transition measures evaluated in Phase 1, and Figure 3 shows the treatments evaluated in Phase 2.

Table 4 shows the range of speed changes caused by the various treatments examined in the Phase 1 research.

The changes in the mean and 85th percentile speed were relatively small for all measures tested. Using a system for ranking treatments based on a combination of mean speed and 85th percentile speed, Pyne et al. determined that at the start of the village transverse lines were the most effective measure, followed by Wundt illusion, countdown speed signs, central hatching with no road narrows sign, the chicane, and the speed limit on the road surface, in that order. The only treatment that produced speeds that were statistically significantly different from speeds in the control run was the transverse lines.

Table 5 shows the range of speed changes caused by the various treatments combined and examined in the Phase 2 research.

The combined treatments used in the Phase 2 research produced lower speeds than those treatments used in Phase 1. Again, using the ranking system that combines effectiveness in reducing mean speed and 85th percentile speed, the measures that were most effective at the start of the village are V2.17, V2.19, and V2.20. The hazard marker posts (V2.03) and the speed limit on the road surface (V2.05) did not have a significant effect on speed at any of the three points. Also, the chicane without hatching (V2.08) produced speeds significantly different from the control at all three locations, but the chicane with hatching (V2.07) did not. The researchers posit that this is probably because the travel lane was less obvious without hatching.

Pyne et al. concluded that the most effective combination of treatments for the high-to-low speed transition zones was the chicane without hatching, associated with countdown speed limit signs on the approach to the village, followed by transverse markings throughout the village. This combination of measures produced the "best" reduction in operating speeds at all three locations through the village.

*Barker and Helliar-Symons (1997)*

Barker and Helliar-Symons (1997) examined the effects of two different low-cost engineering measures designed to alert drivers to a downstream lower speed limit, in hopes of effecting greater compliance with speed limits. The first

TABLE 3
THE EFFECTS OF TRAFFIC CALMING ON RURAL ROADS IN THE UNITED KINGDOM

| Case | Descriptions | Traffic (ADT) | | Speed in mph (km/h) | | | Crashes (injury crashes/year) | | Crash Rates (annual injury crashes/TVD)* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Change | Before | After | Before | After |
| 1 | Narrowings, temporary material on a trial basis | 4,000 | 5,000 | 47 (75) | 35 (56) | –12 (–19) | 1.8 | 1 | 0.45 | 0.20 |
| 2 | Gateway features, traffic islands, markings, and speed roundels | 2,000 | 2,000 | 44 (70) | 36 (58) | –8 (–13) | 0.7 | 1.5 | 0.35 | 0.75 |
| 3 | Gateway signing | 6,900 | 6,900 | 40 (64) | 38 (61) | –2 (–3) | 2.3 | 2 | 0.33 | 0.29 |
| 4 | Speed camera with a gateway added later | 17,500 | 17,500 | 47 (75) | 41 (66) | –6 (–10) | 1.3 | 1 | 0.07 | 0.06 |
| 5 | 40 km/h zone | — | — | — | — | — | — | — | — | — |
| 6 | Give way narrowings, series of round and flat top humps, bus route | 1,700 | 1,500 | 37 (59) | 27 (43) | –10 (–16) | 2.7 | 0.3 | 1.59 | 0.20 |
| 7 | Traffic islands and chicanes with bypasses for cyclists | 10,600 | 11,300 | 47 (75) | 41 (66) | –6 (–10) | 5.7 | 2.7 | 0.54 | 0.24 |
| 8 | Gateway effect with central island located on entry to village | 2,900 | 2,900 | 38 (61) | 35 (56) | –3 (–5) | 0.3 | 0 | 0.10 | 0.00 |
| 9 | Narrowings, speed tables, throttle humps, mini roundabout | 7,300 | 6,850 | 35 (56) | 24 (38) | –11 (–18) | 2.8 | 1 | 0.38 | 0.15 |
| 10 | Narrowings, castellated surfacing, gateways | 2,000 | 1,800 | 42 (67) | 39 (62) | –3 (–5) | 0.7 | 0 | 0.35 | 0.00 |
| 11 | Mini roundabout, road humps, narrowing | 7,100 | 7,100 | 31 (50) | 16 (26) | –15 (–24) | 2 | — | — | — |
| 12 | Mini roundabouts, raised speed tables, narrowings | 7,100 | 7,100 | 31 (50) | 22 (35) | –9 (–14) | 2 | — | — | — |
| 13 | Gateways, refuges, chicanes, mini, closure | 10,000 | 10,000 | 47 (75) | 34 (54) | –13 (–21) | 3.7 | 0 | 0.37 | 0.00 |
| 14 | Reduced number of lanes, refuges, cycle lanes | 9,400 | 9,400 | 60 (96) | 53 (85) | –7 (–11) | 5 | 2.4 | 0.53 | 0.26 |
| 15 | Flat top humps, minis, refuges, landscaping | 8,500 | 9,800 | 45 (72) | 27 (43) | –18 (–29) | 5 | 0 | 0.59 | 0.00 |
| 16 | Gateways, chicanes, textured surfaces, and street lighting | 13,500 | 13,500 | 40 (64) | 35 (56) | –5 (–8) | 3 | 2.4 | 0.22 | 0.18 |
| 17 | Narrowings, gateways, lighting improvements, signs, and markings | 10,200 | — | 51 (82) | 44 (70) | –7 (–11) | 10.7 | 8 | — | — |
| 18 | Road humps, mini roundabouts | 8,400 | 6,300 | 37 (59) | 28 (45) | –9 (–14) | 4 | 1.7 | 0.48 | 0.27 |
| 19 | Gateways, refuges, rumble strips, signs, markings | 550 | 550 | 49 (78) | 41 (66) | –8 (–13) | 3.7 | 1 | 6.73 | 1.82 |
| 20 | Jiggle bars | — | — | 48 (77) | 39 (62) | –9 (–14) | — | — | — | — |
| 21 | Narrowing, cycle track, hatched central reserve | 11,350 | 11,350 | 56 (90) | 44 (70) | –12 (–19) | 4.3 | 4.6 | 0.38 | 0.41 |
| 22 | Road humps, narrowing, chicane | 5,000 | 3,600 | — | — | — | 0.3 | 0 | 0.06 | 0.00 |
| 23 | Road humps, mini roundabouts, 30 mph speed limit | 1,300 | 1,080 | 40 (64) | 25 (40) | –15 (–24) | 0.3 | 0 | 0.23 | 0.00 |
| 24 | Gateways, mini roundabouts, road humps | 10,100 | 10,100 | 42 (67) | 39 (63) | –3 (–5) | 1.3 | 0.8 | 0.13 | 0.08 |
| 25 | Edge and center markings and road studs to narrow traveled way | 10,100 | 10,100 | 40 (64) | 32 (51) | –8 (–13) | 1.3 | 0 | 0.13 | 0.00 |
| Average | | | | | | –8.7 (–14) | | | 0.70 | 0.24 |

*TVD = thousand vehicles per day.

**Village Treatments — Phase One**

V1.01Village sign and speed limit sign 150m from start of buildings, urban centre line (1m mark, 5m gap) and continuous edge lines between speed limit signs, otherwise rural centre lines (2m mark, 7m gap), edge lines with 1m mark and 3.5m gap (control and practice).

All the following have edge and centre lines and signs as for control unless otherwise stated. Treatments involving narrowing also have the appropriate road narrows sign 150m before start of narrowing. Any central areas, shoulders and the chicane are delineated by continuous lines. All treatments start on the approach to the village and continue through it unless otherwise stated.

V1.02Trees at roadside, on both sides, on approach to village.
V1.03Broken centre lines with lines getting progressively closer together up to start of village, then gap remains constant size through village.
V1.04Centre line with 2m mark and 2m gap.
V1.05Wundt illusion on approach to village (chevrons across entire width of road, chevrons get less sharp as approach start of village)
V1.06Transverse line across lane with reducing spacing on approach to village.
V1.07Hazard marker posts with 10m spacing on both sides of approach to village.
V1.08Chicane, delineated by hatched areas.
V1.09Road narrowing by nearside parking bay, and delineated by line with 1m mark and 1m gap.
V1.10Road narrowing by central hatched area, with road narrows sign.
V1.11Road narrowing by central hatched area, without road narrows sign.
V1.12Road narrowing by central area with transverse lines with reducing spacing.
V1.13Road narrowing by shoulder with hatching.
V1.14Road narrowing by shoulder with transverse lines.
V1.15Street lights.
V1.16SLOW on road surface alongside village sign.
V1.17Speed limit on road surface alongside village sign (circular sign).
V1.18Count down speed limit signs.

FIGURE 2 Transition zone treatments evaluated in Phase 1 research [*Source*: Pyne et al. (1995)].

**Villages — Phase Two**

Treatments in italics were used in phase one.

*V2.01Village sign and speed limit sign 150m from start of buildings, urban centre line (1m mark, 5m gap) and continuous edge lines between speed limit signs, otherwise rural centre lines (2m mark, 7m gap), edge lines with 1m mark and 3.5m gap (control and practice).*

All the following have edge and centre lines and signs as for control unless otherwise stated. Treatments involving narrowing also have the appropriate road narrows sign 150m before start of narrowing. Chicanes and narrowing are delineated by continuous white lines.

*V2.02Hazard marker posts 10m spacing.*
V2.03Hazard marker posts reducing spacing. Hazard marker posts on both sides of carriageway between speed limit signs and start of buildings, as above, but getting closer together as approach start of buildings. Use same spacing as for transverse lines if possible. Road markings as for V2.01.
*V2.04Countdown speed limit signs.*
*V2.05Speed limit on road surface (circular sign).*
V2.06Countdown speed limit signs on posts and speed limit on road surface (i.e. as V2.04 + V2.05)
*V2.07Chicane with hatching.*
V2.08Chicane without hatching (i.e. as V2.07 but no hatching).
*V2.09Yellow transverse lines with reducing spacing, between speed limit signs and start of buildings.*
V2.10White transverse lines with reducing spacing, between speed limit signs and start of buildings, (i.e. as V2.09 but white transverse lines).
V2.11Yellow transverse lines with reducing spacing between speed limit signs and start of buildings (as V2.09), then with constant spacing through village which stop at end of buildings.
*V2.12White Wundt illusion between speed limit signs and start of buildings.*
V2.13Yellow Wundt illusion between speed limit signs and start of buildings (i.e. as V2.12 but yellow Wundt illusion lines).
V2.14Yellow Wundt illusion between speed limit signs and start of buildings, then straight lines with constant spacing (same spacing as for transverse lines) through village which stop at end of buildings.
V2.15Chicane without hatching, plus yellow transverse lines. Transverse lines are between white lines delineating chicane only. Transverse lines reduce in spacing between speed limit signs and start of buildings, then have constant spacing through village and stop at end of buildings (i.e. V2.08 + V2.11), but transverse lines do not go all the way across the lane.
V2.16As V2.15 but with hazard marker posts with 10 m spacing (i.e. V2.15 + V2.02).
V2.17As V2.15 but with countdown speed limit signs (i.e. V2.15 + V2.04).
V2.18As V2.15 but with speed limit on the road surface (i.e. V2.15 + V2.05).
V2.19As V2.15 but with hazard marker posts, countdown speed limit signs and speed limit on the road surface (i.e. V2.15 + V2.04 + V2.02 + V2.05).
V2.20As V2.19 but without chicane (i.e. V2.19 - V2.08).
V2.21Wundt illusion in yellow as V2.14. Also countdown speed limit signs, hazard marker posts with 10 m spacing and speed limit on the road surface (i.e. V2.14 + V2.02 + V2.04 + V2.05).

FIGURE 3 Transition zone treatments evaluated in Phase 2 research [*Source*: Pyne et al. (1995)].

measure was a speed limit roundel marking—elongated circles with the speed limit in the center, laid in the white markings on the road surface in the middle of the travel lane. The second measure was countdown signs—a standard speed limit sign together with three, two, and one black diagonal bars on a white background mounted below the speed limit sign (see Figure 4) and respectively placed 985, 655, and 330 ft (300, 200, and 100 m) from the start of the reduced speed limit.

TABLE 4
RANGE OF SPEED REDUCTIONS IN SIMULATED TRANSITION ZONES (PHASE 1)

| | Mean Speed mph (km/h) | 85th Percentile Speed mph (km/h) |
|---|---|---|
| Start of Village | –2.3 to +1.2 (–3.7 to +1.9) | –3.0 to +2.1 (–4.8 to +3.4) |
| Middle of Village | –1.4 to +0.3 (–2.2 to +0.5) | –2.8 to +1.6 (–4.5 to +2.6) |
| End of Village | –1.7 to +0.1 (–2.7 to +0.2) | –9.4 to +5.0 (–15.0 to +8.0) |

TABLE 5
RANGE OF SPEED REDUCTIONS IN SIMULATED TRANSITION ZONES (PHASE 2)

| | Mean speed mph (km/h) | 85th Percentile Speed mph (km/h) |
|---|---|---|
| Start of Village | –4.2 to –1.1 (–6.7 to +1.8) | –7.2 to –2.9 (–11.5 to +4.6) |
| Middle of Village | –3.0 to +0.5 (–4.8 to +0.8) | –4.1 to +1.1 (–6.6 to +1.8) |
| End of Village | –3.4 to –0.6 (–5.4 to +1.0) | –6.7 to +2.0 (–10.7 to +3.2) |

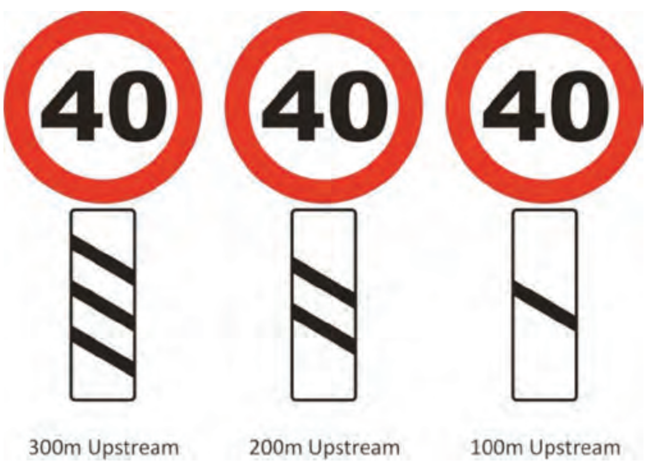



FIGURE 4 Countdown speed signs [*Source*: Barker and Helliar-Symons (1997)].

The roundels were field-tested at 12 villages, and the countdown signs were field-tested at five villages. After studies were conducted from 1 week to 12 months after installation. The research conclusions were as follows:

- Roundels used on the approach to 40 mph (65 km/h) speed limits produced a 3 mph (5 km/h) mean speed reduction.
- Roundels used on the approaches to 30 mph (50 km/h) speed limits did not have a significant effect on mean speeds.
- The countdown speed signs did not have a significant effect on mean speeds.
- Owing to the small sample size, the effects of either measure on crashes are inconclusive.

*Farmer et al. (1998)*

In a trial of speed feedback signs placed at entrances to six rural villages in Norfolk, England, Farmer et al. (1998) used mean and 85th percentile speeds recorded at the signs and in the center of the village to determine effectiveness. Speeds were assessed 1 month, 6 months, and 12 months after installation. The results show that both the mean and 85th percentile speeds show a sustained reduction at the signs, with the mean speed reduction over all sites of 4.3 mph (6.9 km/h). A smaller effect was noticed in the center of the village.

*Berger and Linauer (1998)*

Berger and Linauer (1998) examined the effects of gateway treatments on five two-lane roads at the transition from rural to urban areas in Austria. The treatments were raised islands placed in between the two travel lanes that were supplemented with appropriate signs and markings. Four different island designs were used, each intending to provide some degree of road narrowing (by dividing the two lanes) and deflection. The island shapes are shown in Figure 5.

The study methodology was a before-after analysis of mean, 85th percentile, and maximum observed speeds recorded near the town sign (which presumably is proximate to the island). The results are shown in Table 6.

Not surprisingly, the incidence of speed reduction increased as the deflection increased. These results were used to develop the following regression models relating the island shape and expected speed:

Metric:

$V85 = 14.797\text{Ln}(L/2d) + 19.779 \qquad R^2 = 0.9098$

$V_m = 12.907\text{Ln}(L/2d) + 17.753 \qquad R^2 = 0.9693$

Where: $V85$ = 85th percentile speed (km/h)

$V_m$ = mean speed (km/h)

$L$ = length of island + length of both tapers (m)

$d$ = lateral deflection of lane (m)

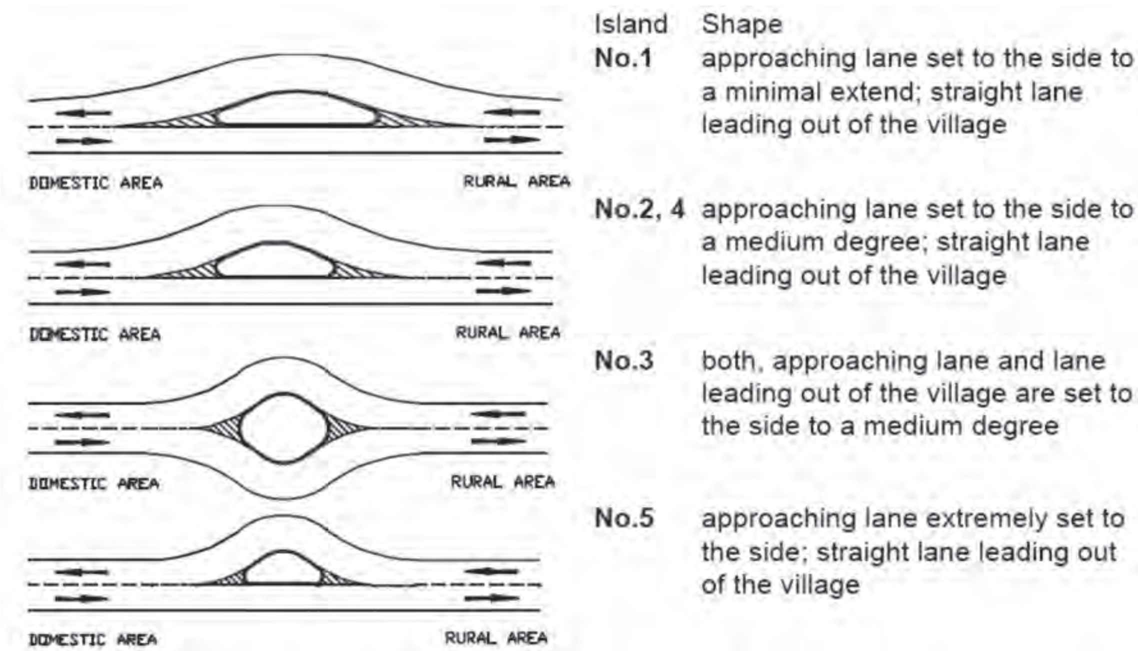



FIGURE 5 Raised islands at city limits [*Source*: Berger and Linauer (1998)].

TABLE 6
SPEED EFFECTS OF GATEWAY TREATMENTS IN AUSTRIA

| Speed* | Period | Island Design Type (see Figure 5) | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Mean | Before | 32.4 (54.0) | 34.8 (58.0) | 36.0 (60.0) | 39.0 (65.0) | 39.0 (65.0) |
| | After | 32.5 (54.1) | 29.0 (48.4) | 26.5 (44.1) | 28.3 (47.2) | 24.1 (40.1) |
| | Change | 0% | –17% | –27% | –27% | –38% |
| 85th Percentile | Before | 37.2 (62.0) | 40.2 (67.0) | 42.0 (70.0) | 45.6 (76.0) | 46.2 (77.0) |
| | After | 36.6 (61.0) | 32.7 (54.5) | 30.3 (50.5) | 33.1 (55.2) | 26.8 (44.6) |
| | Change | –2% | –19% | –28% | –27% | –42% |
| Maximum | Before | 42.0 (70.0) | 52.8 (88.0) | 51.6 (86.0) | 57.0 (95.0) | 58.2 (97.0) |
| | After | 45.7 (76.2) | 35.6 (59.3) | 33.7 (56.1) | 39.5 (65.8) | 28.1 (46.9) |
| | Change | +9% | –33% | –35% | –31% | –52% |

*All speeds in mph (km/h).

U.S. Customary:

$$V85 = 9.194\text{Ln}(L/2d) + 12.290$$

$$V_m = 8.020\text{Ln}(L/2d) + 11.031$$

Where: $V85$ = 85th Percentile speed (mph)

$V_m$ = mean speed (mph)

$L$ = length of island + length of both tapers (ft)

$d$ = lateral deflection of lane (ft)

The authors note that Island Design No. 3 has additional advantages of—

- Requiring motorists to reduce speed just prior to leaving the urban area (which may promote a uniform, lower speed throughout the urban area), and
- Preventing motorists entering the urban area from using the opposing lane (anecdotal observations).

*U.K. Department of the Environment, Transport and the Regions (undated)*

Subsequent to a 1994 report on speed control in villages, the U.K. Department of the Environment, Transport and the Regions (undated) commissioned a study on comprehensive traffic calming schemes in villages, particularly on trunk (i.e., major) roads. To qualify for the study, sites required traffic volumes of at least 8,000 vehicles per day, of which 10% were heavy vehicles. The objective of the study was to assess whether traffic calming could be implemented that would reduce the 85th percentile speed of vehicles to the speed limit. Nine sites were reviewed, with six of the sites receiving a speed limit reduction concurrently with the installation of traffic calming. Table 7 presents the site characteristics.

Speed studies were conducted before, 1 month after, and 12 months after the installation of traffic calming measures. Table 8 shows the effects of the traffic calming on mean and 85th percentile speeds at the gateways and within the village. The following conclusions were reached:

TABLE 7
CHARACTERISTICS OF VILLAGE TRAFFIC CALMING ON MAJOR ROADS

| Site | Daily Volume | Proportion of Heavy Vehicles (%) | Village Population | Speed Limit, mph (km/h) | |
|---|---|---|---|---|---|
| | | | | Original | New |
| 1 | 11,500 | 18 | 400 | 60 (100) | 40 (65) |
| 2 | 5,500 | 10 | 5,400 | 30 (50) | 20 (30) |
| 3 | 9,000 | 15 | 1,900 | 40 (65) | 30 (50) |
| 4 | 9,000 | 16 | 350 | 30 (50) | 30 (50) |
| 5 | 8,000 | 16 | 1,200 | 40 (65) | 30 (50) |
| 6 | 17,000 | 10 | 3,900 | 30 (50) | 30 (50) |
| 7 | 17,000 | 15 | 150 | 60 (100) | 40 (65) |
| 8 | 13,000 | 20 | 2,200 | 30 (50) | 30 (50) |
| 9 | 16,500 | 18 | 3,370 | 50 (80) | 40 (65) |

- Speed reductions were achieved at all of the gateways.
- The mean after speeds were close to the speed limits, but the 85th percentile speeds remained considerably above the speed limit.

*Alley (2000)*

Alley (2000) assessed the effectiveness of different gateway treatments typically found on New Zealand roads using a driving simulator, with mean speed as the measure of effectiveness. He categorized the treatments as narrowings, raised traffic islands, and oversized speed restriction signs. The report also specified that the implementation of these measures across New Zealand has met with varying levels of success, including at least one situation where operating speeds actually increased.

Alley used a human factors approach to developing transition zone measures and hypothesized that the effectiveness of the speed reduction is related to an increase in the local edge rate presented to a motorist passing through the transition zone. The local edge rate is the number of elements (edges) that pass a stable reference point within the optical field in 1 second, such as the rate at which utility poles pass the A-pillar as one drives down the road. Translating this hypothesis to transition zone treatments, Alley proposed that the more elements that are introduced into the transition zone, the more effective the speed reduction, because the increased edge rate will increase the perception of speed.

Two experiments were undertaken to test the hypothesis. (The Alley research actually includes four experiments, but the first two experiments were used to validate the driving simula-

TABLE 8
MEAN AND 85TH PERCENTILE SPEEDS—BEFORE AND AFTER SCHEME INSTALLATION (MPH)

| Site | New Speed Limit (mph) | N/W Gateway (inbound) | | | | | | S/E Gateway (inbound) | | | | | | In Village (mean of both directions) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before | | After1* | | After2* | | Before | | After1 | | After2 | | Before | | After1 | | After2 | |
| | | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile | Mean | 85th %ile |
| 1 | 40 | 43 | 48 | 40 | 44 | | | 46 | 52 | 42 | 47 | | | 40 | 45 | 38 | 42 | | |
| 2 | 20 | 33 | 39 | 23 | 29 | 25 | 30 | 36 | 43 | 24 | 32 | 25 | 31 | 30 | 36 | 21 | 27 | 22 | 28 |
| 3 | 30 | 41 | 49 | 33 | 39 | 33 | 40 | 42 | 49 | 33 | 40 | 33 | 41 | 34 | 39 | 28 | 32 | 27 | 30 |
| 4 | 30 | 41 | 48 | 28 | 33 | 33 | 39 | 39 | 46 | 31 | 36 | 32 | 37 | 31 | 36 | 29 | 32 | 28 | 31 |
| 5 | 30 | 38 | 43 | 31 | 37 | 31 | 35 | 37 | 42 | 34 | 40 | 32 | 37 | 39 | 44 | 33 | 37 | 34 | 39 |
| 6 | 30 | 39 | 45 | 39 | 49 | 37 | 44 | 43 | 49 | 39 | 45 | 37 | 44 | 35 | 41 | 36 | 41 | 34 | 39 |
| 7 | 40 | 48 | 56 | 42 | 49 | 40 | 50 | 53 | 63 | 48 | 53 | 50 | 55 | 51 | 58 | 41 | 46 | 41 | 47 |
| 8 | 30 | 46 | 53 | 37 | 44 | 36 | 41 | 42 | 49 | 33 | 41 | 31 | 37 | 39 | 44 | 32 | 37 | 31 | 34 |
| 9 | 40 | 42 | 48 | 37 | 41 | 38 | 43 | 46 | 52 | 40 | 45 | 38 | 43 | 41 | 46 | 38 | 43 | 39 | 44 |
| Avg. | | 41.2 | 47.7 | | | 34.1 | 40.3 | 42.7 | 49.4 | | | 34.8 | 40.6 | 37.8 | 43.2 | | | 32.0 | 36.5 |
| Change | | | | | | 17% | 16% | | | | | 19% | 18% | | | | | 15% | 16% |

* "After1" are speeds measured about 1 month after installation, and "After2" are speeds measured about 12 months after installation.
%ile = percentile.

tor as a viable representation of real life driving.) In the first experiment, 31 participants of varying age and driving experience were asked to drive through five different urban/rural thresholds, each treated with different engineering measures on a two-lane rural road. The five thresholds are as follows:

1. Conventional speed-restriction signs placed on the right and left sides of the road, denoting the reduced speed limit of 45 mph (70 km/h).

2. All measures in Alternative 1, plus painted hatching on the paved shoulder, and a “half-pinch” (the edge lines on both sides of the road are deflected toward the centerline to slightly narrow the travel lanes).

3. All measures in Alternative 2, plus a narrow painted median to further reduce the lane width.

4. All measures in Alternative 3, plus roadside traffic islands consisting of raised curbs on the previously paved shoulder.

5. All measures in Alternative 4, except the speed-restriction signs are replaced with oversized speed-restriction signs.

The presentation order of the five alternatives was random. The urban area had a 45 mph (70 km/h) speed limit and was 0.6 mile (one km) long. Speed measurements were reported for five locations: 820 ft (250 m) upstream of the threshold (in the rural zone), at the threshold, and 820 ft (250 m), 1,640 ft (500 m), and 2,460 ft (750 m) downstream of the threshold (in the urban area). The results are shown in Figure 6.

There was no significant difference between the approach speeds at 820 ft (250 m) upstream of the threshold for all five alternatives, demonstrating that the participants were approaching each threshold at the same speed. At the threshold and 820 ft (250 m) downstream of the threshold, Alternative 5 produced the lowest speeds of any of the alternatives (as expected). The alternative that produced the next lowest speeds at these locations is Alternative 1: the conventional speed signs. This aforementioned result was not expected, as the hypothesis suggests that the recorded speeds should decrease as the alternative number increases. It is interesting to note that the full reduction in speed is not realized until 1,640 ft (500 m) past the gateway/threshold.

In the second experiment, the researcher removed information concerning the speed limit from the scenarios to investigate the effects of gateway shape and size and lateral placement on operating speed in the vicinity of the transition zone. The threshold alternatives examined were:

1. One oversized sign placed on the right side of the road;

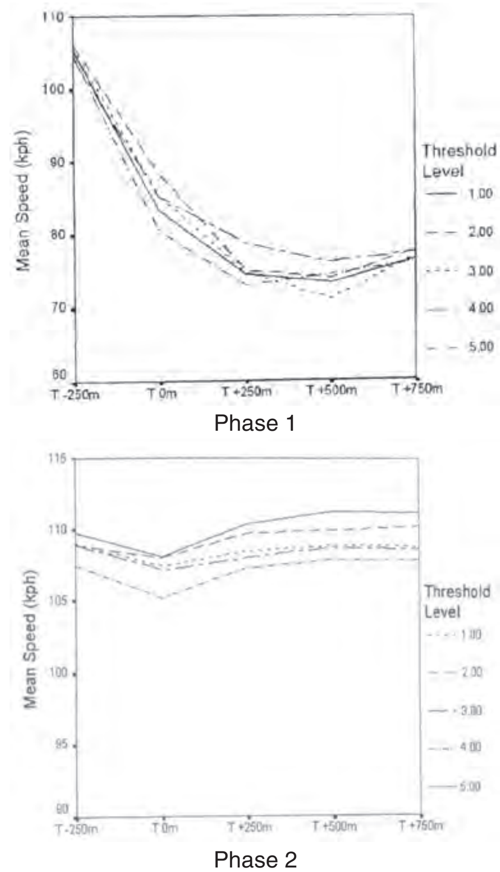



FIGURE 6 Effect of perceptual measures in New Zealand [*Source*: Alley (2000)].

2. Oversized signs placed on both sides of the road;

3. The same as Alternative 2, but reducing the width between the curbs from 28.1 ft to 22.8 ft (8.56 m to 6.94 m);

4. The same as Alternative 2, but with a different sign shape; and

5. The same as Alternative 4, but reducing the width between the curbs from 28.1 ft to 22.8 ft (8.56 m to 6.94 m).

In the second experiment, the researcher removed information on the speed limit from the scenarios to investigate the effects of gateway shape and size and lateral placement on operating speed in the vicinity of the transition zone. The same threshold alternatives from the first experiment were examined.

Figure 6 also shows the results of the simulator testing on speeds upstream, downstream, and at the gateways. Alternatives 3, 4, and 5 showed small but significant speed reductions [less than 1.5 mph (2.5 km/h)] at the gateway. However, at 820 ft, 1,640 ft, and 2,460 ft (250 m, 500 m, and 750 m) downstream of the gateway, speeds measured for all threshold designs were not significantly different than the upstream speeds. In comparing the measured speeds between alternatives, there were no consistent patterns or trends to suggest any of the gateway designs was more effective than the others. However, the removal of the urban speed limit information seems to have eliminated the gateways' downstream effects on speed.

Although the order of presentation for threshold alternatives was counterbalanced in both experiments, the researchers examined and found that the likelihood of a participant decelerating for the gateway decreased as the presentation order increased. In other words, repeated exposure to gateways seems to lessen the desired effect of the gateway on speed. This habituation effect is consistent with an unreferenced study cited by Alley, where a gateway at the high-to-low speed transition on a state highway in New Zealand achieved a 6.2 mph (10.4 km/h) reduction in the average speed 6 months after installation, but only a 3.3 mph (5.2 km/h) reduction 12 months after installation.

*Winnett and Wheeler (2002)*

Winnett and Wheeler (2002) conducted an evaluation of the effectiveness of vehicle-activated signs (VAS) in reducing speeds and crashes in the U.K. One type of VAS evaluated was a dynamic speed limit sign (a "speed roundel") for speed limit changes, employed mainly at village sites on rural, undivided roads (see Figure 7).


FIGURE 7 Vehicle-activated speed signs [*Source*: Winnett and Wheeler (2002)].

Sites were selected for VAS implementation if they had a recent history of crashes in which inappropriate speed was a contributory factor or a record of excessive speed for the conditions was believed to be a potential problem. Sites selected for evaluation also required suitable sight lines to the VAS by the approaching driver, as well as traditional traffic control devices (i.e., fixed signs and markings) that were in compliance with the applicable standards. The VAS implemented was a speed roundel, the U.K. equivalent to the SPEED LIMIT SIGN (R2-1), that was blanked out and activated by motorists exceeding the speed limit. Some of the roundels were supplemented with flashing beacons. All of the VAS were located 66 ft to 164 ft (20 m to 50 m) downstream of the beginning of the speed limit change (i.e., within the village speed limit).

With respect to speed data, the first after data were collected about 1 month after the VAS became operational. To establish whether any speed changes were sustained, further data collections were made 1 year after the VAS were placed in operation, and for some sites additional data were collected 3 years after installation. A minimum of 7 days' continuous data were collected at each site in both the before and after periods. Speeds were collected at or immediately downstream of the VAS. The primary measure of effectiveness for speed is the percentage of vehicles exceeding the speed limit. Table 9 shows the study results.

VAS on the approach to reduced speed limits for villages appeared to be very effective in reducing speeds; in particular, they were capable of reducing the number of drivers who exceed the speed limit, without the need for enforcement such as safety cameras. Moreover, there was no evidence that drivers became less responsive to the signs over time, even over 3 years.

*Hildebrand et al. (2004)*

Hildebrand et al. (2004) examined the effectiveness of transitional speed zones in rural areas in New Brunswick, Canada. The intent of the study was to determine if tempering large changes in the posted speed limit [25 mph (40 km/h)] with an intermediate posted speed limit was more effective than an abrupt change alone. Six sites with transitional speed limits were compared with seven sites without transitional speed limits, using mean speed, percentage exceeding the speed limit, and speed dispersion as measures of effectiveness. The study concluded that the transitional speed limits did not have any significant impact on speed.

*Agustsson (2005)*

Agustsson (2005) reported on the effectiveness of "environmentally friendly through-roads," which are streets where traffic is managed by using different forms of speed-reducing measures. Twenty-one of these newly developed roads were implemented to reduce speed, increase safety, and improve road design. The measures used included gates, roadside reservations, medians, roundabouts, raised areas, changes in road surface, road markings, signing, lighting, road closures, rumble strips, and bicycle lanes. The average length of the through-road is about 0.6 mile or 1 km (it is not clear if this was the total length of the road or the length of the road that was treated, although it is expected that it is the latter).

TABLE 9
SUMMARY OF SPEED REDUCTIONS AT ROUNDEL SIGNS

| Speed Limit | No. of Sites | Mean Speed, mph (km/h) | | | Change in Percent Exceeding Speed Limit | |
|---|---|---|---|---|---|---|
| | | Average Before | Average After | Average Change | Maximum for Group | Minimum for Group |
| 30 mph (50 km/h) | 17 | 34.5 (55.2) | 30.0 (48.0) | –4.5 (–7.2) | –51 | –15 |
| 40 mph (65 km/h) | 5 | 38.2 (61.1) | 35.1 (56.2) | –3.1 (–5.0) | –12 | –1 |
| 20 mph (30 km/h) where a 30 mph (50 km/h) speed limit existed before the trial | 6 | 31.1 (49.8) | 24.9 (39.8) | –6.2 (–9.9) | –58 | –38 |
| 30 mph (50 km/h) where a 40 mph (65 km/h) speed limit existed before the trial | 7 | 39.7 (63.5) | 30.8 (49.3) | –8.9 (–14.2) | –80 | –50 |
| 50 mph (80 km/h) | 1 | 52.0 (83.2) | 47.9 (76.6) | –4.1 (–6.6) | –51 | –15 |
| All | 36 | 39.1 (62.6) | 33.7 (53.9) | –5.4 (–8.6) | –80 | –1 |

The evaluation indicated that the average speed was reduced in the near-term and remained lower by 6 mph (10 km/h), a 17% reduction. However, Agustsson noted that there was a large variation in effectiveness depending on where and which type of traffic measure was used. The effect of the environmentally friendly through-roads on the speed profile was equally impressive (see Figure 8). The percentage of motorists traveling in excess of the speed limit was more than halved, from 75% to 36%.

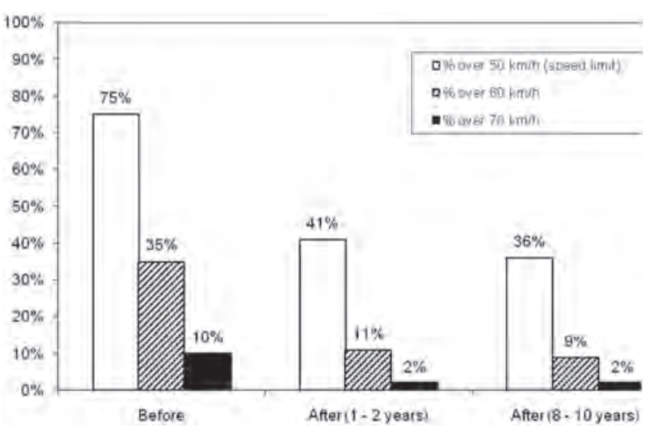
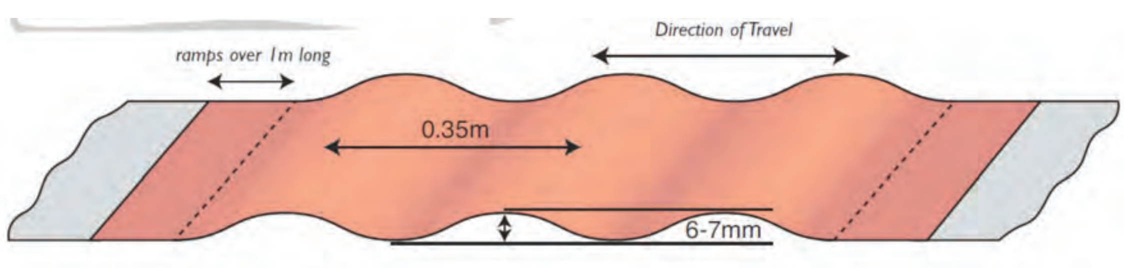



FIGURE 8 Effect of environmentally adapting roads on speed profile [*Source*: Agustsson (2005)].

*Department for Transport (2005)*

The U.K. Department for Transport (2005) developed and tested a quieter alternative to conventional transverse rumble strips known as a rumblewave surface. The rumblewave surface delivers the auditory and tactile stimulus to vehicle occupants in an attempt to elicit a slower travel speed, but does not generate as much ground vibration or noise for the surrounding community. The recommended profile for a rumblewave is shown in Figure 9. A profile with a wave length of 1.1 ft (0.35 m) and a wave height of about one quarter of an inch (6 or 7 mm) is recommended, as this profile produces the largest increases in interior noise and vibration for a range of vehicle types but creates little increase in exterior noise levels. The final layout of the surface would be determined by local conditions.

Rumblewave surfaces were piloted at seven locations, including a high-to-low speed transition, as shown in Table 10. The measures of effectiveness for the pilot program were mean and 85th percentile speeds, and personal injury crashes. The speed results are shown in Table 11 and indicate that both the mean and the 85th percentile speeds exhibited reductions at all pilot locations. In the worst case, the reduction was only 1%; in the best case, reductions of 5% and 6% were measured. No statistical tests of significance were presented.




*Note: This diagram is not to scale, the typical number of corrugations in a 22m section would be 57.*

FIGURE 9 Rumblewave surface [*Source*: Department for Transport (2005)].

TABLE 10
RUMBLEWAVE PILOT LOCATIONS

| Site | Problem | ADT | Speed Limit mph (km/h) | Rumblewave Sections | | |
|---|---|---|---|---|---|---|
| | | | | No. of Sections | Length feet (m) | Spacing feet (m) |
| 1 | Horizontal curve | 4,200 | 30 (50) | 1 | 66 (20) | N/A |
| 2 | 40 to 30 mph speed limit change on a semi-urban, major road | 9,200 | 40–30 (65–50) | 1 initially, 1 8 months later | 72 (22) | 328 (100) |
| 3 | Low speed limit with no other calming | 1,300 | 20 (30) | 4 | 39, 56, 2x72 (12, 17, 2x22) | 184–302 (56–92)* |
| 4 | High vehicular, pedestrian, and cyclist volumes, and a high crash rate | 21,500 | 30 (50) | 9 | 7x39, 49, 59 (7x12, 15, 18) | 0–643 (0–196)* |
| 5 | Residential area with schools and shops, shortcutting, and a high crash rate | 4,100 | 30 (50) | 6 | 2x33, 39, 49, 2x56 (2x10, 12, 15, 2x17) | 272–686 (83–209)* |
| 6 | High to low speed rural transition | 3,600 | 60–40 (100–65) | 2 | 72 (22) | 164 (50) |
| 7 | Residential area close to road, high crash rate | 9,600 | 30 (50) | 5 | 26, 2x39, 2x72 (8, 2x12, 2x22) | 302–804 (92–245)* |

*Depending on intersections.

TABLE 11
EFFECTS OF RUMBLEWAVE SURFACES ON OPERATING SPEEDS

| Site | Mean Speed | | | 85th Percentile Speed | | |
|---|---|---|---|---|---|---|
| | Before mph (km/h) | After mph (km/h) | Change (%) | Before mph (km/h) | After mph (km/h) | Change (%) |
| 1 | 31.0 (49.6) | 30.6 (49.0) | 1 | 36.3 (58.1) | 35.8 (57.3) | 1 |
| 2 | 37.1 (59.4) | 36.3 (58.1) | 2 | 42.1 (67.4) | 41.5 (66.4) | 1 |
| | | 35.7 (57.1) | 4 | | 41.3 (66.1) | 2 |
| 3 | 26.8 (42.9) | 25.1 (40.2) | 6 | 33.5 (53.6) | 32.4 (51.8) | 3 |
| 4 | 29.5 (47.2) | 27.6 (44.2) | 6 | 34.7 (55.5) | 32.8 (52.5) | 5 |
| 5 | 28.5 (45.6) | 27.1 (43.4) | 5 | 34.2 (54.7) | 32.7 (52.3) | 4 |
| 6 | 38.9 (62.2) | 38.2 (61.1) | 2 | 44.4 (71.0) | 44.8 (71.7) | 1 |
| 7 | 32.1 (51.4) | 31.9 (51.0) | 1 | 37.3 (59.7) | 36.7 (58.7) | 2 |

*Kennedy (2005)*

As part of a larger study concerning psychological traffic calming, Kennedy (2005) experimented with village traffic calming in a small village in the U.K. The main street through the village was a wide and straight two-lane road with just under 2,000 vehicles per day, a 40 mph (65 km/h) speed limit, and a crash-free history (the rural speed limit was not mentioned). The measures applied at the transition zone were stone gateways with a village name plate and speed limit signs showing a new speed limit of 30 mph (50 km/h), build-outs at the side of road preceded by hatching, and removal of the directional dividing line. Complementary measures were installed throughout the village to assist in managing speeds downstream of the gateway. Additionally, the gateway was moved closer to the built-up area, to better emphasize the start of the village. Speed measurements taken proximate to the gateways revealed that mean speeds were reduced by 4 to 8 mph (6.5 to 13 km/h) to 37 mph (59 km/h), with similar decreases in the 85th percentile speeds.

*Forbes (2006)*

Forbes (2006) conducted a retrospective, observational before-after study of the safety effects of traffic management in rural settlements located on rural arterial roads. The study involved a literature review and some original research using data collected from several small developed areas in Ontario, Canada. The new research documented the types of measures implemented and their efficacy related to crash risk and speed management. Twelve treatment sites were selected by convenience. Speed of travel was evaluated using 85th percentile speed, mean speed, percentage of vehicles exceeding the speed limit, and speed variance as the metrics. Table 12 shows the sites used in the analysis and the data available at each site.

TABLE 12
SITES SELECTED FOR ANALYSIS

| Settlement | Treatment | Data Available |
|---|---|---|
| Ashburn | Edge line | Speed |
| Claremont | Edge line | Speed |
| Epsom | No passing zone | Speed |
| Sandford | CSZ, no parking in front of school, and gateway signing | Speed |
| Kilbride | Pavement narrowing through markings, roadside posts, sections of textured pavement | Crash |
| Alberton | Speed limit reduction | Crash |
| Kirkwall | Speed limit reduction | Crash |
| Belfountain | Lanes narrowed by pavement markings, and “SLOW” marked on pavement in 5 locations | Speed |
| Palgrave | Gateway signing, and some minor signing | Speed |
| Terracotta | Lanes narrowed by pavement markings, “road watch” program initiated, and raised reflective markers added | Speed |
| Laskay | Gateway signing and posted speed reduction | Crash & speed |
| Udora | Gateway signing | Crash & speed |

At the nine sites where speed data were available, the traffic management measures were successful in reducing mean and 85th percentile speeds, and increasing speed compliance, with a few explainable exceptions. The average reduction in the 85th percentile speed was 3.6 mph (6 km/h). Overall, the results indicated that traffic management in rural settlements in Ontario was effective in managing speed. However, the results should be viewed with some caution as the sample sizes were small, the treatments applied at each site varied considerably, and there may have been co-interventions that contributed to the improvements (i.e., increased awareness and enforcement that are unaccounted for in the analysis).

*Quimby and Castle (2006)*

Quimby and Castle (2006) investigated the effects of simplified streetscapes on operating speeds. As the name implies, simplified streetscapes are projects that reduce visual clutter and complexity, usually through the removal of unnecessary street furniture and signs. In the most radical projects, the simplified streetscape includes the removal of signs and markings as well as physical separations between modes of transport in order to create driver uncertainty and reduce operating speeds. This research only marginally relates to speed management in rural areas through two reported projects. First, the village of Starston in the U.K. demonstrated that removal of the directional dividing line resulted in a 7 mph (11 km/h) speed reduction. Second, a similar line removal plan for 30 mph (50 km/h) zones in Wiltshire, England, resulted in a 5% reduction in travel speeds.

*Charlton and Baas (2006)*

The goal of a study by Charlton and Baas (2006) was to identify research findings that could be used to develop an approach to speed management for New Zealand roads that is commensurate with the self-explaining road concept. The literature review identified two distinct types of speed management treatments:

- Measures that are implemented at a location where a change in speed occurs; and
- Measures that encourage drivers to maintain an appropriate speed within the zone.

The former type of speed management incorporates rural high-to-low speed transition zones and is of interest in this synthesis. Charlton and Baas categorized engineering measures intended to effect a speed change into three types: gateways, physical measures, and visual measures. The synthesized information contained in the Charlton and Baas report is reproduced in Figure 10. With respect to gateways, the researchers noted that the effects are somewhat variable, but reiterated the desire for a downstream setting that reinforces the need for the lower speed. In fact, they stated that when the downstream effects of various gateways are compared, all types produce speed reductions of 2 to 3 mph (3 to 5 km/h). However, when the gateway is combined with in-village road narrowing, the downstream effects are more pronounced—about a 9 mph (14 km/h) reduction at the gateway and 10 mph (16 km/h) in the village.

The researchers drew some firm conclusions from their review of the literature and their survey of experts and knowledgeable practitioners concerning speed transition zones:

- The location of the measure is directly related to effectiveness. It is better to site the treatments at a location that appears to warrant a speed change than at a jurisdictional boundary or other seemingly arbitrary location.
- If the measures are not accompanied by downstream changes in road conditions, increases in urban density, or similar conditions, the speed reductions produced by the gateway may dissipate within 820 ft (250 m).
- Visual treatments (e.g., signing and perceptual narrowing) appear to be more appropriate for higher-speed environments, whereas physical treatments produc-

ing deflection or discomfort (e.g., chicanes, and speed humps) may be unsuitable for speeds higher than 20 to 30 mph (30 to 50 km/h).

*Sandberg et al. (undated)*

Sandberg et al. (undated) studied the long-term effects of permanent dynamic speed feedback displays on operating speed where rural highways transition into urbanized areas. The study design was a before-after observational study with a control group. The sites were located on county roads with a speed limit of 45 to 55 mph (70 to 90 km/h), with a 10 mph (16 km/h) or greater reduction in the posted speed limit, and a history of speed-related safety concerns. There were four treatment sites and one control site.

Data were collected at each treatment site at a location upstream of the dynamic display sign, at a point where the sign is not visible, and adjacent to the dynamic sign where the lowered speed limit begins. After results were collected 1 week, 2 months, 7 months, and 1 year after installation. The study sites with the dynamic displays experienced reductions in the 85th percentile speed averaging 6.9 mph (11.0 km/h), which was sustained over 12 months.

*Knapp and Rosales (2007)*

An increasingly popular form of traffic management that may be useful for rural settlements located on multilane roads is "road diets," or lane reductions. Typically, road diets involve converting a four-lane road to a two-lane road, with a center

| Treatment type | | % reduction | Avg speed (km/h) post-installation | C85 speed (km/h) post-installation |
|---|---|---|---|---|
| **Gateways & urban thresholds**   | Signing & pavement marking | 0 – 3% | 67.2 | 89.6 |
| | High visibility | 7.5% | 64 | 76.8 |
| | High visibility + physical features | 15-27% | 52.8-66 | 70.4 |
| **Physical treatments**  | Transverse rumble strips & mats | 0.1-6% | 43-62 | 48-72 |
| | Traffic medians | 9% | 49.3 | 57.3 |
| | Chicanes | 26% | 36.8 | 44.8 |
| | 10° path angle | – | 40 | > 48 |
| | 15-20° path angle | – | < 32 | 32-40 |
| | Speed cushions 75mm high | 9.3% | 27.2 | 35.2 |
| | Speed humps 75mm high | 21% | 23.5 | 30.4 |
| **Visual treatments**   | Static signs Speed roundels | 0 | Depends on speed limit | Depends on speed limit |
| | Oversized signs | 0-3% | 67.2 | 89.6 |
| | Dynamic signs | 11% | Depends on speed limit | Depends on speed limit |
| | Visual narrowing | 11-20% | Depends on speed limit | Depends on speed limit |
| | Transverse lines | 8-14% | 57.5 - 65 | 77.5-82.8 |
| | Coloured pavement | 0% | – | – |

Note: empty cells above indicate that no published data were found for that measure.

FIGURE 10 Effects of engineering measures on speed change [*Source*: Charlton and Baas (2006)].

turn lane and bicycle lanes on either side of the road. Knapp and Rosales (2007) aggregated the results from a number of different road diet studies, analyzing the effects on both crash risk and operating speed. The impact of road diets on operating speeds is available but is not very detailed. The authors summarized before-after studies from 13 four-lane to three-lane conversions implemented in a number of states. The converted roadways had average daily traffic volumes between 8,400 and 24,000 vehicles per day, and experienced the following impacts on speed:

- Average or 85th percentile speed reductions usually less than 5 mph (8 km/h); and
- Up to a 70% reduction in excessive speeding (i.e., the number of vehicles traveling 5 mph (8 km/h) faster than the posted speed limit).

The settings for these studies are not provided in the article, so the results are not necessarily directly applicable to transition zones. Nonetheless, road diets might be implemented at the downstream end of a transition zone and carried through the developed area as a means of reinforcing the lower speed limits.

*Rodegerdts et al. (2007)*

Rodegerdts et al. (2007) sought to develop a set of operational, safety, and design tools that were based on U.S. experience with roundabouts. Although this research does not specifically mention the use of roundabouts in transition zones, roundabouts may be used as gateways to small towns (if an intersection is present within the transition zone), and the tools are therefore useful in this regard.

With respect to operating speed, the following prediction models were developed for vehicles entering and exiting roundabouts:

METRIC:

$$V_{exit} = MIN\left( aR_3^b \; ; \; 3.6\sqrt{\left(\frac{aR_2^b}{3.6}\right)^2 + 4.2d_3} \right)$$

$$V_{enter} = MIN\left( aR_1^b \; ; \; 3.6\sqrt{\left(\frac{aR_2^b}{3.6}\right)^2 + 2.6d_1} \right)$$

Where: $V_{exit}$ = the predicted exit speed for the roundabout (km/h)

$R_1$ = path radius on entry to the roundabout (m)

$R_2$ = path radius on the circulating roadway (m)

$R_3$ = path radius on exit from the roundabout (m)

*a*, *b* = see Table 13

$d_3$ = distance between the midpoint of the path on the circulating roadway and the point of interest on the exit (m)

$V_{enter}$ = the predicted entry speed for the roundabout (km/h)

$d_1$ = distance between the point of interest on the entry and the midpoint of the path on the circulating roadway (m)

U.S. CUSTOMARY:

$$V_{exit} = MIN\left( aR_3^b \; ; \; \frac{1}{1.47}\sqrt{\left(1.47aR_2^b\right)^2 + 13.8d_3} \right)$$

$$V_{enter} = MIN\left( aR_1^b \; ; \; \frac{1}{1.47}\sqrt{\left(1.47aR_2^b\right)^2 + 8.4d_1} \right)$$

Where: $V_{exit}$ = the predicted exit speed for the roundabout (mph)

$R_1$ = path radius on entry to the roundabout (ft)

$R_2$ = path radius on the circulating roadway (ft)

$R_3$ = path radius on exit from the roundabout (ft)

*a*, *b* = see Table 13

$d_3$ = distance between the midpoint of the path on the circulating roadway and the point of interest on the exit (ft)

$V_{enter}$ = the predicted entry speed for the roundabout (mph)

$d_1$ = distance between the point of interest on the entry and the midpoint of the path on the circulating roadway (ft)

TABLE 13
SPEED PREDICTION PARAMETERS FOR ROUNDABOUTS

| | Metric | | U.S. Customary | |
|---|---|---|---|---|
| | e = +0.02 | e = –0.02 | e = +0.02 | e = –0.02 |
| a | 8.7602 | 8.6164 | 3.4415 | 3.4614 |
| b | 0.3861 | 0.3673 | 0.3861 | 0.3673 |


FIGURE 11 Optical speed bars in Virginia [*Source*: Arnold and Lantz (2007)].

*Arnold and Lantz (2007)*

As part of a larger experiment with traffic control devices in rural areas, Arnold and Lantz (2007) assessed the effect of transverse optical bars (shown in Figure 11) on the approach to a small town, where the speed limit drops from 55 mph to 45 mph (90 km/h to 70 km/h). They were placed on both approaches to the town, and speeds were assessed before, 7 days after, and 90 days after installation to assess any novelty effect.

The results are shown in Table 14. Stations 1 through 3 were located well in advance of the bars in the 55 mph (90 km/h) speed zone, at the end of the bars just at the start of the 45 mph (70 km/h) speed zone, and approximately in the center of town, respectively.

TABLE 14
RESULTS OF OPTICAL SPEED BAR EXPERIMENT

| Time Period | Westbound | | | Eastbound | | |
|---|---|---|---|---|---|---|
| | Data Collection Period | | | | | |
| | Before | After* | After 90** | Before | After* | After 90** |
| *Station 1* | | | | | | |
| All days | | 56.71 | 59.16 | | 59.54 | 59.69 |
| Weekday | | 56.71 | 58.78 | | 59.58 | 59.64 |
| Weekend | | 56.71 | 59.42 | | 59.45 | 59.79 |
| Day (6 a.m. to 6 p.m.) | | 56.86 | 59.12 | | 59.73 | 59.87 |
| Night (6 p.m. to 6 a.m.) | | 56.56 | 59.23 | | 59.35 | 59.5 |
| *Station 2* | | | | | | |
| All days | 54.42 | 49.31 | 51.02 | 56.77 | 55.57 | 47.22 |
| Weekday | 54.49 | 49.59 | 50.85 | 56.75 | 55.68 | 47.18 |
| Weekend | 54.25 | 48.74 | 51.45 | 56.79 | 55.3 | 47.34 |
| Day (6 a.m. to 6 p.m.) | 54.74 | 49.86 | 51.85 | 57.02 | 56.16 | 47.71 |
| Night (6 p.m. to 6 a.m.) | 54.09 | 48.85 | 50.19 | 56.51 | 54.97 | 46.74 |
| *Station 3* | | | | | | |
| All days | 45.56 | 39.98 | 46.91 | 37.25 | 41.99 | 47.04 |
| Weekday | 44.95 | 39.96 | 46.95 | 37.43 | 42.02 | 47.09 |
| Weekend | 45.68 | 40.06 | 46.63 | 36.79 | 41.94 | 46.7 |
| Day (6 a.m. to 6 p.m.) | 46.05 | 40.19 | 47.23 | 36.93 | 41.79 | 46.75 |
| Night (6 p.m. to 6 a.m.) | 45.05 | 39.72 | 46.53 | 37.57 | 42.2 | 47.37 |

[*Source*: Arnold and Lantz (2007)].
*After = within 7 days of installation.
**After 90 = Approximately 90 days after installation.

Note that the predicted entry/exit speed is independent of the speed on the rural approach and is determined by the characteristics of the circulating roadway and the distance from the roundabout.

The optical speed bars had an overall positive impact, as vehicle speeds recorded at the 45 mph (70 km/h) speed limit sign at the downstream end of the bars decreased for all time periods 90 days after installation at both ends of town. Based on the experiment results, the magnitude of the speed decrease from optical speed bars in transition zones is expected to be 3 to 9.5 mph (5 to 15 km/h). No conclusions can be drawn about the habituation effect, as speeds increased with time at one end of town but decreased with time at the other end of town.

*Fitch and Crum (2007)*

Fitch and Crum (2007) also tested optical speed bars on the approaches to several small villages in Vermont with less than impressive results. Speeds were measured on Saturdays and midweek to examine the effects of the striping on both local and tourist traffic. The researchers concluded that the striping is ineffective at reducing 85th percentile speeds, producing only a 1.0 mph (1.6 km/h) reduction 4 months after installation. Curiously, the speed-reducing effect seemed to be stronger with drivers who were exposed to the markings on a daily basis.

*Department for Transport (2007)*

The U.K. Department for Transport (2007) reported that 85th percentile speed reductions of 3.5 mph (5.6 km/h) and 6 mph (9.6 km/h) for "before" speed limits of 40 mph and 60 mph respectively are achievable by implementing local 30 mph (50 km/h) speed limits. This result comes from a 1994 program implemented in Suffolk County Council where 30 mph (50 km/h) speed limits were enacted in 450 villages and communicated by standard speed limit signing and entry roundels. However, it is noted that the new limits were complemented by a policy of implementing physical traffic calming where a crash problem was evident, mobile speed cameras, and a high-profile anti-speeding campaign. Hence, it is not possible to attribute the speed reductions to any one particular measure.

*Hallmark et al. (2007)*

Hallmark et al. (2007) set out to examine the effects of selected transition zone treatments at several rural communities in Iowa. Site selection criteria included the following:

- Through, paved, major county or state highway;
- No traffic calming currently in place or planned;
- No construction, reconstruction, or significant maintenance activities planned along the route during the study period;
- No access control; and
- No adverse geometry such as sharp horizontal curves or steep vertical curves where treatments would be placed.

Of the 18 sites that met the inclusion criteria, the five locations with the most significant speeding problems (determined by the difference between the posted speed and prevailing travel speed) were selected for treatment. Speed limits outside the transition areas were 55 mph and 60 mph (90 and 100 km/h), and speed limits in the villages were 25 mph to 35 mph (40 km/h to 55 km/h).

An extensive literature review was used to assemble a list of potential treatments. Treatments for implementation were selected in consultation with the local government, and were generally low cost, had the ability to accommodate farm vehicles and large trucks, and were compatible with the rural setting and driver expectations. Seven different treatments were tested, as shown in Table 15.

Speed and volume data were collected from 1 month to 1 year after implementation, with the 85th percentile speed being the primary measure of effectiveness. The results, shown in Table 16, revealed that the speed feedback signs, speed table, median island using tubular markers, and speed limit markings with red background are the most effective. The converging chevrons and transverse pavement markings were moderately effective, producing speed reductions of less than 3 mph (5 km/h). The remaining treatments were either ineffective or only marginally effective.

*Dixon et al. (2008)*

Dixon et al. (2008) conducted a literature review on rural speed transition zones leading to driving simulator testing of several alternative transition zone treatments. Because the study uses a driving simulator, the alternatives investigated were limited to either physically or perceptually narrowed roads at the transition locations. The following transition zone treatments were included in the full-scale simulation:

- Layered landscape
- Gateway with lane narrowing
- Median treatment only
- Median with gateway treatment
- Medians in series with no pedestrian crosswalks
- Medians in series with pedestrian crosswalks

The speed transition was in all cases from 55 mph to 35 mph (90 km/h to 55 km/h), with a 45 mph (70 km/h) stepped-down speed limit in the transition zone. Speed measurements were taken at several locations starting in the 55 mph (90 km/h) section and throughout the transition zone up to and including the gateway.

Table 17 shows the results, which indicated that all speed reductions were minimal but the most effective alternatives were the median treatments, particularly the medians in a series or combined with a gateway. The layered landscape treatment and the gateway with lane narrowing treatment did not result in statistically significant speed reductions. Also, the speed reductions generally occurred vicinal to the transition treatments—the reductions generally did not persist downstream of the treatment.

TABLE 15
DESCRIPTION OF TRANSITION ZONE TREATMENTS IN IOWA

| City (population) | Treatment | Roadway | AADT (veh/day) | Cross section (all are two-lane) |
|---|---|---|---|---|
| Union (427) | Transverse pavement makrings' with speed feedback sign | D-65 (west edge of City) | 830 | Asphalt (22.4 ft), unpaved shoulders |
| | Transverse pavement markings' with speed feedback sign | S-62/SH (from intersection with D-65 to north city limit) | 1,680 | Concrete (40.0 ft), curb and gutter |
| | Lane narrowing using painted center island and edge line markings | | | |
| | Transverse pavement markings' | SH 215 (near south city limit) | 1,000 | Asphalt (22.4ft), unpaved shoulders |
| Roland (1,324) | Converging chvrons with "25 MPH" pavement legend | E-18 (near east and west city limits) | 2,300 | Asphalt (22.6 ft), unpaved shoulders |
| | Lane narrowing using shoulder widen-ing and "25 MPH" pavement legend | E-18 (from intersection with R-77 to east city limit) | 2,300 | Concrete (36.0 ft), curb and gutter |
| | "25 MPH" pavement legend | E-18 (from intersection with R-77 to west city limit) | 2,300 | Asphalt (22.6 ft), unpaved shoulders |
| Gilbert (987) | Speed table | E-23 (center of community) | 1,480 | Asphalt (22.0 ft), shoulders |
| Slater (1,306) | Lane narrowing with center island using tubular markers channelizing markers | R-38 (from intersection with SH210 to south city limit) | 2,060 | Concrete (25.8 ft), curb and gutter |
| | Speed feedback sign | R-38 (near north city limit) | 2,870 | Asphalt (22.6 ft), unpaved shoulders |
| | "SLOW" pavement legend | SH 210 (west from intersection with R-38 to west city limit) | 2,940 | Asphalt (22.5 ft), unpaved shoulders |
| Dexter (689) | "35 MPH" pavement legend with red background | F-65 (near east and west city limits as well as at curve before west city limit) | 1,000 | Asphalt (25.4 ft), unpaved shoulders |

[*Source*: FHWA (2009)].
A request for experimentation was submitted to and approved by FHWA for this treatment.

TABLE 16
RESULTS OF THE IOWA TRANSITION ZONE TREATMENTS

| Treatment | Change in 85th percentile speed (mi/h) | Cost | Maintenance | Application |
|---|---|---|---|---|
| Transverse pavement markings' | -2 to 0 | $ | Regular painting | community entrance |
| Transverse pavement markings' with speed feedback signs | -7 to -3 | $$$ | Regular painting | community entrance |
| Lane narrowing using painted center island and edge marking | -3 to +4 | $ | Regular painting | entrance or within community |
| Converging chevrons' and "25 MPH" pavement markings | -4 to 0 | $ | Regular painting | community entrance |
| Lane narrowing using shoulder markings and "25 MPH" pavement legend | -2 to 4 | $ | Regular painting | entrance or within community |
| Speed table | -5 to -4 | $$ | Regular painting | within community |
| Lane narrowing with center island using tubular markers | -3 to 0 | $$$ | Tubes often struck needing replacement | within community |
| Speed feedback sign (3-months after only) | -7 | $$$ | Troubleshooting electronics | entrance or within community |
| "SLOW" pavement legend | -2 to 3 | $ | Regular painting | entrance or within community |
| "35 MPH" pavement legend with red background | -9 to 0 | $ | Background faded quickly; accelerated repainting cycle | entrance or within community |

$ = under $2,500
$$ = $2,500 to $5,000
$$$ = $5,000 to $12,000
'Experimental approval required per Section 1A, 10 of MUTCD
[*Source*: FHWA (2009)].

TABLE 17
SPEED REDUCTIONS IN SIMULATED TRANSITION ZONES

| Treatment | Reduction in Speed (mph) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 55 to 35 mph Sign | 55 to 45 mph Sign | 45 to 35 mph Sign | 55 to 300' Downstream of 45 mph Sign | 300' Upstream to 300' Down-stream of 45 mph Sign | 55 mph Sign to 300' Down-stream of 35 mph Sign | 45 mph Sign to 300' Down-stream of 35 mph Sign | 55 mph Sign to Treatment Location |
| *Mean Speed -- All* | | | | | | | | |
| A – Control 2 Lanes (1) | 12.7 | 0.5 | 12.2 | 2.4 | 5.1 | 13.2 | 12.6 | -- |
| B – Control 2 Lanes (2) | 9.4 | 1.8 | 7.6 | 2.0 | 4.0 | 11.3 | 9.5 | -- |
| C - Layered Landscape | 10.7 | 1.0 | 9.7 | 2.8 | 4.2 | **14.1** | 13.1 | 4.6 |
| D - Gateway with Lane Narrowing | 11.0 | 2.8 | 8.2 | 1.9 | 4.5 | **15.3** | 12.5 | 5.5 |
| E - Control 2 Lane with Center Lane | 11.7 | 3.0 | 8.6 | 1.9 | 4.6 | 15.2 | 12.1 | -- |
| F – Median Only | **12.2** | 3.4 | 8.8 | 2.9 | 5.2 | **15.8** | 12.4 | 3.4 |
| G – Median with Gateway | **13.9** | 6.5 | 7.4 | 2.4 | 4.3 | **15.4** | 8.9 | 10.2 |
| H - Medians in Series No Crosswalks | **13.1** | 5.3 | 7.8 | 2.5 | 4.7 | **16.5** | 11.2 | 10.7 |
| I - Medians in Series with Crosswalks | **12.5** | 8.1 | 4.4 | 2.9 | 5.5 | 12.5 | 7.6 | 10.0 |
| ***85$^{th}$ Percentile Speed -- All*** | | | | | | | | |
| A – Control 2 Lanes (1) | 4.1 | -1.2 | 5.3 | 2.9 | 3.7 | 5.1 | 6.3 | -- |
| B - Control 2 Lanes (2) | 3.3 | -0.3 | 3.6 | -0.1 | -0.1 | 4.9 | 5.2 | -- |
| C - Layered Landscape | 3.6 | -0.9 | 4.5 | 1.5 | 0.4 | **9.1** | 10.1 | 1.2 |
| D - Gateway with Lane Narrowing | **7.3** | 1.0 | 6.3 | 0.2 | 0.7 | **9.3** | 8.3 | 3.0 |
| E - Control 2 Lane with Center Lane | 9.4 | 3.2 | 6.3 | 0.3 | 2.6 | 11.8 | 8.6 | -- |
| F – Median Only | 9.4 | 0.1 | 9.3 | 3.0 | 3.4 | **12.0** | 11.9 | 0.1 |
| G – Median with Gateway | **10.2** | 2.8 | 7.4 | -0.1 | 0.1 | 11.4 | 8.6 | 5.6 |
| H - Medians in Series No Crosswalks | **11.2** | 4.9 | 6.2 | 2.2 | 3.4 | **14.8** | 9.9 | 10.7 |
| I - Medians in Series with Crosswalks | **11.5** | 4.7 | 6.8 | 5.3 | 8.0 | 11.5 | 9.8 | 5.6 |

[*Source*: Dixon et al. (2008)].

*Jamson et al. (2008)*

As part of a larger research project, Jamson et al. (2008) conducted a driver simulator study to estimate the effectiveness of a number of low-cost, speed-reducing treatments at village entries. The treatments included perceptual illusions as well as physical restrictions, and are listed here:

- Vehicle-activated signs with SLOW DOWN
- Countdown signs
- Rumble strips with raised profile
- Dragon's teeth
- Combs with chevrons
- Combs (see Figure 12)
- Build-outs
- Trees

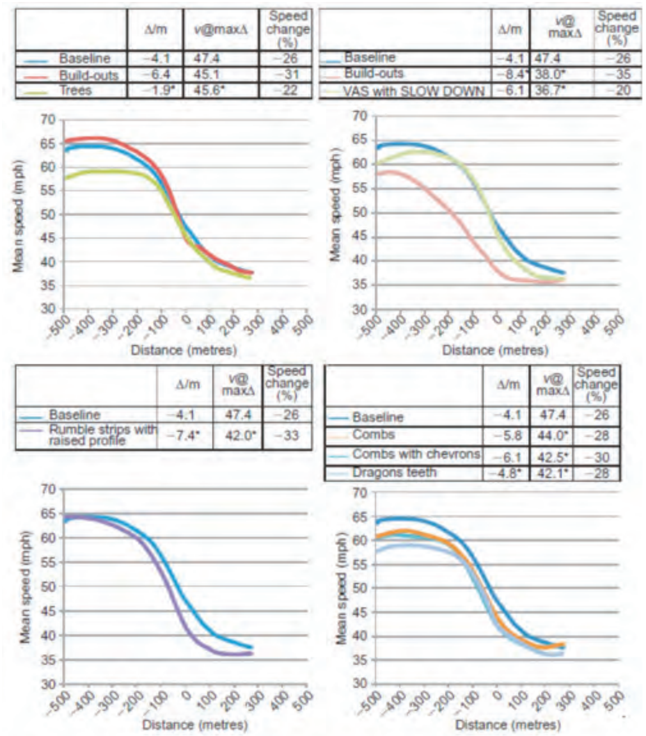

FIGURE 12 Pavement marking combs [*Source*: Jamson et al. (2008)].

Measures of effectiveness were as follows:

- Absolute change in speed within the impact zone (km/hΔ)
- Δ per meter (Δ/m)—this standardizes the Δ enabling comparison across treatments
- The lowest travel speed observed in the impact zone—Speed at maximum Δ (v@max Δ)—this refers to vehicle speed at the point at which the change in speed is greatest.
- Speed at the downstream end of the impact zone
- Percentage of speed change across the impact zone

The impact zone is treatment specific, starts at the point where the driver first perceives the treatment, and ends at the point where the treatment is reached. Figure 13 presents the results of the simulator studies for village entries.

Countdown signs produced the best results across all three performance indicators, yielding a net 9% reduction in speed approaching the village. The speed profile of the countdown signs is also markedly different from other treatments, showing motorists slowing earlier. Rumble strips with a raised profile showed the second best performance (with a net 7% reduction in speed). This is notable because the location and duration of rumble strips are similar to other surface treatments, such as dragon's teeth or combs with chevrons, which did not perform as well. The tactile feedback seems to provide extra emphasis, which results in better performance. The vehicle-activated signs performed the worse, but the report noted that this device had to be located downstream of the village entry in order to comply with governing legislation, so it is not directly comparable to the other treatments.




Note: * denotes statistically significant difference from the baseline at the 0.05 level.

FIGURE 13 Speed reductions at transition zones [*Source*: Jamson et al. (2008)].

Based on the performance of the countdown signs, the researchers advanced this measure to a second level of investigation that aimed to determine if repeated exposure to this treatment would lessen the observed effects. To this end, simulator participants were exposed to the countdown-treated approach four times, with results shown in Figure 14.

The shape of the speed profile for treated drives is distinctively different from the baseline. The change in speed over the impact zone and the speed at the village entry for all drives were statistically significantly different than the baseline speed. This result suggests that the countdown signs are an effective speed-reducing measure, and that they may have a lasting effect.

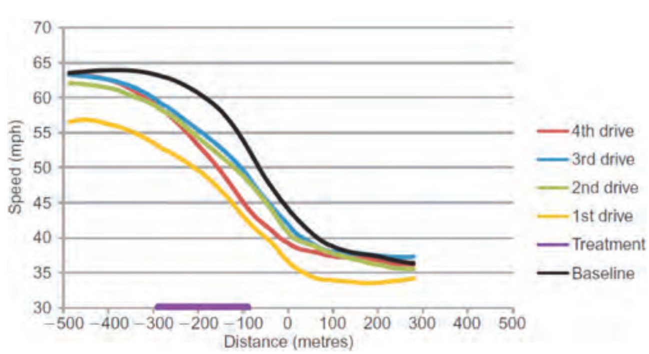



FIGURE 14 Effects of countdown signs on speed [*Source*: Jamson et al. (2008)].

*Donnell and Cruzado (2008)*

Donnell and Cruzado (2008) conducted research on the use of speed feedback signs to manage speeds at high-to-low speed transitions on rural roads in Pennsylvania. The study methodology was a before-after examination of operating speeds. At each of the 17 study sites, the feedback signs were placed for a 1-week period, as it is common practice for the DOT to use the limited number of feedback signs at a greater number of sites. At four sites, the signs were implemented for 2 weeks to determine if the longer deployment had any effect on speeds. Enforcement was not a part of the overall treatment. The speed feedback sign was placed 500 ft (150 m) downstream of the speed threshold. Thirteen of the 17 sites were high-to-low speed transition zones, with a speed differential of either 15 or 20 mph (24 to 32 km/h).

Speeds were measured before placement of the feedback signs, during the time that the sign was in place, and after sign removal to determine if there were any residual effects on speed. Only free-flow speeds during daylight, in off-peak hours on weekdays, and on dry pavement were included in the analysis. Speeds were measured about 0.5 mile (0.8 km) upstream of the speed feedback sign (where the feedback sign could not be seen), at the feedback sign, and 500 ft (150 m) downstream of the feedback sign. Metrics included mean speed, 85th percentile speed, speed variance, and percentage of vehicles exceeding the posted speed limit.

The results showed that on average, mean speed reductions of approximately 6 mph (10 km/h) were achieved at the speed feedback sign and downstream of the sign for the 13 sites where there was a high-to-low speed transition (from the before to the during period). This effect was present only while the sign was in place, and mean speeds rebounded to before levels in the week after sign removal. Implementing the speed feedback sign for 2 weeks permitted the mean speed reductions to be sustained for the entire deployment period, but in these instances mean speeds also rebounded to pre-deployment levels shortly after the signs were removed.

*Abate et al. (2009)*

Abate et al. (2009) conducted an evaluation of two speed transition zones (one on each approach) to a village in Salerno, Italy. The measures employed included transverse rumble strips, dragon's teeth markings, an optical narrowing created by pavement markings at the edge of the road, and an overhead information sign (or flag portal) that is cantilevered from the right side of the road (see Figure 15). A photograph of the flag portal is shown in Figure 16.

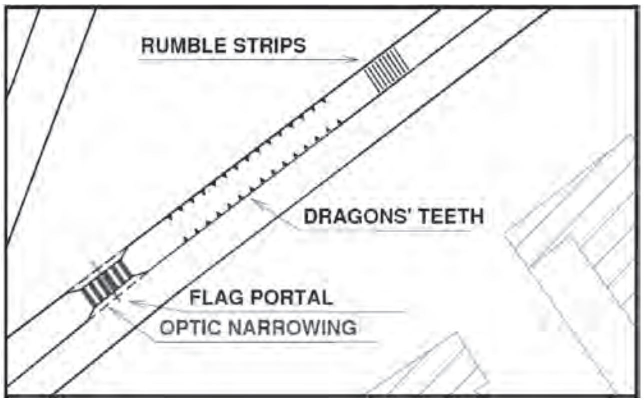



FIGURE 15 Gateway treatment in Salerno, Italy [*Source*: Abate et al. (2009)].


FIGURE 16 Italian flag portal [*Source*: Abate et al. (2009)].

Speed was measured at several stations before, in, and after the transition zone. Although it is difficult to extract from the document the exact effect of the gateway treatment, it is clear that the authors reported a successful reduction in operating speed.

*Lamberti et al. (2009)*

The purpose of driver simulator research conducted by Lamberti et al. (2009) was to investigate drivers' speed choice on rural highways that cross small urban communities in situations with and without gateways and village traffic calming, and to examine the effects of low-cost versus high-cost gateways. Operating speed on transition zones that did not have a gateway was measured in the field; operating speed in transition zones with gateways were estimated from driving simulator runs.

The 85th percentile speed on the approaches to the test village was about 55 mph (90 km/h). The speed limit in the built-up area of the village is 30 mph (50 km/h). Two sample gateways were advanced for testing:

- Alternative 1—Transverse rumble strips, transverse optical bars, peripheral transverse bars, a roadside fence converging toward the carriageway, a transverse strip of colored road surface with markings resembling brick pavers, and a sign gantry.
- Alternative 2—The same measures as Alternative 1, but with the "brick pavers" replaced with a mountable central island that creates a horizontal deflection. The deflection is about 123 ft (37.5 m) long, and creates a lateral shift of 8 ft (2.5 m).

Figure 17 shows images of the two alternatives.

Alternative 1

Alternative 2

FIGURE 17 Simulated transition gateways [*Source*: Lamberti et al. (2009)].

Mean speeds were measured in the rural area preceding the gateway (labeled the "control"), at the gantry of the gateway, and in the village midpoint. Table 18 shows the results of the experiment for the existing condition (ALT0), the Alternative 1 gateway (ALT1), and the Alternative 2 gateway (ALT2).

TABLE 18
EFFECTS OF GATEWAYS ON OPERATING SPEEDS

| Station | Direction | Mean Speed, mph (km/h) | | |
|---|---|---|---|---|
| | | Alt0 | Alt1 | Alt2 |
| Control | South | 49.6 (79.4) | 47.1 (75.3) | 45.3 (72.4) |
| Gateway | South | 48.1 (77.0) | 38.1 (61.0) | 37.6 (60.1) |
| Village Midpoint | South | 47.1 (75.4) | 40.5 (64.8) | 38.0 (60.8) |
| Control | North | 51.3 (82.1) | 50.6 (80.9) | 47.3 (75.6) |
| Gateway | North | 45.0 (72.0) | 38.1 (61.0) | 38.5 (61.6) |
| Village Midpoint | North | 47.2 (75.5) | 41.5 (66.4) | 38.9 (62.2) |

[*Source*: Lamberti et al. (2009)].

The results were promising—the gateways produced speed reductions of 6.9 to 10.6 mph (11 to 17 km/h) at the gateways. The additional cost of constructing a mountable island to create the horizontal deflection (Alternative 2) did not appear to be worth the effort, as the mean speeds were essentially the same as those produced by the lower cost Alternative 1 gateway. However, these were the results of a simulator study, and field studies and observations find that drivers tend to flatten the horizontal deflections by traversing painted islands, resulting in a less effective gateway than a raised median.

*Chartier (2009)*

In a presentation concerning rural to urban transition zones, Chartier (2009) included a case study concerning a transition zone improvement in the Hamlet of Burketon of the Township of Clarington, Ontario, Canada. A single transition zone was shown as an approach to an intersection (the start of the urban area), with transition zone improvements of dragon's teeth, edge and centerline markings, and a row of regularly spaced trees planted on one side of the road (the other side of the road is a wooded area). The speed limit in the urban area is 30 mph (50 km/h); the speed limit in the rural area is 50 mph (80 km/h).

Both the mean and the 85th percentile speeds were used to assess treatment effectiveness, measured at the rural/urban threshold and 787 ft (240 m) downstream of the threshold. Table 19 shows the results: at the threshold there was almost a 5 mph (8 km/h) reduction or a 10% reduction in the 85th percentile speed for both directions combined, and about a 3 mph (5 km/h) or 7% reduction in the mean speed. Even with the transition zone treatment in place, the mean and 85th percentile speeds were still 6 mph (10 km/h) and 12 mph (20 km/h) higher than the posted speed limit of 30 mph (50 km/h). The changes in the mean and 85th percentile speeds 787 ft (240 m) downstream of the threshold were less impressive at about 0.6 mph and 2 mph (1 km/h and 3 km/h ), respectively. However, the "before" mean and 85th percentile speeds at this downstream location were significantly lower than the same measures at the threshold, indicating that the built environment is having a calming influence on travel speeds.

TABLE 19
SPEED DATA FROM BURKETON, ONTARIO

| | Before | | | After | | | Change | |
|---|---|---|---|---|---|---|---|---|
| | *N** | Mean | 85th% | *N** | Mean | 85th% | Mean | 85th% |
| *At rural/urban threshold* | | | | | | | | |
| Southbound | 45 | 66.9 | 77.1 | 42 | 61.5 | 69.1 | –5.4 | –8.0 |
| Northbound | 57 | 68.6 | 77.2 | 52 | 64.3 | 69.7 | –4.3 | –7.5 |
| Combined | 102 | 67.8 | 77.1 | 94 | 63.1 | 69.4 | –4.7 | –7.7 |
| *240 meters downstream of threshold* | | | | | | | | |
| Southbound | 29 | 58.6 | 63.9 | 41 | 56.6 | 60.0 | –2.0 | –3.9 |
| Northbound | 44 | 55.1 | 61.8 | 54 | 55.2 | 59.9 | 0.1 | –1.9 |
| Combined | 73 | 56.5 | 63.0 | 95 | 55.8 | 59.9 | –0.7 | –3.1 |

[*Source*: Chartier (2009)].
**N* = Number of vehicles, 85th% = 85th percentile.

All speeds reported in km/h.

*Cruzado and Donnell (2009)*

Cruzado and Donnell (2009) explored the effect of roadway, roadside, and traffic control elements on operating speeds in transition zones on rural, two-lane highways in Pennsylvania. Twenty sites were used in the analysis. All sites were free of major intersections, had less than 10% heavy vehicles, and had visible pavement markings on smooth road surfaces. Additionally, each site had a REDUCED SPEED AHEAD sign as per the 2003 *MUTCD*. The speed reductions were all either 20 mph or 15 mph (30 km/h or 25 km/h), except for one site that was a 10 mph (15 km/h) speed reduction. The rural speed limits were 40 mph, 45 mph, and 55 mph (65 km/h, 70 km/h, and 90 km/h).

Speeds were recorded in the rural area, at the start of the transition zone (defined as the REDUCED SPEED AHEAD sign), and at the end of the transition zone (defined as the start of the reduced limit). Only free flow speeds were used in the analysis. Transition zone features that were collected for analysis were lane width, paved shoulder width, stabilized shoulder width, total paved roadway width, lateral offset to obstructions, presence of curb and gutter, access density, horizontal and vertical alignment data, posted speed limits in the urban and rural areas, and the number and type of warning signs.

The analysis employed both ordinary least squares linear regression and multilevel models, both of which provided similar results for most of the independent variables. Table 20 shows the results from the multilevel model, which the researchers considered to be a better representation of the data.

TABLE 20

FACTORS INFLUENCING SPEED REDUCTIONS IN TRANSITION ZONES

| Predictor | Two-Level Model | | |
|---|---|---|---|
| | Estimate | SE | Z |
| Speed1 Centered | 0.17 | 0.017 | 9.85 |
| Speed Limit 55-40 mph[a] | 2.87 | 1.088 | 2.63 |
| Speed Limit 45/40-25 mph[a] | 2.98 | 1.098 | 2.71 |
| Delta Lane Width (ft) | 2.22 | 2.517 | 0.88* |
| Delta Paved Shoulder (ft) | 1.09 | 0.311 | 3.51 |
| Delta Lateral Clearance (ft) | 0.10 | 0.116 | 0.82* |
| Total Driveways | 0.38 | 0.224 | 1.69† |
| Curb Intro[b] | 0.67 | 1.673 | 0.40* |
| Intersection Ahead Warning Sign[c] | 2.47 | 1.728 | 1.43† |
| School/Children Warning Sign[c] | 7.64 | 1.900 | 4.02 |
| Curve Ahead Warning Sign[c] | -2.91 | 1.793 | -1.62† |
| Transition Zone Length | 0.75 | 0.252 | 2.97 |
| Curve with Warning Sign[d] | 4.91 | 1.284 | 3.82 |
| Curve without Warning Sign[d] | 1.88 | 1.026 | 1.83† |
| Constant | -6.63 | 1.869 | -3.55 |
| **Random Components** | **Estimate** | **SE** | - |
| Transition Zone $\left(\sqrt{\psi^{(2)}}\right)$ | 1.44 | 0.276 | |
| Residual $\left(\sqrt{\theta}\right)$ | 5.95 | 0.079 | |

[a] Baseline is speed limit reduction from 55 to 35 mph
[b] Baseline is no curb and gutter present in transition zone
[c] Baseline is no warning signs present in transition zone
[d] Baseline is presence of a tangent section
* Not statistically significant at a 20 percent confidence level.
† Statistically significant at a 20 percent confidence level.
*All values in table are in U.S. units (1 mph = 1.61 km/h, 1 ft = 0.305 m)*

[*Source*: Cruzado and Donnell (2009)].

These results are interpreted as follows:

- The presence of a school/children warning sign had the largest influence on speed transition (the difference between the speed measured at two ends of the transition zone)—a 7.6 mph (12.1 km/h) reduction in speed.
- A horizontal curve that also has a warning sign resulted in a 4.9 mph (7.8 km/h) reduction in speed across the transition zone.
- The remaining features of the transition zone that influenced speed in decreasing order of importance were the posted speed limits, an intersection ahead warning sign, a curve without warning signs, paved shoulder width, the transition zone length, and the number of driveways.
- Lane width, lateral clearance, and the presence of curb and gutter were not statistically significant, and therefore are not influential on speed transitioning.

The researchers also noted that the speed reduction is compromised by a CURVE AHEAD warning sign.

*Russell and Godavarthy (2010)*

Russell and Godavarthy (2010) conducted an evaluation of four different speed management measures on rural roads in Kansas: colored pavement, a solar speed display, a mobile speed trailer, and optical speed bars. The objective of the study was to test measures that mitigate speeds on the through approaches at stop-controlled intersections and at other road segments. The colored pavement (see Figure 18) and the solar displays were implemented at rural to urban transitions; the remainder of the speed management measures were used at approaches to rural intersections or horizontal curves.

Mean and 85th percentile speeds were the measure of effectiveness. All speeds were measured manually using a handheld radar gun, and are shown in Table 21.

The colored pavement treatment did not definitively reduce operating speeds, but did show promise at one of the three sites. The solar speed displays and mobile speed trailer showed promise, but the researchers stated that these are short-term results from a limited number of installations and more extensive testing should be undertaken to confirm the speed-reducing capabilities of these devices. The optical speed bars, which were used on the approaches to horizontal curves, exhibited conflicting results and could not be determined to be effective measures.

FIGURE 18 Colored pavement [*Source*: Russell and Godavarthy (2010)].

TABLE 21
RESULTS OF KANSAS STUDY ON RURAL SPEED MANAGEMENT

| Treatment | Location Description | 85th Percentile Speed (mph) | | Mean Speed (mph) | |
|---|---|---|---|---|---|
| | | Before | After | Before | After |
| Colored Pavement | 65 mph → 55 mph → 45 mph on a two-lane road | 54.8 | 55.3 | 51.1 | 50.7 |
| | 65 mph → 55 mph → 30 mph on a two-lane road | 57.4 | 47.7* | 48.8 | 42.4* |
| | | 51.8 | 52.9 | 46.6 | 47.8 |
| Solar Speed Display | 70 mph → 55 mph on a four-lane road with a painted median | 56.8 | 56.4 | 53.2 | 51.5* |
| | 65 mph → 55 mph on a two-lane road | 58.5 | 56.3* | 54.9 | 51.8* |
| | | 63.2 | 54.1* | 57.3 | 50.2* |
| Mobile Speed Trailer | Approach to an intersection on a four-lane road with a 70 mph | 73.2 | 71.1* | 69.8 | 67.3* |
| | | 69.1 | 58.8* | 62.4 | 55.3* |
| Speed Bars | 55 mph → 45 mph advisory speed at a horizontal curve | 45.2 | 45.2 | 42.2 | 41.3 |
| | | 47.6 | 46.3 | 43.9 | 40.8* |
| | | 46.8 | 45.9 | 43.1 | 41.0* |
| | 65 mph → 30 mph advisory speed at a horizontal curve | 52.5 | 59.7 | 47.8 | 52.9 |
| | | 55.3 | 56.1 | 47.8 | 49.2 |

*Significantly different from the Before measurements at a 95% level of confidence.

## Crash Studies

*Tziotsis (1992)*

The purpose of research by Tziotsis (1992) was to investigate the magnitude and characteristics of crashes that occur on “feeder roads” to provincial cities (i.e., roads on the immediate outskirts). These facilities are generally partially developed sections of road that connect the typical urban road to a rural road (i.e., a transition zone). The transition zones examined were on average 1.3 miles (2.2 km) in length and were defined by the speed limit [i.e., 45/50/55 mph (75/80/90 km/h) in transition zones, and 60/65mph (100/110 km/h) for the rural road zones]. Five years of crash data were used in the analysis of both aggregate crash statistics from several transition zones and investigations of the safety performance of individual transitions.

The aggregate analysis confirmed that transition zones experienced crash rates that are markedly higher than those experienced on rural roads. Transition zones experienced an annual crash rate of 72 casualties per 100 million vehicle-miles (45 casualties per 100 million vehicle-kilometers), whereas rural zones produced a crash rate of 43 casualties per 100 million vehicle-miles (27 crashes per 100 million vehicle-kilometers). Furthermore, as a proportion of total crashes, rear-end and dusk/dawn crashes peaked within the transition zones. This report did not consider the direction of movement for crash-involved vehicles and therefore did not compare crash rates of vehicles leaving the built-up area with those of vehicles entering the built-up area.

The researchers concluded that the increased crash rate in the transition zone was related to inadequate road design and an increase in roadside development that occurs in the transition zone. Specific transition zone design deficiencies were insufficient curve delineation, lack of turning lanes and acceleration/deceleration lanes, inadequate shoulders, and poles located in hazardous locations.

*Herrstedt et al. (1993)*

Herrstedt et al. (1993) provided data from a wide variety of traffic calming measures that have been put into practice in Denmark, France, and Germany. The examples span a wide variety of locations where these measures may be used effectively (e.g., urban centers, approaches to villages). Of interest to this synthesis are locations where measures were implemented on a highway that runs “through a town.” Table 2 presents examples of some treatment at the high-to-low speed transition where a highway traverses a town and the text mentions a “gateway” or “portal.”

The varied measures that were implemented showed a 44% and 36% reduction in injury and all crashes, respectively. However impressive this reduction in crash risk, it is of limited value in high-to-low speed transition zones. It is not possible to tease out the effects of the high-to-low speed transition treatment from the effects of the "in town" measures that were also employed. Nonetheless, these examples highlight that transition treatments can be effective in reducing crash risk as well as speeds.

*County Surveyors' Society (1994b)*

The County Surveyors' Society (1994b) of the U.K. collected and summarized data on 85 traffic calming installations in the United Kingdom, with 25 of the installations classified as rural road/area installations. The intentions of this effort were to provide practitioners with a snapshot of traffic calming in the U.K., and to detail a number of case studies so that practitioners might better understand what plans and measures work and do not work in different situations.

Table 3 shows a summary of the crash risk effects of traffic calming on the 25 rural case studies. All of the traffic calming was implemented for one or more of the following objectives: reduce speed, reduce crash occurrence, and/or reduce through traffic. However, the measures implemented at each site were not implemented for the same reasons and are not of the same form (e.g., humps versus narrowings). Therefore, this analysis is necessarily general.

Traffic calming on rural roads had a dramatic impact on crash occurrence—a 65% reduction in crash occurrence. Of the 20 sites that reported before-after crash and volume data, 18 experienced reductions in crash rates and two experienced increases in crash rate. This result is impressive but should be treated with caution because the evaluation methodologies are naïve before-after studies of crash occurrence. There is no accounting for sundry effects or regression-to-the-mean (RTTM) artifacts, and at some sites the "after" periods were quite short. Nonetheless, a reduction in crash rate is expected, although it is more likely in the range of a 45% to 55% reduction.

The report data do not indicate whether the rural road is a primary route or a local road. If the "before" traffic volume was used as a surrogate for road classification, for the eight sites with daily traffic volumes greater than 10,000 (which are assumed to be primary routes or arterial roads) the crash rate was reduced by 47%.

*Wheeler and Taylor (2000)*

Wheeler and Taylor (2000) conducted a retrospective study of crash occurrence broken down by severity for 56 traffic-calming designs in various villages across the U.K. The roads under study were all classified as major or main roads. The traffic calming designs implemented varied significantly and were classified as follows:

A. No measures in the village, but use of gateway signing associated with significant markings/colored surface/minor narrowing, and in some cases physical measures at the gateway.

B. Measures within the village, involving mainly road markings, colored surfaces and traffic islands, some with gateway features.

C. Significant physical measures within the village, involving horizontal and vertical deflections, usually in conjunction with gateways.

Overall, 1,400 casualty crashes were analyzed and categorized as slight injury crashes, or fatal and serious injury crashes. The analysis included all crashes on the main road (including intersection crashes) between the gateways (or speed limit reductions for the village if no gateway was present). Table 22 shows the aggregated before-after frequency.

TABLE 22
EFFECTS OF VILLAGE TRAFFIC CALMING IN THE U.K.

| Period | No. of Crashes: Slight Injury | No. of Crashes: Fatal + Serious Injury | No. of Crashes: All | % Fatal + Serious Injury | Years (average) |
|---|---|---|---|---|---|
| Before | 89.8 | 35.3 | 125.2 | 28.2 | 7.2 |
| After | 76.8 | 17.0 | 93.8 | 18.1 | 5.3 |
| CRF | 0.14 | 0.52 | 0.25 | — | — |

CRF = crash reduction factor

The sites averaged one to three crashes per year pre-traffic calming, with a low of no crashes to a high of 15.6 crashes/year. Injury crashes were reduced at 34 of the 56 sites; only 10 of the 34 sites had statistically significant reductions. However, using the aggregated crash data, the reductions in all crash categories were statistically significant. Furthermore, using national crash trends as an improvised control group, Wheeler and Taylor concluded that the crash reduction factors for traffic-calming on main roads in villages are 0.20 to 0.25 for all injury crashes, and 0.33 to 0.50 for serious injury and fatal crashes.

Wheeler and Taylor did not appear to explicitly control for RTTM effects, but the report mentions that "many villages have more of a perceived problem than a real safety problem." This indicates that the majority of the sites studied were not likely suffering from a high rate of crashes and the RTTM effect would be less pronounced. Additional analysis included examining the effects of traffic calming based on different types of calming, road volumes, and speed reductions (see Table 23).

TABLE 23
CRASH REDUCTIONS FOR TRAFFIC CALMING ON MAIN ROADS IN THE UNITED KINGDOM

| | Fatal + Serious Injury | | | All Injury | | |
|---|---|---|---|---|---|---|
| | Before | After | CRF | Before | After | CRF |
| *Traffic Calming Type* | | | | | | |
| A. Gateways Only | 7.7 | 3.5 | 0.55 | 25.9 | 21.1 | 0.19 |
| B. Calming in Village | 15.6 | 10.3 | 0.34 | 48.0 | 46.0 | 0.04 |
| C. Aggressive Calming | 11.7 | 3.5 | 0.70 | 49.7 | 27.3 | 0.45 |
| *Traffic Volume* | | | | | | |
| <4,000 vpd | 2.3 | 0.9 | 0.61 | 7.2 | 6.1 | 0.15 |
| 4,000 to 7,999 | 4.5 | 2.3 | 0.49 | 17.3 | 11.2 | 0.35 |
| 8,000 to 11,999 | 17.6 | 8.9 | 0.49 | 61.3 | 44.9 | 0.27 |
| >12,000 vpd | 9.3 | 5.3 | 0.43 | 32.5 | 32.1 | 0.01 |
| *Speed Reduction* | | | | | | |
| 0–2 mph (0–3 km/h) | 5.8 | 2.7 | 0.53 | 19.7 | 17.8 | 0.10 |
| 3–4 mph (5–6.5 km/h) | 7.5 | 5.5 | 0.27 | 26.6 | 22.8 | 0.14 |
| 5–6 mph (8–10 km/h) | 2.1 | 1.5 | 0.29 | 8.4 | 5.7 | 0.32 |
| ≥7 mph (11 km/h) | 4.8 | 0.9 | 0.81 | 16.7 | 8.9 | 0.47 |

CRF = crash reduction factor, vpd = vehicles per day.

The reduction in crashes at the "gateways only" sites is relatively impressive. The report notes that the gateways were typically more substantial than simply signing and minor markings; they often included minor narrowings, surface treatments, and so on. In the "calming in villages" group, the majority of the crash savings resulted from sites that had calming in the village, and gateways (as opposed to those without). It is clear that the "aggressive calming" group yielded the most significant crash reductions.

*Crowley and MacDermott (undated)*

Crowley and MacDermott (undated) conducted an evaluation of traffic calming projects implemented on national primary roads in Ireland between 1993 and 1996. The evaluation quantified the reductions in crashes resulting from traffic calming in villages and towns. Twenty-one different traffic-calming projects were evaluated. There is considerable variation in the traffic calming implemented at each site; the average cost of implementation for traffic calming on both approaches was €215,000 (2000 prices) with a range of €29,000 to €432,000. The 21 sites were divided into 14 sites that had traffic calming implemented on both approaches and 7 sites that had traffic calming implemented on only one approach. Table 24 shows the effects of the traffic calming on crash occurrence.

TABLE 24
EFFECTS OF TRAFFIC CALMING ON CRASH OCCURRENCE ON IRISH NATIONAL PRIMARY ROADS (1993 TO 1996)

| Group | Crash Type | No. of Crashes | | Average of Annual Number of Crash | | CMF |
|---|---|---|---|---|---|---|
| | | Before | After | Before | After | |
| Both Approaches (N =14) | Fatal | 11 | 1 | 0.11 | 0.01 | 0.13 |
| | Serious Injury | 19 | 7 | 0.20 | 0.13 | 0.71 |
| | Minor Injury | 49 | 20 | 0.54 | 0.35 | 0.64 |
| | All Casualty | 79 | 28 | 0.84 | 0.50 | 0.59 |
| One Approach (N = 7) | Fatal | 0 | 0 | 0.00 | 0.00 | — |
| | Serious Injury | 9 | 1 | 0.09 | 0.02 | 0.26 |
| | Minor Injury | 9 | 6 | 0.09 | 0.10 | 1.07 |
| | All Casu-alty | 18 | 7 | 0.18 | 0.12 | 0.67 |

CMF = crash mitigation factor.

The evaluation demonstrated impressive results but did not control for exposure (i.e., traffic volumes) and other sundry effects. Moreover, the evaluation expressly noted that the primary criterion for selecting traffic calming projects is the number of crashes, and therefore RTTM effects may overestimate the effectiveness of the traffic calming.

The RTTM effect is highlighted if the crash movement factors for the 14 locations with traffic-calming implemented on both approaches are calculated separately for the nine locations with annual casualty crash frequencies less than one, and the five locations with annual casualty crash frequencies greater than one (see Table 25). The effectiveness of traffic calming at the locations with the higher "before" crash frequency appears to be much higher, at least part of which is simply RTTM effects.

TABLE 25
REGRESSION-TO-THE-MEAN EFFECTS ON THE IRISH DATA

| Group | Crash type | Average of Annual Number of Crash | | CMF |
|---|---|---|---|---|
| | | Before | After | |
| Frequency < 1.0 (N = 9) | Fatal | 0.05 | 0.01 | 0.28 |
| | Serious Injury | 0.07 | 0.06 | 0.82 |
| | Minor Injury | 0.18 | 0.15 | 0.83 |
| | All Casualty | 0.30 | 0.22 | 0.74 |
| Frequency > 1.0 (N = 5) | Fatal | 0.06 | 0.00 | — |
| | Serious Injury | 0.13 | 0.08 | 0.65 |
| | Minor Injury | 0.36 | 0.20 | 0.55 |
| | All Casualty | 0.54 | 0.28 | 0.52 |

CMF = crash mitigation factor.

*Winnett and Wheeler (2002)*

Winnett and Wheeler (2002) conducted an evaluation of the effectiveness of vehicle-activated signs (VAS) in reducing speeds and crashes in the United Kingdom. One type of VAS evaluated was a dynamic speed limit sign (a "speed roundel") for speed limit changes employed mainly at village sites on rural, undivided roads (see Figure 7).

Sites were selected for VAS implementation if they had either a recent history of crashes in which inappropriate speed was a contributory factor, or a record of excessive speed for the conditions was believed to be a potential problem. Sites selected for evaluation also required suitable sight lines to the VAS by the approaching driver, and traditional traffic control devices (such as fixed signs and markings) that were in compliance with the applicable standards. The VAS implemented was a speed roundel, the U.K. equivalent to the SPEED LIMIT SIGN (R2-1), that was blanked out and activated by motorists exceeding the speed limit. Some of the roundels were supplemented with flashing beacons. All of the VAS were located 66 ft to 164 ft (20 m to 50 m) downstream of the beginning of the speed limit change (i.e., within the village speed limit).

The 5-year "before" and "after" crash analysis covered the period from 1990 to 2000. For the speed limit VAS, all crash data were obtained for the length of road of about 0.6 mile (1 km) from the start of the speed limit. This section would be without intersections, which could generate crashes not influenced by the sign. The casualty crash frequency was analyzed using Empirical Bayes techniques that account for RTTM and maturation effects. At the 19 sites with a 30 and 40 mph (50 and 65 km/h) urban speed limit (and available crash data) the VAS produced a statistically significant reduction in casualty crash frequency of 34% (± 8%).

*Garder et al. (2002)*

Garder et al. (2002) conducted a study to evaluate the safety effect of traffic calming on arterial roads and to examine the acceptance of these measures. They found that there are a limited number of traffic-calmed arterials—even fewer that have been evaluated. The North American experience indicates that measures that might be considered traffic calming have mostly been implemented for mobility/capacity reasons (i.e., roundabouts, and four-lane to three-lane conversions). The effectiveness of arterial traffic calming has been "moderate," although there is a clear reduction in pedestrian injuries. Public opinion surveys indicated that horizontal deflections are preferred to vertical deflections on arterial roads.

*Souleyrette et al. (2003)*

Souleyrette et al. (2003) analyzed the safety records of various types of on-street parking in smaller communities in the state of Iowa. Specifically, the researchers wanted to compare the safety performance of streets that had diagonal parking with streets that had other types of curbside parking. Several factors were examined to determine possible contributions to crash occurrence, including road width, clearance to parked vehicles, traffic volumes, community population, and length of parking area. None of these factors, with the possible exception of population, displayed a clearly definable relationship to crash occurrence. The difference in average non-intersection crash rates for diagonal and parallel parking streets was almost negligible (see Table 26). In fact, those observed rates were less than sample locations with no parking at all. The authors recognized that the research did not present a statistically sound sample of locations, but stated that the data gathered were quite substantial and covered most areas of the state of Iowa. They concluded that there is no compelling reason for a blanket prohibition of angle parking along Iowa's primary extensions in all urban areas, and that each community should be examined on a case-by-case basis.

TABLE 26
CRASH RATES FOR CURBSIDE PARKING

| Parking (one side/ other side) | No. of Segments | Average AADT | Average Crash Rate (100 MVM) | |
|---|---|---|---|---|
| | | | All | Non-intersection |
| Diagonal/Diagonal | 72 | 2,100 | 1,620 | 400 |
| Parallel/Parallel | 26 | 2,350 | 910 | 420 |
| Diagonal/None* | 4 | 1,070 | 2,710 | 860 |
| Parallel/None* | 3 | 1,260 | 1,540 | 0 |
| Diagonal/Parallel | 19 | 2,300 | 1,750 | 320 |
| Parallel/Parallel with Diagonal in the centre of the street* | 3 | 3,510 | 1,450 | 250 |
| None/None* | 14 | 5,040 | 1,870 | 630 |

*Small sample size—use with caution.
AADT = average annual daily traffic, MVM = million vehicle miles.

*Agustsson (2005)*

Agustsson (2005) reported on the effectiveness of "environmentally friendly through-roads," which are streets where traffic is managed by using different forms of speed-reducing measures. Twenty-one of these newly developed roads were implemented to reduce speed, increase safety, and improve road design. The measures used include gates, roadside reservations, medians, roundabouts, raised areas, changes in road surface, road markings, signing, lighting, road closures, rumble strips, and bicycle lanes. The average length of the through-road is about 0.6 mile or 1 km (it is not clear if this is the total length of the road or the length of the road that was treated, although it is expected that it is the latter).

Ten years of crash data (5 years in the before period and 5 years in the after period) are used in a before-after study with a control group. The control group consists of national and country roads that traverse towns with populations of less than 5,000. Crash occurrence was reduced for all crash severities; however, none of the differences were significant at a 95% level of confidence (see Figure 19). A more detailed analysis by Agustsson revealed that although the percentage of multivehicle crashes was reduced the percentage of single-motor-vehicle crashes increased (both significant differences at a 95% level of confidence). The likely explanation for this result is that the new road schemes present more obstacles, such as islands and bollards, for a motorist to strike.

*Department for Transport (2005)*

The U.K. Department for Transport (2005) tested rumblewave surfaces, which are a quieter alternative to transverse rumble strips at seven pilot locations. A rumblewave surface is shown in Figure 9.

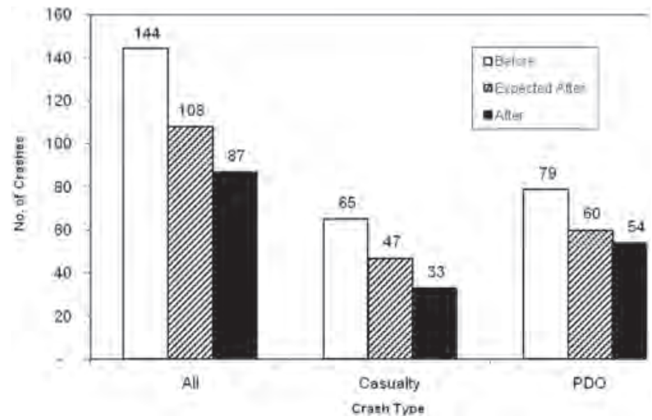



FIGURE 19 Effect of environmentally adapting through roads on crash occurrence [*Source*: Agustsson (2005)].

Rumblewave surfaces have been piloted at seven locations, including a high-to-low speed transition, as shown in Table 10. Table 27 shows the effects of rumblewaves on the rates of personal injury crashes. The reduction in casualty crashes is significant, averaging a 55% reduction (range from 24% to 100%). However, in three of the six locations that were evaluated for crash risk, one of the problems being addressed was a high incidence of crashes; this raises the specter of RTTM bias and suggests that the 55% reduction is an overly optimistic estimate.

*Forbes (2006)*

Forbes (2006) conducted a retrospective, observational before-after study of the safety effects of traffic management in rural settlements located on rural arterial roads in Ontario, Canada. The research documented the types of measures implemented and their efficacy related to crash risk at 12 treatment sites selected by convenience.

The crash analysis employed an Empirical Bayes analysis using crash frequency categorized by severity as the primary measure of effectiveness. Table 12 shows the sites used in the analysis and the data available at each site. The analysis indicated that the various traffic management measures were successful in reducing crash occurrence by 22% (28% for casualty crashes) at the five sites where crash data were available. Overall, these results indicated that traffic management in rural settlements in Ontario was effective in improving safety. Nonetheless, the results should be viewed with some caution as the sample sizes were small, the treatments applied at each site varied considerably, and there may have been co-interventions that also contributed to the improvements (i.e., increased awareness and enforcement that were unaccounted for in the analysis).

TABLE 27
EFFECTS OF RUMBLEWAVE SURFACES ON INJURY CRASHES

| Site* | Before (36 months) | | After | | | Reduction (%) |
|---|---|---|---|---|---|---|
| | No. of Casualty Crashes | Annual Frequency | Months in-service | No. of Casualty Crashes | Annual Frequency | |
| 2 | 13 | 4.3 | 33 | 3 | 1.1 | –75 |
| 3 | 2 | 0.7 | 24 | 0 | 0 | –100 |
| 4 | 31 | 10.3 | 23 | 8 | 4.2 | –60 |
| 5 | 13 | 4.3 | 22 | 6 | 3.3 | –24 |
| 6 | 5 | 1.3 | 22 | 1 | 0.5 | –67 |
| 7 | 13 | 4.3 | 24 | 5 | 2.5 | –42 |
| Average | | 4.3 | | | 1.9 | –55 |

*Site 1 crash data were not reported.

*Quimby and Castle (2006)*

As part of the Quimby and Castle (2006) investigation into the effects of simplified streetscapes on crash risk, three projects relevant to this synthesis were identified. Opeinde in the Netherlands is a large area simplification plan that included removal of pavement markings, and different curb and road surfacing which denote a public space that is shared by different modes of transport rather than one where motorized traffic has priority. The plan includes marking the entry points to the town with a large tubular steel arch that serves as a gateway (see Figure 20).

FIGURE 20 Opeinde Gateway [*Source*: Quimby and Castle (2006)].

The 5-year before crash record included one fatal crash, seven injury crashes, and 24 property damage only crashes. The 3-year after crash record for this simplified streetscape involved one injury crash and five property damage only crashes.

When combined with the crash data from a small number of other Dutch simplified streetscape projects, conclusions are difficult to draw. With the exception of the previously cited treatment, there have been no serious crashes in either the before or after periods at treated sites. Property damage only crashes decline in some instances and increase in others. The only discernable trend is that property damage only crashes seem to increase in the year after simplification, indicating a behavior adjustment period for road users.

Quimby and Castle also reported that the removal of longitudinal pavement markings can be effective in lowering speeds and crash rates in certain rural road circumstances. A centerline removal plan for 30 mph (50 km/h) zones in Wiltshire, England, resulted in a 35% decrease in crashes and a 5% reduction in travel speeds. However, the authors also report that another study involving seven sites in England using a before-after with comparison group methodology showed that removing directional dividing lines did not produce any statistically significant change in crashes.

*Knapp and Rosales (2007)*

An increasingly popular form of traffic management that may be useful for rural settlements located on multilane roads is "road diets," or lane reductions. Typically, "road diets" involve converting a four-lane road to a two-lane road, with a center turn lane and bicycle lanes on either side of the road. Knapp and Rosales (2007) aggregate the results from a number of statistically robust road diet studies, analyzing the effects on crash risk. The treatments were typically four-lane to three-lane conversions with varied settings, locations, and methodological approaches. Table 28 summarizes the details of the safety effects presented in four of the statistically robust studies.

Except for the Huang et al. (2005) study, road diets appeared to produce a 20% to 40% reduction in crash risk. The articles do not provide settings for these studies, so the impressive results are not necessarily directly applicable to transition zones. Nonetheless, road diets are a measure that might be implemented at the downstream end of a transition zone and carried through the developed area to reinforce the lower speed limits.

TABLE 28
STUDY RESULTS FOR ROAD DIETS

| Researcher | Statistical Methods | No. of Sites | Change in Crash Risk | |
|---|---|---|---|---|
| | | | Measure | Reduction |
| Huang et al. (2005) | Before-after with yoked comparison | 12 converted sites, 25 comparison sites | All crashes | 6% |
| Stout and Souleyrette (2006) | Before-after | 14 | All crashes | 21% |
| | Before-after with yoked comparison | 14 | All crashes | 38% |
| Gates et al. (2007) | Empirical Bayes | 7 | All crashes | 44% |
| Pawlovich et al. (2007) | Full Bayes | 15 | Crashes per mile<br>Crash rate | 25%<br>19% |

*Andersson et al. (2008)*

Andersson et al. (2008) analyzed the safety performance of town gates in transition zones between rural and urban areas of Denmark. The area of influence for each gate was determined to be 656 ft (200 m) on either side of the gate [i.e., a 1,312 ft (400 m) section of road]. A total of 251 town gates were included in the analysis, broken down into the following three categories:

- Gates consisting of physical measures only (102 sites)
- Gates consisting of visual measures only (40 sites)
- Gates consisting of a combination of physical and visual measures (109 sites).

Examples of these gateways are shown in Figure 21. Physical measure gates generally consisted of a central traffic island with deflections for both directions of travel, bicycle facilities, and illumination. At just under 80% of the physical measure gates, upstream warning of the gate was provided. The visual measures gates were typically characterized by an urban zone sign placed on a special background. More than 70% of these gates were fully or partially illuminated, with 28% having special illumination for the urban zone sign. The physical and visual measures gates were characterized by either a speed hump or a central traffic island. Approximately 70% had an urban zone sign on a special background, and 40% had special illumination. Almost half of the physical and visual measures gates had warning signs and almost all of them were illuminated.

Safety performance was estimated using 3 to 5 years of before-after crash data and a control group consisting of county and state roads in urban and rural settings, excluding motorways and highways. At 31% of the 251 sites there were no recorded crashes in the area of influence in both the before and after periods. The following crash trends were reported:

- A significant increase of 34% in the number of property damage only crashes
- No significant change in the number of personal injury crashes
- A 100% increase in the number of single motor vehicle crashes
- A 29% decrease in crossing crashes with road-users
- A significant increase of 28% in urban area crashes, and a minor 6% increase in rural areas crashes (not statistically significant).


FIGURE 21 Danish gateways [*Source*: Andersson et al. (2008)].

Of the three categories of gates, the physical and visual measures gates offered the best safety performance. The physical measures gates showed a 43% and 68% increase in personal injury and property damage only crashes, respectively. Faring somewhat better were the visual measures gates, which produced no change in personal injury crashes and a statistically insignificant decrease of 29% in property damage only crashes. Finally, the combined physical and visual measures gates yielded a 28% decrease in injury crashes, and a 36% increase in property damage only crashes (neither result was statistically significant).

The difference between the posted speed limits in the rural and the urban areas seemed to influence safety performance, with gates on roads where the difference in posted speed limits is less than 20 mph (30 km/h) being more effective than gates at transitions of greater than 20 mph (30 km/h). Based on somewhat insufficient data, the researchers concluded that at gates that are only physical measures, speed humps are more effective than traffic islands, but the same is not true if the gate is also outfitted with visual measures.

*Veneziano et al. (2009)*

The state of California undertook a Gateway Monument Demonstration Program and constructed seven gateways for five communities from 2005 to 2008, inclusive. The gateways were freestanding structures or signage at the roadside that communicated the name of a city, county, or township to road users (see Figure 22 for an example gateway).


FIGURE 22 An example gateway in California [*Source*: Veneziano et al. (2009)].

Crash data assembled for analysis came from at least 0.1 mile (0.2 km) upstream and downstream of the gateway monument, adjusted according to location-specific features that warrant inclusion of additional road segments. Three years of before data and 3 years of after data (if available) were used in an Empirical Bayes crash analysis. Table 29 summarizes the site data.

An examination of crash number and type by the researchers at each of the gateway sites indicated that no deterioration in safety was observed at any gateway sites. On a collective basis, the Empirical Bayes analysis showed a reduction in the total number of crashes of 2.2% to 32.0%, depending on the base safety performance function used in the analysis. The researchers concluded that these results indicate that gateways are not detrimental to safety, as opposed to being a safety benefit.

## DOCUMENTED PRACTICES AND GUIDANCE

### Australia

In an early report concerning better balancing the needs of traffic movement, and the needs of village residents and businesses, Armstrong et al. (1992) advanced the concept of "entry portals" to raise driver awareness of changes in the road environment that require different driver behavior. A portal marks the beginning of an area where a different (usually lower) speed profile applies. Where the difference in the desired speed on the open road and the the village street is great, and in order to avoid any abrupt changes in speed, it is suggested that two portals be introduced. The upstream portal conditions the driver to a speed reduction and the downstream portal forces the driver to reduce speed to the level required in the village before entering the village.

No evaluations or case studies are provided. Similarly, there is no specific design guidance. The most relevant piece of documentation on recommended practices for rural high-to-low speed transitions was the New Zealand Land Transport Safety Authority's "Guidelines for Urban/Rural Speed Thresholds" (Land Transport Safety Authority 2002). These guidelines outline the principles to be used in the application and design of engineering treatments at urban/rural thresholds to promote consistency and good design practice.

With respect to warrants for engineering measures at these locations, it is noted that thresholds are a potential technique only on roads that have a difference in the warranted speed limits of 12 mph (20 km/h) or more and when one or more of the following conditions are present:

- Vehicle speeds on the approach to the settlement or through the urban areas are inappropriately high
- The injury crash rates are higher than average or need to be reduced
- Vulnerable road users such as pedestrians and cyclists feature in the crash analysis.

In general, the guidelines touch on all of the expected factors in gateway development: placement, roadway narrowing, lighting, conspicuity, accommodation of cyclists or pedestrians, surface treatments, vertical deflections, landscaping, and traffic control devices.

The New Zealand guidelines recommend the dimensions shown in Figures 23–25 for effective rural/urban thresholds. Vertical deflections such as speed humps and raised crosswalks are not recommended for urban/rural thresholds.

TABLE 29
SUMMARY OF CALIFORNIA GATEWAY DATA

| Location | Length (m) | No. of Lanes | Lane Width (ft) | Shoulder Width* (ft) | Before | | | After | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AADT** | Years of Data | Total Crashes | AADT** | Years of Data | Total Crashes |
| Willow Creek | 0.7 | 2 | 12 | 11 | 3,000 | Aug 03–Jul 06 | 2 | 3,300 | Aug 06–Apr 08 | 1 |
| Paso Robles Rte. 46 | 0.6 | 2 | 12 | 8 | 17,000 | Aug 98–Jul 01 | 0 | 20,000 | Aug 01–Jul 04 | 4 |
| Nevada County | 0.4 | 4 | 12 | 10 | 27,500 | Sep 03–Aug 06 | 5 | 34,000 | Sep 06–Apr 08 | 1 |
| Tehachapi | 0.4 | 4 | 12 | 8 | 10,100 | Nov 02–Oct 05 | 3 | 10,900 | Nov 05–Apr 08 | 1 |
| Paso Robles US 101 | 0.05 | 1 | 12 | 9 | 9,600 | Aug 98–Jul 01 | 3 | 12,900 | Aug 01–Jul 04 | 6 |
| | | | | | | | | | | |
| | Before | | | | | | After | | | |
| | Minor AADT | Major AADT | Years of Data | Total Crashes | | | Minor AADT | Major AADT | Years of Data | Total Crashes |
| Rocklin WB | 2,770 | 25,000 | May 02–Apr 05 | 12 | | | 3,400 | 29,500 | May 05–Apr 08 | 7 |
| Rocklin EB | 11,050 | 24,000 | May 02–Apr 05 | 11 | | | 11,350 | 28,200 | May 05–Apr 08 | 15 |

[*Source*: Veneziano et al. (2009)].
*Average width for two sides of the roadway.
**AADT (average annual daily traffic) was obtained for the middle year of each before and after period.

## Europe

Herrstedt et al. (1993) developed a catalogue of ideas on Danish traffic calming that also provides some insights and guidance on speed reductions in transition zones. To start, the authors noted that the selection of speed reduction measures in any situation depends first and foremost on the target/desired speed, and the road classification (i.e., roadway function). For desired speeds of 30 mph (50 km/h) or higher, eight treatments are identified in the catalogue (see Table 30).

There is no specific reference to which, if any, of these treatments might be acceptable at a rural-urban threshold.

European countries have long recognized the need for transition zones on the approaches to villages as a component of an overall speed management strategy (European Transport Safety Council 1995). The European approach to these zones is founded on two principles:

- Measures in transition zone must be complemented by measures along the through route within the urban area; and

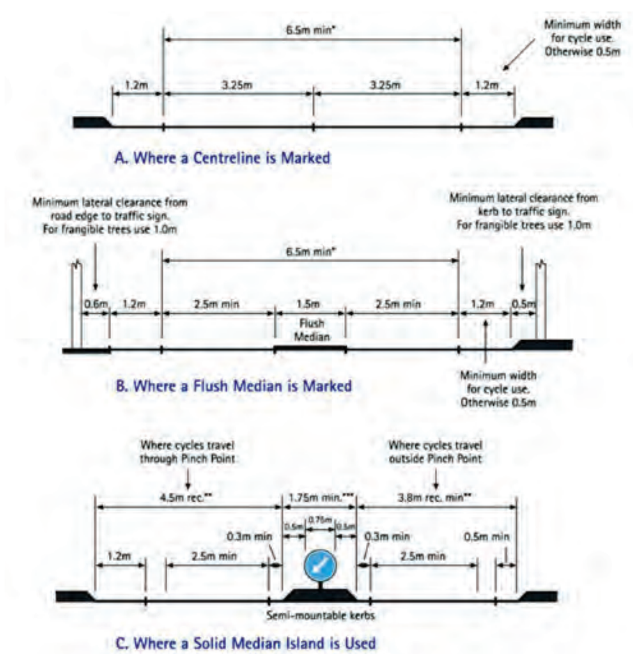



FIGURE 23 Minimum widths for urban/rural thresholds [*Source*: Land Transport Safety Authority (2002)].

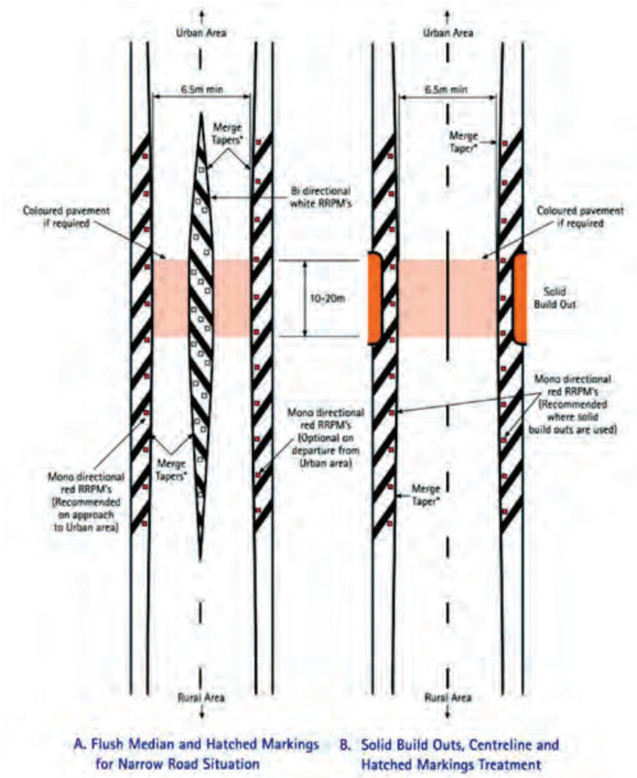



FIGURE 24 Standard transition measure in New Zealand [*Source*: Land Transport Safety Authority (2002)].

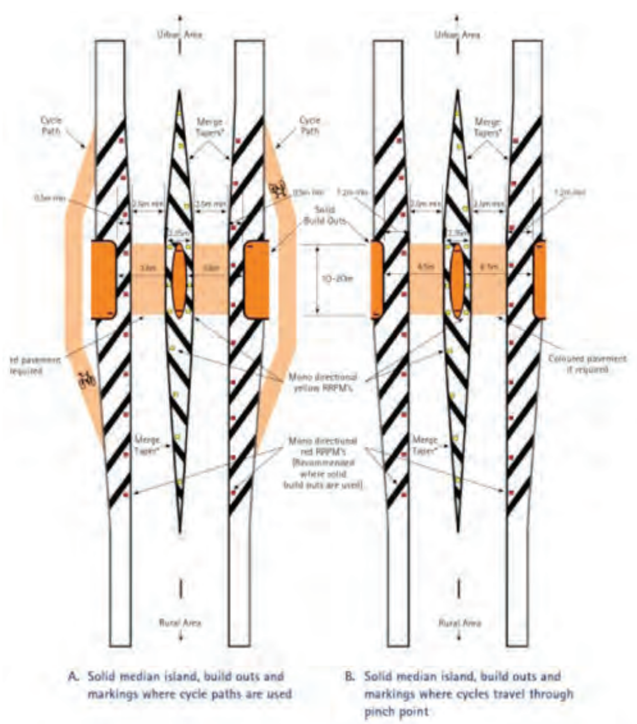



FIGURE 25 Standard transition measure with raised median in New Zealand [*Source*: Land Transport Safety Authority (2002)].

TABLE 30
SPEED REDUCTION MEASURES FOR DESIRED SPEEDS OF 30 MPH (50 KM/H) OR HIGHER

| Treatment | Road Class | | Desired Speed | | AADT | |
|---|---|---|---|---|---|---|
| | Traffic Road | Local Road | ≥40 mph (60 km/h) | 30 mph (50 km/h) | >3,000 | ≤3,000 |
| Pre-warnings | X | X | X | X | X | X |
| Gates | X | X | X | X | X | X |
| 2-lane raised areas | X | X | | X | X | X |
| 2-lane humps | X | X | | X | X | X |
| Staggerings | X | X | X | X | X | X |
| Staggerings with raised area | X | X | | X | X | X |
| 2-lane narrowing from road center | X | X | | X | X | X |
| 2-lane narrowing from roadside | X | X | | X | X | X |

[Adapted from Herrstedt et al. (1993)].

- The transition zone measures should achieve a cumulative effect culminating at a feature called the gateway to the town or village.

With respect to the second principle, the European guidance is to influence the driver's perception of appropriate speed by altering the physical relationship between the width of the road and the height of the nearby vertical elements such as trees and buildings. Research has shown that speeds are lower where the height of vertical elements is greater than the width of the road. In the transition zone, speed can be lowered to more acceptable levels by progressively introducing road narrowing and vertical elements at the roadside. The transition zone should be terminated at a gateway, which should coincide with the threshold to the urban area. It is recommended that the gateway be the most prominent visual element in the transition zone, and visible over at least the stopping sight distance for the 85th percentile of the approach speed.

The Irish National Roads Authority (2005) have developed a set of traffic calming guidelines for towns and villages located on national roads that includes a specific section on transition zones. The Irish guidelines for transition zones rely heavily on the concept of "optical width": the relationship of the horizontal and vertical elements of the road and the roadside. Urban and rural cross sections generally have vastly different ratios of horizontal dimension (offered by the road bed and the roadside clear zone) to the height of the vertical elements located at the roadside. Figure 26 provides an example of the different optical widths for urban and rural areas. The guidance for effective transition zones is that the optical width should be progressively reduced throughout the length of the transition zone to achieve the dominance of the vertical elements culminating in a gateway.

These guidelines also advocate for a gradual change from a rural to an urban character in the transition zone. To this end, it is noted that the urban and rural environments typically have the characteristics shown in Table 31. Design features that may be included in high-to-low speed transition zones include the following:

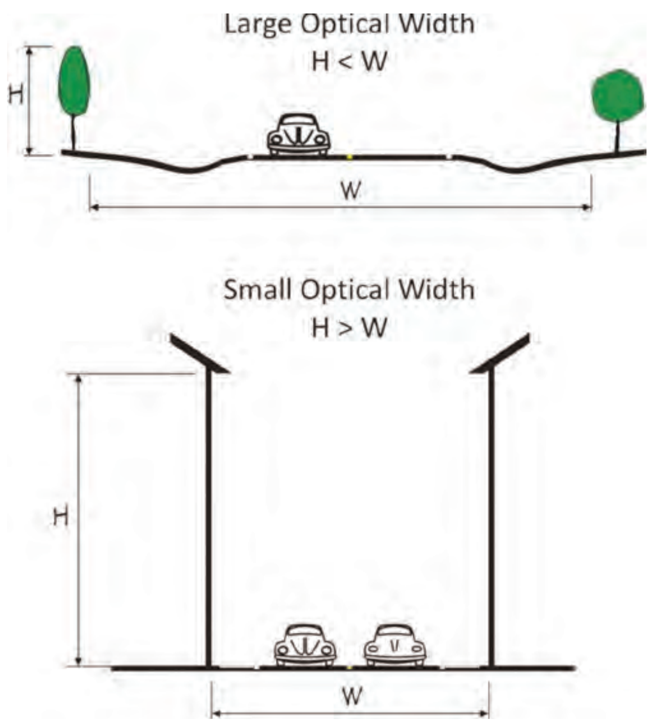



FIGURE 26 Optical width [*Source*: Irish National Roads Authority (2005)].

TABLE 31
URBAN AND RURAL STREET CHARACTERISTICS

| Feature | Rural Road | Urban Street |
|---|---|---|
| Boulevard grass | Not mowed | Mown grass |
| Roadside vegetation | Native species | Evergreen ground cover |
| Trees in the road allowance | Irregular spacing and clumping | Single or double rows of regularly spaced trees |
| Sidewalks | Absent | Present |

- Prohibition of overtaking in the transition zone, using signs, solid centerlines, and gateway islands
- Eliminating or reducing the hard shoulder, using crosshatching inside the edge line to increase the visual effect
- Narrowing the carriageway
- Provision of rumble strips or rumble areas if speeds are not sufficiently reduced by other measures
- Signs with a vertical emphasis
- Use of appropriate softscape elements such as trees, shrubs, and grass boulevard treatment, which change in composition and degree of formality along the transition zone into the town
- Provision of cyclist and pedestrian facilities
- Use of the town sign in conjunction with the area speed limit sign in the design of the gateway.

The Irish guidelines also recommend the use of a gateway at the downstream end of the transition zone to mark a change in the character of the surrounding area from rural to urban. Gateway design features include the following:

- The gateway should be conspicuous, the most prominent element in the transition zone, and located at the downstream end of the transition zone.
- The gateway should be visible over the stopping distance for the 85th percentile approach speed.
- The gateway should not interfere with sightlines at intersections, etc.
- The gateway location should be cognizant of likely future developments.
- When the gateway has been located in the field, the existing speed zones should be reviewed and changed, if necessary, so that the location of the 30 mph (50 km/h) or 35 mph (60 km/h) speed limit sign corresponds with the gateway.
- Illumination, where provided, should extend at least two poles beyond the gateway.
- Curbs on gateway islands and build-outs should be painted (yellow and black).
- Direct lighting of gateway signs at gateways without a center island is optional, but has been found to be very effective, particularly on long approaches.
- The road surface may be colored or textured for the length of the gateway.
- Hard shoulders should, in general, be replaced with parking bays within the gateway.
- A ¾ inch (2 mm) high narrow rib may be overlaid on crosshatching lines.

For roadsides in transition zones, the Irish guidelines identify landscaping as an important element and promote individual treatment according to the landscape character of the area. The main roadside/landscaping design elements may include the following:

- The grass boulevard should be maintained to a high standard over the length of the transition zone to signal a degree of formality.
- Hedges, when provided, should be 5 to 6 ft (1.5 to 2.0 m) high and composed of a mix of indigenous/naturalized shrubs (70%) and deciduous ornamental shrubs (30%) at the start of the zone, changing to an even split between deciduous ornamental shrubs and evergreen shrubs toward the end, so as to provide a higher amenity value in the vicinity of the built-up area.
- Full standard trees should be planted in "clumps" at the back of the transition zone signs where a suitable backdrop does not exist.
  – Each clump should consist of three to five native or naturalized trees that integrate well into the existing landscape.
  – Trees should be planted at 6 to 12 ft (2 to 4 m) on-center within each clump.
  – No tree whose girth would be expected to exceed 6 inches (150 mm) should be located any closer than 15 ft (4.5 m) from the road edge.
- A single row of full standard trees may be provided at 60 ft (20 m) spacing along the grass boulevard or within the hedgerow in settings that are already urban in character.

Figures 27 through 33 show examples of typical transition zone landscape designs.

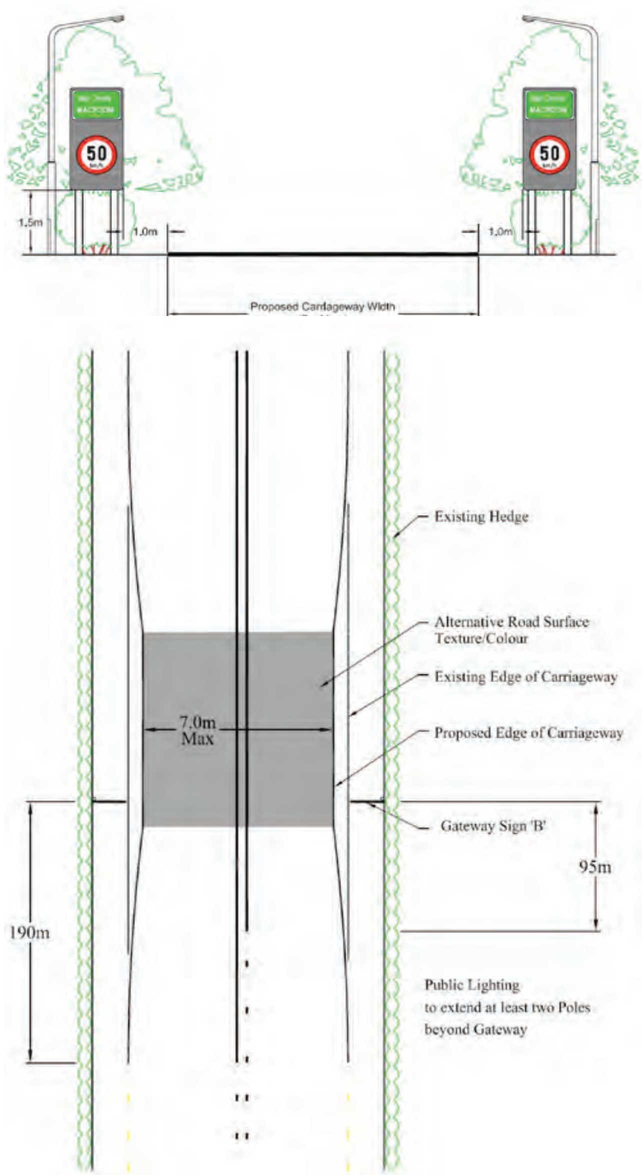



FIGURE 27 Transition zone for 40 to 50 ft (12 to 16 m) right-of-way without a path [*Source*: National Roads Authority (2005)].

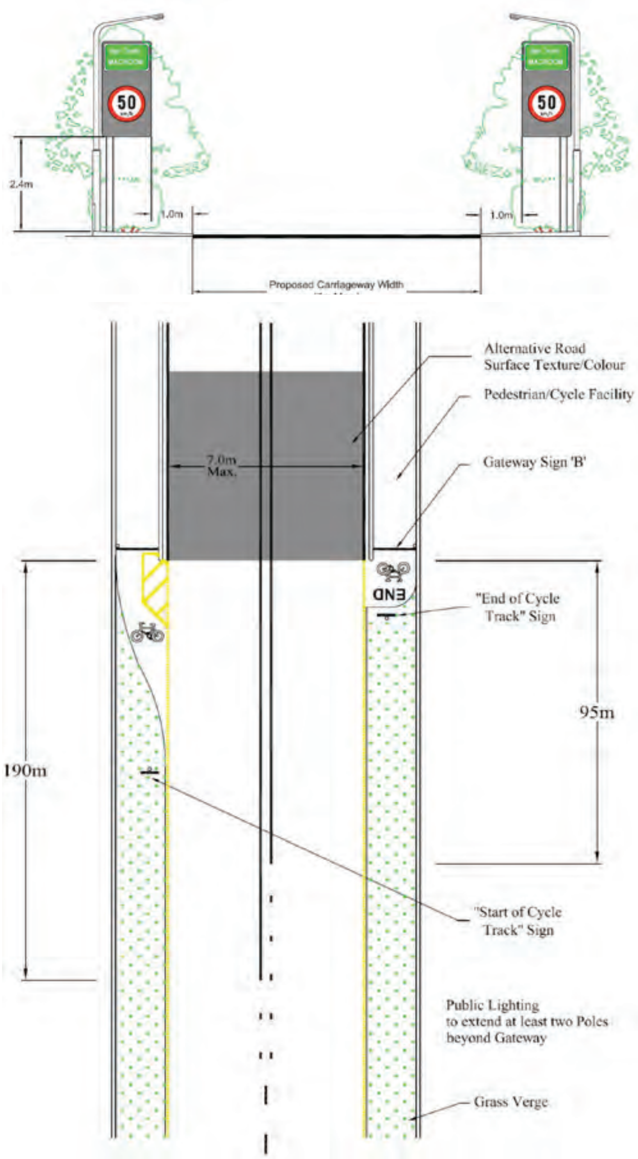



FIGURE 28 Transition zone for 40 to 50 ft (12 to 16 m) right-of-way with a path [*Source*: National Roads Authority (2005)].

The landscaping at the gateway (see Figure 34) should reinforce the vertical character of the sign and narrow the driver's cone of vision. To achieve this:

- Provide evergreen shrubs, less than 5 ft (1.5 m) high, to anchor down the sign.
- Plant an upright standard tree within the shrub planting and behind the sign. A number of similar trees with a final height of 26 to 40 ft (8 to 12 m) should be planted at regular intervals inside the gateway.
- Embankments may be mass planted with ground cover shrubs and a hedgerow planted along the boundary fence at the top of the embankment.

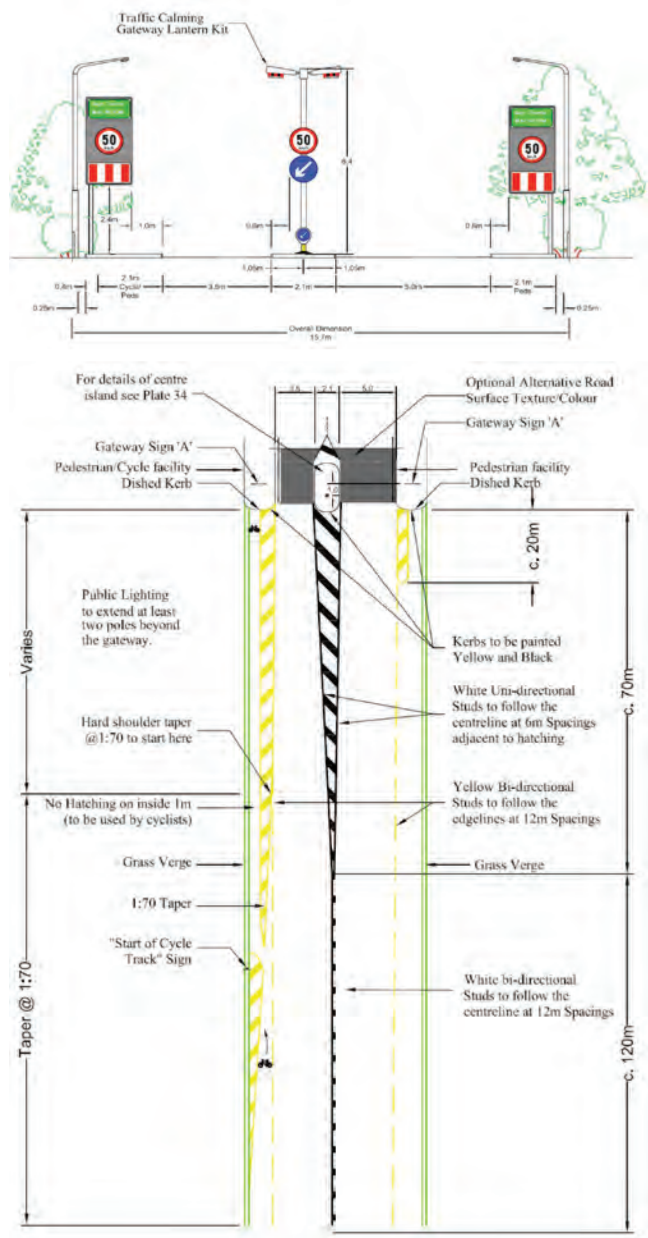



FIGURE 29 Transition zone for 50 to 63 ft (16 to 19 m) right-of-way [*Source*: National Roads Authority (2005)].

Finally, the Irish guidelines allow for the provision of rumble strips and tactile surfaces where adequate speed reductions are not being achieved in the transition zone. Two treatments are available:

- A "rumble area" overlaid on to the surface with a length of 400 ft (120 m) and the last patch terminating 164 ft (50 m) from the gateway sign; and
- The rumble strip installation, which consists of bars of thermoplastic material over a length of about 656 ft

(200 m) and installed so that it corresponds with the length of longitudinal pavement markings in the transition zone.

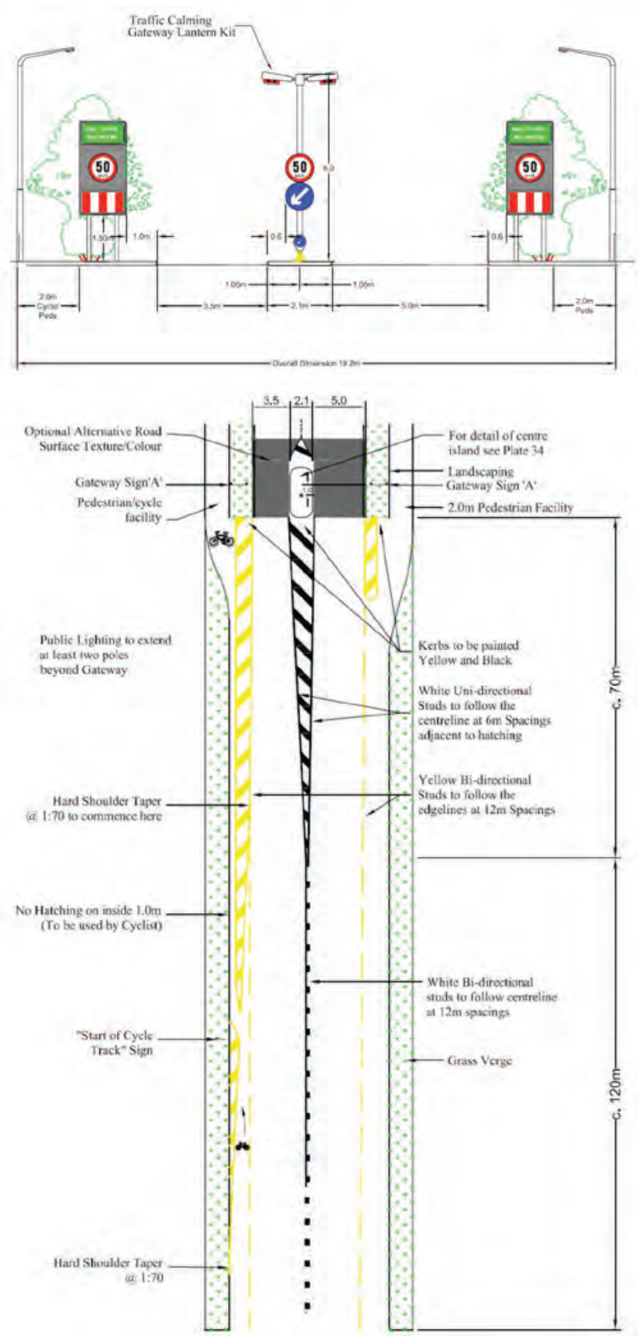



FIGURE 30 Transition zone for 63 to 69 ft (19 to 21 m) right-of-way [*Source*: National Roads Authority (2005)].

Kennedy (2005) reported the following broad principles that form the basis for successful psychological traffic calming, which includes gateways and treatments usually implemented at high-to-low speed transitions:

- More complex environments tend to produce lower operating speeds owing to increased cognitive load and perceived risk.
- Natural traffic calming such as winding roads and "humpback" bridges can be very effective and more acceptable to drivers.

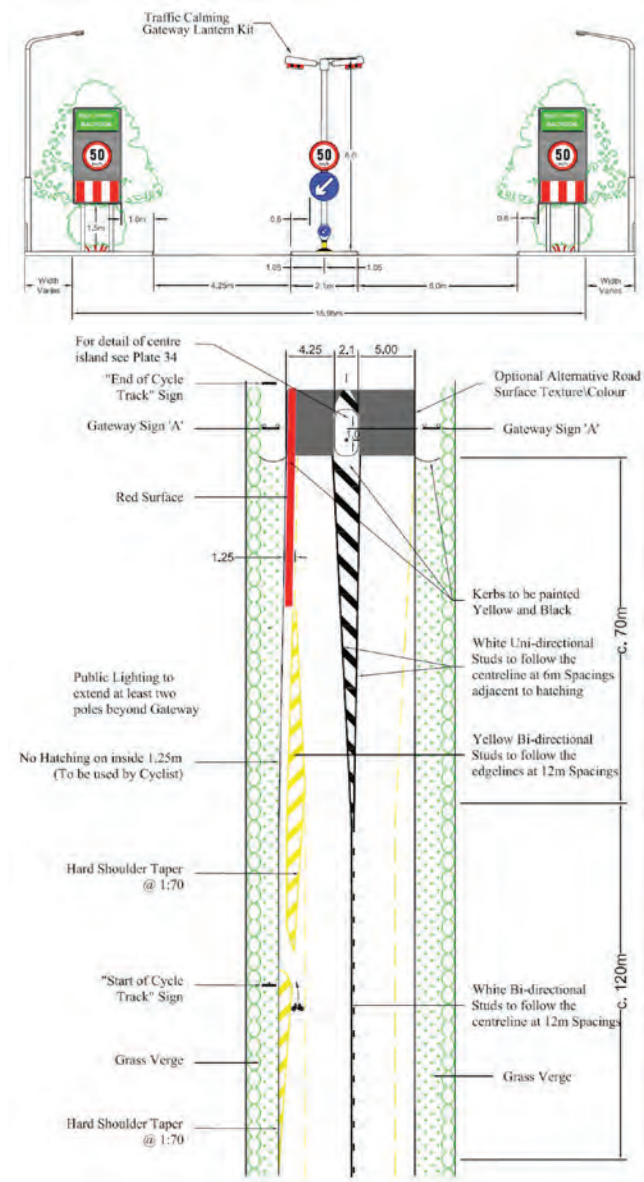



FIGURE 31 Transition zone with an on-road cycling path [*Source*: National Roads Authority (2005)].

- Emphasizing changes in environment can increase awareness and/or reduce speeds.
- Enclosing a distant view and/or breaking up linearity can reduce speeds.
- Creating uncertainty can reduce speeds.
- Combinations of measures are more effective than individual measures but are most costly and visually intrusive.
- Roadside activity can reduce speeds.

Kennedy also stated that as well as being effective in managing speeds, measures need to be visually appealing, particularly in historic areas and rural environments. She suggests using local building materials for gateways, and developing plans that are consistent with the colors and character of the area. Kennedy's work reinforces the axiom that there is no single, unique, and widely accepted measure, and that each situation must be dealt with individually in a holistic manner.

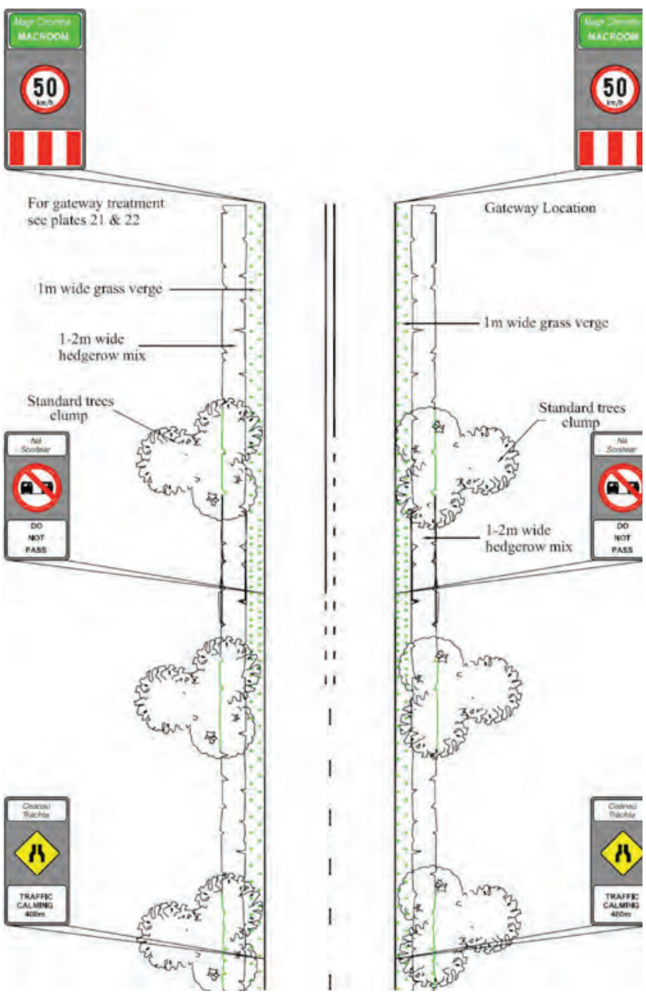



FIGURE 32 Standard transition zone landscaping in an open rural area [*Source*: National Roads Authority (2005)].

As part of a program to develop cost- and safety-efficient designs for rural roads for developing countries Kirk et al. (undated) from the U.K. Transport Research Laboratory offer advice on managing speed on the approaches to roadside and ribbon development along major roads. The cost- and safety-efficient material recognizes that there are three distinct zones in the rural to urban transition:

- The *approach zone* is used to warn drivers that they are about to enter a section of road that has a higher level of development and the need to adapt driving behavior;
- The *core zone* is the area of greater development and activity, which requires slower travel speeds for safety reasons; and
- The *transition zone*, which lies between the approach zone and core area, is where drivers are expected to achieve the necessary speed reduction.

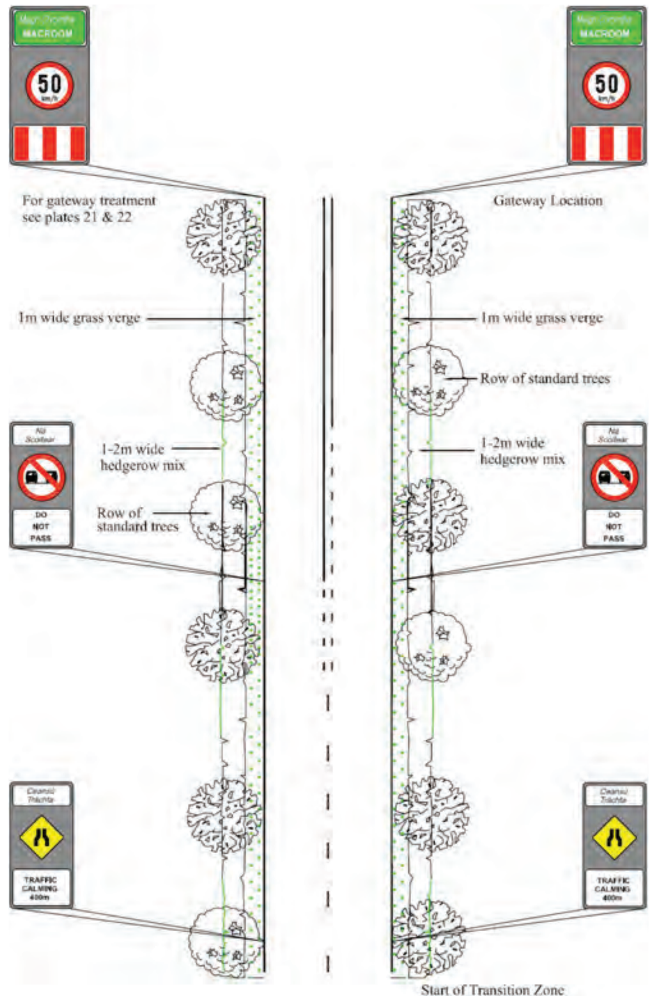



FIGURE 33 Standard transition zone landscaping in a built-up, semirural area [*Source*: National Roads Authority (2005)].

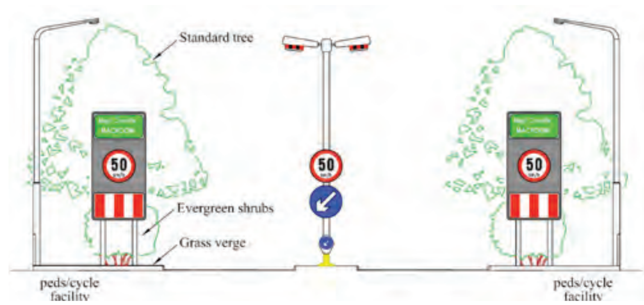



FIGURE 34 Typical gateway landscaping [*Source*: National Roads Authority (2005)].

Typical devices and techniques that would be used in the approach zone are gateways, pavement markings, and rumble strips—features that highlight the change in the road environment but do not physically slow drivers. The physical changes in road geometry occur in the transition zone. After the warning in the approach zone, horizontal deflections and changes in the road cross section are implemented in the transition zone to physically slow drivers down before entering the core area.

Although not specific to transition zones, the Netherlands and some Scandinavian countries are employing the concept of recognizable road design (RRD) to elicit driver behavior that is more consistent with the road and its setting (SWOV 2007). RRD starts with the same basic North American premise that roads have two primary functions: mobility and access. This principle is carried forward into the road design, suggesting that each road category (designated by function) has its own design and speed limit characteristics. Further, the design and speed limit for every road in a specific category needs to be homogeneous to achieve a road design that is recognizable and elicit proper driving behavior.

The initial attempts at creating a RRD system use the following characteristics to distinguish between road categories:

1. Road surface
2. Median treatment
3. Type of edge line markings
4. (Anti) flow marking, or diagonal stripes that partly cover the lane from the edge line and/or the centerline marking. Stripes in the driving direction are a narrow-illusion marking (/ \).
5. Color and shape of curb marker posts
6. Setting characteristics such as buildings, parking spaces, and exit roads
7. Presence of on-street bicycle lanes.

Of these characteristics, it is thought that the median treatment and the type of edge line markings are the essential elements for RRD. It is noted that in the Netherlands, a broken or dashed edge line is used to denote a road category, whereas broken edge lines are not used in North America.

The RRD principles are applicable to transition zones in that transition zones can use characteristics of the "access roads" to communicate to drivers that they are approaching a built-up area from a rural area (or a "distributor road"). In practical terms, under the Dutch guidelines the high-speed rural area (80 km/h) would have a median or a marked centerline and a broken/dashed edge line. The lower speed urban area would have neither a marked centerline nor an edge line. Therefore, it would seem appropriate for the centerline and the edge line markings to halt somewhere in the transition zone to communicate the downstream change in road function.

The U.K. Department of Transport (2007) has distilled traffic calming research and experience into a single publication that includes some design suggestions for gateways and entry treatments. Specifically, the guidelines state the following:

- A gateway should be visible over at least the stopping sight distance for the 85th percentile approach speed so as not to surprise the driver.
- The gateway should be visually linked to the start of the village.
- Gateways should be as conspicuous as possible while remaining visually pleasing.
- Gateways are only marginally enhanced by pavement markings, because markings are not visible from significant distances.
- Surface treatments and road narrowings at gateways should be at least 16 ft (5 m) but no longer than 33 ft (10 m).
- Physical narrowings must take into consideration heavy vehicles, agricultural vehicles, and other larger commercial vehicles. If physical narrowings cannot be achieved because of expected vehicle types, then pavement markings and different surface materials can be used to visually narrow the road while providing overrun areas.
- Roadside features should be set back sufficiently to avoid vehicles coming in contact with these elements. Careful consideration must also be given to the consequences of impacting any roadside element.

#### North America

The Chesapeake Country Scenic Byway Alliance (2001) looked into the issue of rural to urban transitions as part of a corridor management plan for a National Scenic Byway. This planning document advocates that consolidating community entrance signs and reinforcing their visibility with attractive landscaping is the most direct way to convey to drivers that they are transitioning from a rural road to a settled place. The entrance/gateway signing should be large enough to be noticeable, and distinguishable from proximate commercial signs. The Alliance emphasized the need for traffic calming in and on the approaches to settled areas, and specifically mentioned the following techniques:

- Making the road look narrower, through modest physical changes in paving and landscaping
- Encouraging roadside businesses to use landscaping rather than pavement near the roadside so as to consolidate entrances, and mark entries
- Using decorative planting at entries and around the base of welcome signs

- Planting street trees continuously along the approach to a community to reinforce the transition from a rural to a settled area.

As part of a larger study on connections between rural town centers in Washington State, Puget Sound Regional Council (2004) developed a toolkit of context-sensitive solutions to offer some guidance to roadway designers in providing state routes that serve their mobility function and also are an effective main street for a rural community. The Options and Innovations Toolbox presents planning and design tools, including many tools that were considered new applications that were untested. The toolbox is specifically oriented to rural corridors and their town centers. The toolbox suggests that managing speed in town centers may be assisted by considering the need for speed reductions in the planning stages of a road's life-cycle including:

- Consideration of the full corridor, not just individual segments (e.g., the transition zone or the town center). The slower speeds that are desirable in a rural town center may be more easily achieved if the overall travel time in the corridor is considered and design features are more appropriate for the setting. For example, synchronized traffic signals may be used in the town center to promote travel at a slower, consistent speed, while the design features in the rural areas should support higher travel speeds between communities.
- Access management that discourages the placement of accesses in the transition zone where drivers are already preoccupied with speed and path choices.
- Appropriate selection of road classification and design speeds for the corridor as it passes through the community. Most of what is permitted with respect to lane widths, lateral clearances, clear zones, and the like are in part determined by the design speed selected.

The toolbox mentions land use planning that places appropriate businesses or uses at the edge of town, landscaping, and urban design guidelines as speed management considerations in the planning phase. The toolbox also touches on specific elements of roadway design that could be considered in transition areas:

- Effective transition area design requires a sequence of two or more elements to safely transition speed gradually. For example, a transition might start with a landscaped median, followed by replacing the shoulders with a curb-gutter-and-sidewalk street edge. Additionally, view-framing street trees, colored shoulders, and a gateway may be placed.
- Specifically mentioned physical improvements suitable for transition areas are colored shoulders, medians, landscaping, gateways, and roundabouts or special intersections.

In Virginia, the Thomas Jefferson Planning District Commission (2004) has developed the "Design Manual for Small Towns: Transportation and Land Use Strategies for Preserving Small Town Character," similar to the Puget Sound document. It provides similar platitudes concerning speed management and engineering measures available, but lacks any details concerning effectiveness or specific warrants for use.

In a novel effort to lower operating speeds near schools in Needham, Massachusetts, the municipality erected non-standard traffic signs designed by middle school students (Kocian 2008). These signs resemble posters that might be found on refrigerator doors, rather than on the roadside (see Figure 35), and are intended to solicit an emotional/compassionate response to slow down. Despite the obvious shortcomings concerning the legibility of the font and the increased response time required for a non-standard sign, the notion of tapping into a motorist's emotional or empathetic side to achieve reductions in speed may hold some promise for future research in rural/urban transition zones.


FIGURE 35 Experimental empathetic traffic sign [*Source*: Kocian (2008)].

In a presentation on rural to urban transition zones, Chartier (2009) provided advice to practitioners in the form of principles and design guidelines. The overarching principle that is advocated is the concept of "optical width": the relationship of the horizontal and vertical elements of the road and the roadside. This is similar to the advice provided by the Irish. The optical width is seen as a powerful visual cue for approaching motorists in selecting an appropriate travel speed. Lowering the optical width in the transition zone is an effective speed management measure. This may be achieved by reducing the horizontal elements (e.g., lane narrowings), increasing the vertical dimension (e.g., planting appropriately sized trees closer to the pavement edge), or some combination of both.

TABLE 32
SUMMARY OF LITERATURE REVIEW ON THE EFFECTIVENESS OF RURAL TRAFFIC MANAGEMENT ON SPEED

| Researcher | No. of Study Sites | Measures/Treatment | Method of Study | Results |
|---|---|---|---|---|
| Van Houten and Van Houten (1987) | 1 | "BEGIN SLOWING HERE" sign 86 meters upstream of lower speed limit | Before-after | 18% to 26% reduction in the percentage of motorists traveling over 35 mph (60 km/h) |
| Herrstedt et al. (1993) | 8 | A variety of treatments on roads that run through a town, including gateways and measures in the town | Before-after | 11% reduction in mean speed; 15% reduction in motorists traveling over 35 mph (60 km/h) |
| Pyne et al. (1995) | 0—driving simulator | Gateway consisting of chicane, countdown speed limit signs, and transverse markings in the village | Before-after | 4.2 mph reduction in mean speed, and 7.2 mph reduction in the 85th percentile speed |
| Barker and Helliar-Symons (1997) | 12 | Speed roundels on the pavement surface | Before-after | 3 mph reduction in mean speed for villages with a 40 mph speed limit; no reduction in mean speed for villages with a 30 mph speed limit |
| | 5 | Countdown speed limit signs | Before-after | No significant reduction in mean speed |
| County Surveyors' Society (1994a) | 11 | Traffic-calming on the approach to the village | Before-after | 4.8 to 16 km/h reduction in 85th percentile speed |
| | 9 | Traffic-calming in the village | | 4.8 km/h reduction in 85th percentile speed |
| | 4 | Traffic-calming on the approach to and in the village | | 14.4 to 20.8 km/h reduction in 85th percentile speed |
| County Surveyors' Society (1994b) | 23 | Variety of measures | Before-after | 8.7 km/h speed reduction (or 21% reduction in speed) |
| | 8 | Variety of measures on roads with a daily traffic volume greater than 10,000 | | 7.5 km/h speed reduction (or 16% reduction in speed) |
| Berger and Linauer (1998) | 5 | Raised medians islands that provide narrowing and deflection to approaching traffic | Before-after | 0 to 38% reduction in mean speed; 2 to 42% reduction in 85th percentile speed |
| Farmer et al. (1998) | 6 | Speed feedback signs | Before-after | 4.3 mph reduction in mean speed at the end of the transition zone |
| DETR (undated) | 9 | Traffic calming in villages on major roads (≥8,000 vpd) | Before-after | 15% to 19% reduction in mean speed; 16% to 19% reduction in 85th percentile speed |
| Alley (2000) | 0—driving simulator | Various gateways | Before-after | |
| Winnett and Wheeler (2002) | 36 | Vehicle actuated speed signs | Before-after | Up to an 80% change in percentage of vehicles exceeding the speed limit |
| Hildebrand et al. (2004) | 6 treatment<br>7 control | Transitional speed zones | Cross-sectional | No significant impact on mean speed, percentage exceeding the speed limit, or speed variance |
| Agustsson (2005) | 21 | Environmentally friendly through roads | Before-after | 17% reduction in mean speed, and reduction in the percentage exceeding the speed limit from 75% to 36% |
| Department for Transport (2005) | 7 | Rumblewave surface | Before-after | Reductions in mean and 85th percentile speeds from 1 km/h to 6 km/h |
| Forbes (2006) | 9 | Various gateway treatments and village traffic calming | Before-after | 6 km/h reduction in the 85th percentile speed |

*Table continued on p.47*

*Table continued from p.46*

TABLE 32
SUMMARY OF LITERATURE REVIEW ON THE EFFECTIVENESS OF RURAL TRAFFIC MANAGEMENT ON SPEED

| Researcher | No. of Study Sites | Measures/Treatment | Method of Study | Results |
|---|---|---|---|---|
| Sandberg et al. (undated) | 4 treatment and 1 control | Speed feedback signs | Before-after with control | 6.9 mph reduction in the 85th percentile speed over 12 months |
| Arnold and Lantz (2007) | 2 | Optical speed bars | Before-after | 3 to 9.5 mph reduction in 85th percentile speed over 90 days |
| Hallmark et al. (2008) | 1 | Transverse pavement markings | Before-after | Up to a 2 mph reduction in 85th percentile speed |
| | 2 | Transverse pavement markings with speed feedback signs | | 3 mph to 7 mph reduction in 85th percentile speed |
| | 1 | Lane narrowings using painted median and edge markings | | Mixed results on 85th percentile speed |
| | 1 | Converging chevrons and 25 mph pavement marking | | Up to a 4 mph decrease in 85th percentile speed |
| | 1 | Lane narrowing using edge markings and 25 mph pavement markings | | Mixed results on 85th percentile speed |
| | 1 | Speed table | | 4 to 5 mph decrease in 85th percentile speed |
| | 1 | Lane narrowing with a median of tubular markers | | Up to a 3 mph decrease in 85th percentile speed |
| | 1 | Speed feedback sign | | 7 mph decrease in 85th percentile speed |
| | 1 | SLOW pavement legend | | Mixed results on 85th percentile speed |
| | 1 | 35 mph pavement legend with a red background | | Up to a 9 mph decrease in 85th percentile speed |
| Dixon et al. (2008) | 0—driving simulator | Layered landscape | Before-after with control | 4.6 mph and 1.2 mph reductions in mean and 85th percentile speeds |
| | | Gateway with narrowing | | 5.5 mph and 3.0 mph reductions in mean and 85th percentile speeds |
| | | Median treatment only | | 3.4 mph and 0.1 mph reductions in mean and 85th percentile speeds |
| | | Median with gateway | | 10.2 mph and 5.6 mph reductions in mean and 85th percentile speeds |
| | | Medians in series with no pedestrian crosswalks | | 10.7 mph reductions in mean and 85th percentile speeds |
| | | Medians in series with pedestrian crosswalks | | 10.0 mph and 5.6 mph reductions in mean and 85th percentile speeds |
| Jamson et al. (2008) | 0—driving simulator | | | |
| Donnell and Cruzado (2008) | 13 | Speed feedback sign located 500 feet downstream of threshold | Before-after | 6 mph drop in mean speeds that lasts while the speed feedback sign is in place |
| Lamberti et al. (2009) | 0—driving simulator | Transverse bars, sign gantry | Before-after | 11 to 17 km/h reduction in the mean speeds at the gateway |
| Chartier (2009) | 1 | Dragons teeth, edge lines, centerline, and roadside trees | Before-after | 10% reduction in 85th percentile speed at the threshold |
| Russell and Godavarthy (2010) | 3 | Colored pavement | Before-after | No significant change to a 13% to 17% reduction in mean and 85th percentile speeds |
| | 3 | Solar speed display | Before-after | 1% to 14% reduction in 85th percentile speed; 3 to 12% reduction in mean speed |
| | 2 | Mobile speed trailer | Before-after | 3% to 15% reduction in 85th percentile speed; 4 to 11% reduction in mean speed |
| | 3 | Optical speed bars | Before-after | Mixed results showing speed increases and decreases |

TABLE 33
SUMMARY OF LITERATURE REVIEW ON THE EFFECTIVENESS OF RURAL TRAFFIC MANAGEMENT ON CRASH RISK

| Researcher | No. of Study Sites | Measures/Treatment | Method of Study | Results |
|---|---|---|---|---|
| Herrstedt et al. (1993) | 8 | A variety of treatments on roads that run through a town, including gateways and measures in the town | Before-after | 44% and 36% reduction in casualty and all crashes, respectively |
| County Surveyors' Society (1994b) | 20 | Variety of measures | Before-after | 65% reduction in crash rate |
| | 8 | Variety of measures on roads with a daily traffic volume greater than 10,000 | | 47% reduction in crash rate |
| Wheeler and Taylor (2000) | 56 | Variety of traffic-calming measures on major roads | Before-after with control group | 20% to 25% reduction in casualty crashes, and 33 to 50% reduction in serious injury and fatal crashes |
| Crowley and MacDermott (undated) | 14 | Variety of traffic-calming measures on both approaches of primary roads | Before-after | 41% reduction in casualty crashes |
| | 7 | Variety of traffic-calming measures on one approach of primary roads | | 33% reduction in casualty crashes |
| Winnett and Wheeler (2002) | 19 | Vehicle-actuated speed signs on roads with 30 and 40 mph speed limits | Empirical Bayes | 34% reduction in casualty crashes |
| Souleyrette et al. (2003) | 141 segments | Diagonal parking | Cross-sectional | No substantial difference between non-intersection crash rates |
| Timesonline (2004) | Unknown | Psychological traffic calming (removal of signs and markings) | Unknown | 14% reduction in crashes |
| Agustsson (2005) | 21 | Environmentally friendly through roads | Before-after with control group | Non-significant reduction in crashes (19% reduction in all crashes, 30% reduction in casualty crashes) |
| Department for Transport (2005) | 7 | Rumblewave surface | Before-after | 24% to 100% reduction in casualty crashes, averaging 55% |
| Forbes (2006) | 5 | Various rural traffic calming measures | Empirical Bayes | 22% reduction in all crashes, 28% reduction in casualty crashes |
| Knapp and Rosales (2007) | 62 | Road diets (usually 4 to 3 lane conversions) | Before-after with yoked, comparisons, Bayes methods | 19% to 44% reduction in all crashes |
| Veneziano et al. (2009) | 7 | Gateway monuments | Empirical Bayes | 2.2% to 32% reduction in crashes |

Chartier provides specific design guidelines for transition zones:

- Prohibit passing, using signs, solid center lines, and gateway islands
- Phase out paved shoulders
- Use transverse pavement markings such as crosshatching, blocks, and dragon's teeth
- Narrow lane widths using edge lines
- Use road side signs to increase the vertical dimension
- Use soft landscape elements such as trees, shrubs, and grass boulevard treatments, which change in composition and degree of formality along the transition
- Introduce cycling and pedestrian facilities
- Incorporate town entry sign with area speed limit sign in design of gateway
- Provide rumble strips and possibly roundabout if speeds not sufficiently reduced by other measures.

The presentation also mentions the following design guidelines for gateways:

- Make the gateway conspicuous and the most prominent element in the transition zone
- Locate the gateway at the end of the transition zone

- Ensure forward visibility over stopping distance for 85th percentile approach speed
- Do not obscure intersection sightlines
- Consider likely future developments when locating
- Place a reduced speed limit sign at the gateway location
- Extend roadway lighting, where provided, at least two poles upstream of the gateway
- Consider painting curbs on gateway islands and build-outs
- Consider lighting gateway signs, particularly on long approaches
- Consider coloring or texturing the roadway surface for the length of the gateway
- Provide a minimum width of 16.7 ft (5.1 m) between signs at a gateway to accommodate large commercial vehicles
- Make gateway signs and lighting poles in center islands demountable and frangible
- Avoid sign clutter.

### Global

The World Bank (2005) produced a manual concerning safe road design that includes a chapter on linear villages, with some limited detail concerning speed transition zones. The authors advocate that the location and layout of rural/urban speed transition zones are of critical importance and should be determined from the perspective of the road user.

Determine whether there is a built-up area:

- The distance from the buildings to the centerline of the road is a maximum of 3 times the height of the adjoining buildings, with a maximum of 82 ft (25 m).
- The length of the built-up area is at least 1,312 ft (400 m).
- The building density (building frontage related to road length) for buildings on one side of the road is ≥50% and for buildings on both sides is ≥30%.

Determine the location of the border:

- The border should be where the setting changes (taking into account the potential for short-term changes in development).
- The border should be supported with new environmental characteristics.
- The planned location of the border is visible at the actual approach speeds.

By following this guidance, it is suggested that optimum conditions are created in terms of clarity, recognition, and acceptance of the lower speed limit by road users. Such a redesign of the public space is the only way to ensure compliance with speed limits at the border. Examples of effective measures mentioned are roundabouts, center islands, and bends and plateaus that are suitable for 30 mph (50 km/h) travel.

## SUMMARY OF LITERATURE REVIEW

The majority of the effectiveness studies concerning transition zone treatments and rural/village traffic calming have been conducted in Europe. The general conclusion is that engineering measures are effective at reducing speeds and crashes. One study in particular also revealed that public acceptance of rural settlement traffic calming is high.

The effects of transition zone treatments on operating speed are generally small and are not sustained downstream of the urban/rural threshold without additional downstream measures. The reported crash reduction factors have been quite significant, although methodological shortcomings with some of the studies likely overestimate effectiveness. Nonetheless, the results are impressive enough that even if the sundry factors were accounted for, a sizeable crash reduction is a likely outcome. A summary of the study results on speed and crashes are shown in Tables 32 and 33, respectively.

In addition to the evaluation studies, some general trends and advice may be garnered from the reviewed studies and design guidelines:

- More extensive and aggressive measures tend to produce greater reductions in speed and crash occurrence than less extensive and passive measures.
- There needs to be a distinct relationship between a settlement speed limit and a change in the roadway character.
- No one particular measure is appropriate for all situations. Each settlement must be assessed and treated based on its own characteristics and merits.
- To maintain a speed reduction downstream of the transition zone, it is necessary to provide additional measures through the village. Otherwise, speeds may rebound to previous levels as soon as 820 ft (250 m) from the start of the lower speed zone.

Some jurisdictions in Europe are experimenting with shared spaces, which include removing traffic control and physical separations between road users. This approach to speed management is a paradigm shift in thinking, whereby guidance and direction to the motorist is removed from the street, and drivers are required to exercise additional caution and take more responsibility for their own driving behavior. At present, this approach does not provide any specific guidance concerning speed transition areas and whether this approach is suitable in these critical zones. At any rate, the shared space concept is in fairly limited deployment and the results should be considered unreliable at present.

CHAPTER THREE

# SURVEY RESULTS

## SURVEY PROCEDURES

The 42-question survey was designed to focus on state DOTs and their practices and principles as they relate to speed transition zones on the approaches to rural settlements. Appendix A contains the questionnaire.

The survey was prepared as an online survey hosted on the TRB website, but was also available in hardcopy or as a MS-Word™ template. The survey questionnaire was transmitted to members of the AASHTO Standing Committee on Traffic Engineering in late March 2009. This recipient list included all state DOTs. The online survey was also made available to members of the National Association of County Engineers, and was circulated to traffic engineering personnel in the 10 provinces and 3 territories of Canada through the Transportation Association of Canada. Potential respondents were given 2 weeks to respond. After the initial circulation of the survey, and 2 days before the deadline for responses, a reminder was sent to jurisdictions that had not responded to the first contact. Subsequent to the deadline for responses, telephone contact was made with all nonresponding jurisdictions in an effort to obtain a survey response. Therefore, although participants were initially given 2 weeks to respond, deadline extensions were permitted to increase the response rate.

The responses are summarized by the number of and/or percentage of respondents that selected the different answers for each question. The percentages were calculated as the number of answers to each question divided by the number of responses for that question (i.e., the percentages for different questions may be based on a different number of respondents). Also, several questions permitted multiple responses, in which case the sum of the percentages in the question may be more than 100%.

Sixty-six responses were received from 36 states, 2 provinces, and 28 counties. The response rate for U.S. state DOTs was 72%. The reader is cautioned that the responses from the county government agencies were mainly from agencies in California and Iowa, and therefore are not necessarily representative of the national experience. As a result, the county-level results are provided as a number of responses, but not as a percentage. Appendix B contains the tabulated survey results.

The survey examined the following issues and questions:

- Standard approaches to treating high-to-low speed transitions
- Enhanced or innovative treatments for high-to-low speed transitions
- Case studies.

The following sections present the survey results organized into these three areas.

## SURVEY RESPONSES

### Standard Approaches

Each jurisdiction was asked whether they had a standard approach to treating rural high-to-low speed transitions in both new construction, and retrofit situations. The results show that less than half of the state/provincial respondents have a standard approach to treating rural high-to-low speed transitions, and the majority of the counties do not have a standard approach (see Table 34).

TABLE 34
FREQUENCY OF AGENCIES THAT HAVE STANDARD APPROACHES FOR TREATING HIGH-TO-LOW SPEED TRANSITIONS

| Response | New Construction | | Retrofit | |
|---|---|---|---|---|
| | Number of Responses | Percentage | Number of Responses | Percentage |
| State/Province | | | | |
| No | 19 | 56 | 22 | 61 |
| Yes | 15 | 44 | 14 | 39 |
| Blank | 4 | | 2 | |
| County | | | | |
| No | 18 | 67 | 16 | 62 |
| Yes | 9 | 33 | 10 | 38 |
| Blank | 1 | | 2 | |
| All | | | | |
| No | 37 | 61 | 38 | 61 |
| Yes | 24 | 39 | 24 | 39 |
| Blank | 5 | | 4 | |

In jurisdictions with a standard approach in new construction areas, the majority of respondents rely on traffic control devices as the primary means of communicating and achieving the speed reduction. Geometric changes at the transition were rarely mentioned and were almost always articulated as transitioning from a rural to an urban cross section. One jurisdiction indicated that the roadway geometry in the speed transition area may be altered by "channelization through marking patterned islands" and roundabouts. Similarly, three respondents offered the following road surface treatments as part of their standard approach:

- Rumble strips
- No road surface treatment unless there is an accident history
- Occasional use of raised buttons at points of concern to alert drivers.

Off-road features were not part of the standard approach to transition zones for any of the respondents, although one respondent indicated that the local municipality may elect to erect a "city identification structure" at major road entrances. This last comment suggests that many upper-tier road agencies may not consider off-road features in speed transition zones as part of their responsibility, but may not be opposed to permitting the local municipality from providing such features.

The traffic control devices used to communicate the speed transition in new construction are generally SPEED REDUCED AHEAD signs (W3-5 and W3-5a) as described in the *MUTCD*, followed by a SPEED LIMIT sign (R2-1) that shows the lower speed limit. Some respondents specifically mentioned that they use progressively lower (i.e., stepped-down) speed limits if the speed reduction is more than 10 mph (16 km/h). Specific comments on standard traffic control devices included the following:

- Use SPEED REDUCED AHEAD signs (W3-5a) and post new speed according to state DOT policies, guides, and procedures. The usual practice is to drop speeds in 10 mph (16 km/h) increments at transitions.
- Standard signing in accordance with *MUTCD*
- W3-5 followed by upsized R2-1 (30x36). Speed reduction greater than 10 mph will typically have 2/10 mile transition zones (i.e., 50-40-35-40-50). Will include a second W3-5 if the second reduction is 10 mph but optional for a 5 mph speed reduction. We would still provide upsized lead speed limit sign for the second speed drop.
- Standard speed reduction signing and marking techniques; accentuated markings; and hazard identification beacons
- Speed zones are established to be a transition zone between the high and low. Each speed zone has Reduced Speed Ahead Warning signs (W3-5).
- We use a black and white sign that says:

REDUCE SPEED

XX mph

YY feet

- We use advance speed reduction signing unless the situation is such we need to further address safety concerns. We generally use "reduced speed ahead" warning signs to warn the driver of the speed reduction.
- Utilization of W3-5 or W3-5a signs in accordance with the state *MUTCD*
- Reduce speed limits in increments (50 to 35 and then 35 to 25).
- We place signs alerting traffic to the reduced speed and the community. This is typically done with cooperation from the community. "Reduced speed ahead" signs are placed per *MUTCD*. The speed limit is generally set and posted by the city. We post "Resume Speed" sign as you leave the city and the speed limit returns to state code prescribed speed. We post city name at corporation line with their speed limit in white on green destination sign.
- Transition speed zones are posted.
- "Reduced Speed Ahead" sign followed by a new posted speed limit sign.

For respondents with a standard approach to treating high-to-low speed transition areas in retrofit situations, the methods used are the same as those used in new construction.

Next, respondents were asked about engineering and infrastructure measures that they considered inappropriate to implement at rural high-to-low speed transitions (see Table 35).

The responses are sorted from highest to lowest for the state/province responses, and reveal the following trends:

- More than 70% of state/provincial respondents agree that speed humps, raised intersections or speed tables, speed cushions or road studs, removal of all pavement markings, and removal of most traffic signs are inappropriate measures for speed transition zones.
- Less than 20% of state/provincial respondents believe that roundabouts, central islands/raised medians, centerline or shoulder rumble strips, speed sensitive signals, marked no-passing zones, amber flashing beacons, speed trailers/radar message boards, variable message signs other than speed trailers, transverse pavement markings, chevrons, or dragon's teeth, enhanced speed limit signs and/or markings, added standard warning signs, transitional/stepped down speed limits, gateway/entrance features, introduction/alteration of street lighting, or landscaping changes are inappropriate measures for speed transition zones. This suggests general agreement among the respondents that the previously noted measures are viable (although not necessarily effective) speed reduction techniques.

TABLE 35
MEASURES THAT SHOULD NOT BE USED IN TRANSITION ZONES

| | State/Province Responses (*N* = 38) | | County Responses (*N* = 28) | |
|---|---|---|---|---|
| | Number of Responses | Percentage | Number of Responses | Percentage |
| *Geometric Design* | | | | |
| Chicanes or increasing road curvature | 19 | 50 | 15 | 54 |
| Bulb-outs, neckdowns, chokers, road narrowings | 10 | 26 | 13 | 46 |
| Central islands/raised medians | 7 | 18 | 12 | 43 |
| Traffic circle | 18 | 47 | 12 | 43 |
| Roundabout | 6 | 16 | 3 | 11 |
| Road diet, reduction in the number of through lanes | 9 | 24 | 11 | 39 |
| Adding bicycle lanes | 16 | 42 | 7 | 25 |
| Adding sidewalks or pedestrian paths | 13 | 34 | 7 | 25 |
| None of the above | 7 | 18 | 3 | 11 |
| Other | 1 | 3 | 1 | 4 |
| *Surface Treatments* | | | | |
| Speed humps | 32 | 84 | 21 | 75 |
| Raised intersections or speed tables | 27 | 71 | 15 | 54 |
| Speed cushions or road studs | 27 | 71 | 15 | 54 |
| Pedestrians crosswalks | 24 | 63 | 13 | 46 |
| Transverse rumble strips | 8 | 21 | 3 | 11 |
| Centerline or shoulder rumble strips | 7 | 18 | 4 | 14 |
| Colored or textured pavement | 10 | 26 | 3 | 11 |
| None of the above | 1 | 3 | 2 | 7 |
| Other | 1 | 3 | 0 | 0 |
| *Traffic Control Devices* | | | | |
| Enhanced speed limit signs and/or markings | 1 | 3 | 0 | 0 |
| Add standard warning signs | 0 | 0 | 0 | 0 |
| Unique (non-MUTCD) traffic control signs | 24 | 63 | 14 | 50 |
| All-way stop control | 26 | 38 | 13 | 46 |
| Amber flashing beacons | 4 | 11 | 3 | 11 |
| Speed sensitive signals | 6 | 16 | 5 | 18 |
| Village information signs | 9 | 24 | 5 | 18 |
| Speed cameras | 15 | 39 | 10 | 36 |
| Speed trailers/radar message boards | 5 | 13 | 2 | 7 |
| Variable message signs other than speed trailers | 6 | 16 | 4 | 14 |
| Marked no-passing zones | 6 | 16 | 4 | 14 |
| Transverse pavement markings, chevrons, or dragon's teeth | 6 | 16 | 5 | 18 |
| Removal of all pavement markings | 29 | 76 | 22 | 79 |
| Removal of most traffic signs | 29 | 76 | 21 | 75 |
| Transitional/stepped-down speed limit | 1 | 3 | 0 | 0 |
| None of the above | 1 | 3 | 2 | 7 |
| Other | 2 | | 0 | 0 |
| *Roadside Features* | | | | |
| Gateway/entrance features | 6 | 16 | 7 | 25 |
| Landscaping changes | 3 | 8 | 0 | 0 |
| Street furniture | 9 | 24 | 9 | 32 |
| Introduce/alter street lighting | 5 | 13 | 2 | 7 |
| None of the above | 14 | 37 | 13 | 46 |
| Other | 0 | 0 | 0 | 0 |

- The remaining engineering measures received mixed reactions from the respondents, perhaps indicating that there is no clear consensus of the usefulness of these measures in speed transition zones.

With respect to documentation on agency practices regarding speed transition zones, one state (Arizona) provided its traffic engineering policy on speed limit signing, and Vermont referenced its Traffic Calming Study and Approval Process for State Highways. The Arizona policy provides slightly more detail than the federal *MUTCD* in the application of advance signing. The Vermont document was created in 2003 to provide information about the process for planning, evaluating, and implementing traffic calming projects on state highways in Vermont.

A particularly insightful diagram from the Vermont document is reproduced in Figure 36. There are several points to note concerning this figure:

- There are three distinct zones denoted rural/open, transition, and village, all of which must be considered for a successful speed transition.
- The prototype uses a stepped-down speed limit of 40 to 45 mph to buffer the transition from the 50 mph rural area to the 25 to 35 mph in the village.
- The transition zone terminates at an entry/gateway, which may include median islands, neckdowns, roundabouts, village identification signs, and speed limit signs.

**Enhanced Measures**

Recognizing that each transition may require an individualized treatment, respondents were asked about their experiences with engineering measures that are more than that required by their standard approach (if they have one). These enhanced measures are generally considered when the conditions shown in Figure 37 are present.

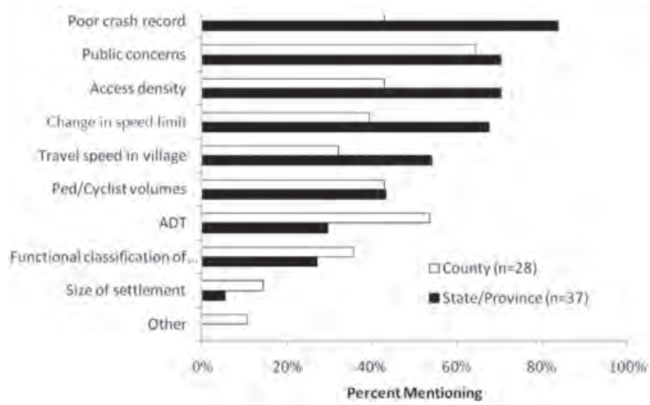



FIGURE 37 Conditions that may prompt more than standard treatment of the transition zone.

From a state/provincial perspective, the most frequently mentioned conditions that would prompt consideration of enhanced speed transition measures are a poor crash record (84%), followed by public opinion, access density, and a

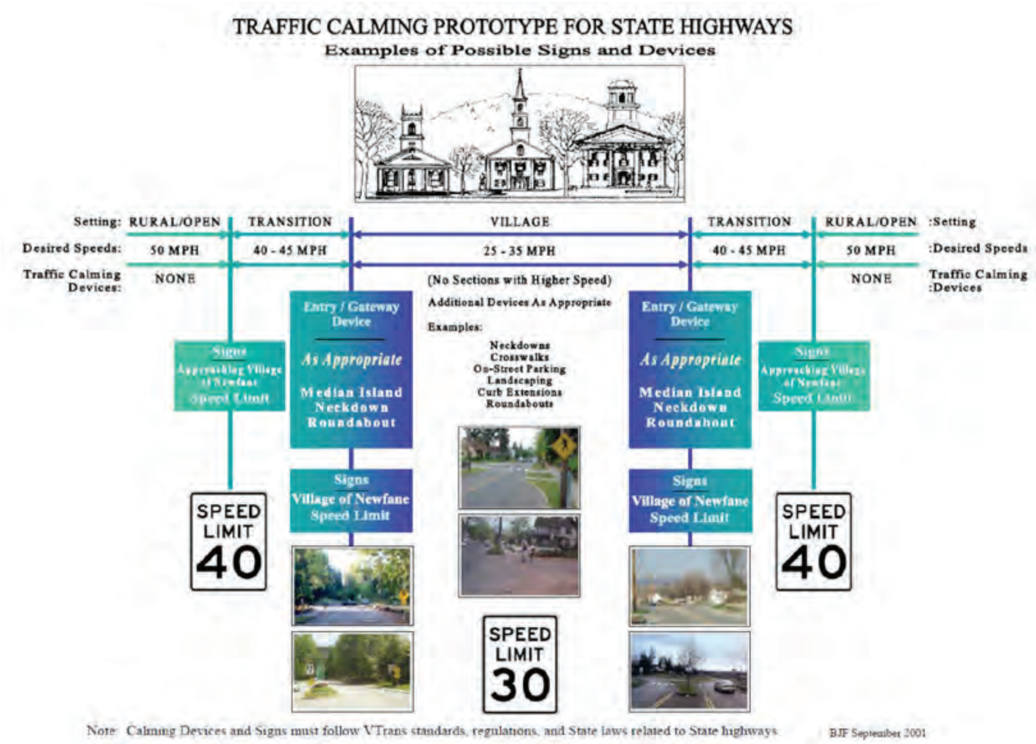



FIGURE 36 Standard approach to transition zones for Vermont [*Source*: Vermont Agency of Transportation (2003)].

significant drop in the posted speed limit (68% to 70%). It is interesting to note that at the county level, public opinion is the most frequently mentioned factor that is considered in implementing enhanced engineering measures for speed transition zones, followed by average daily traffic.

When a speed drop is mentioned, the magnitude of the minimum speed drop ranges from 10 mph (16 km/h) to greater than 30 mph (50 km/h) for state/province respondents, and 5 mph to 30 mph (8 km/h to 50 km/h) for county respondents (see Table 36). The most frequently mentioned minimum speed drop to consider enhanced treatments for speed transitions is 15 or 20 mph (24 or 32 km/h).

TABLE 36
MINIMUM SPEED REDUCTION TO WARRANT ENHANCED MEASURES

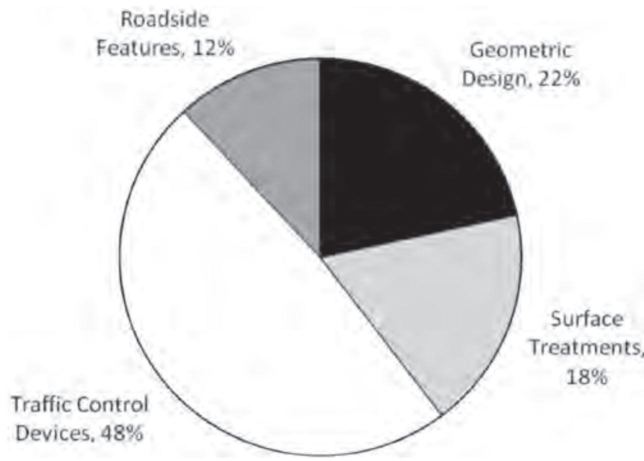
| Minimum Speed Drop, mph (km/h) | State/Province | County |
|---|---|---|
| 5 (8) | 0 | 1 |
| 10 (16) | 4 | 4 |
| 15 (24) | 8 | 4 |
| 20 (32) | 8 | 1 |
| 25 (40) | 0 | 0 |
| 30 (50) | 1 | 1 |
| 35 (60) | 1 | 0 |

The other factor that is considered by one county is the presence of agricultural equipment on the road.

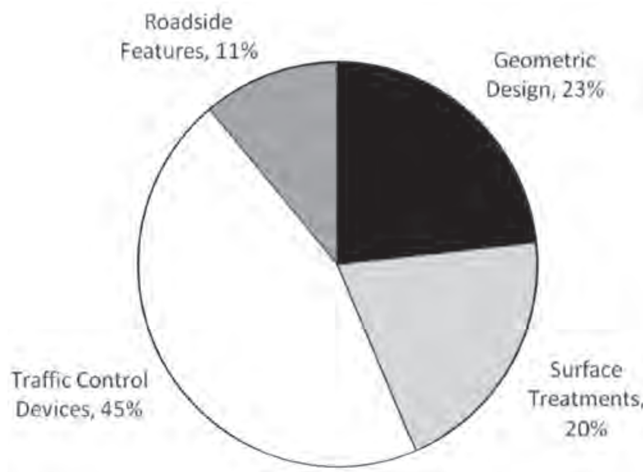
The size of the settlement is not a factor considered by many of the state/province ($N = 2$) or county ($N = 4$) respondents in deciding on enhanced speed transition measures. However, agencies that mentioned the size of the settlement as a factor cited population of the settlement, length of development fronting on the street, and presence of certain amenities in roughly equal amounts as the specific indicator of settlement size.

The respondents have tried several different engineering treatments in addition to their standard practices to transition from high-to-low speeds. With respect to state and provincial respondents, almost half (48%) of the enhanced measures were traffic control devices, followed by geometric design measures (22%), surface treatments (18%), and finally roadside features (12%) (see Figure 38). The county respondents yielded a similar profile of responses.

Perhaps more telling is that between 40% and 50% of state/provincial and county respondents have never tried any geometric design, surface treatment, or roadside measures outside of what might be considered the standard approach. Although practitioners generally recognize that traffic signing alone is an ineffective method of managing speed, the respondents have been reluctant to experiment with more aggressive and physical measures.




State and Provincial Respondents




County Respondents

FIGURE 38 Categories of measures tried in transition zones.

There were a total of 17 case studies reported by respondents (10 from state DOTs and 7 from county engineers). The Vermont Agency of Transportation case study referred to its experimentation and evaluation of dynamic striping in four towns (as mentioned previously in the literature review). None of the county agency case studies reported conducting effectiveness evaluations. In all cases, the speed transition measures were placed on two-lane, undivided roads with rural speed limits ranging from 45 mph to 55 mph (72 km/h to 88 km/h). The speed transitions required motorists to slow down by 15 mph to 30 mph (24 km/h to 48 km/h). A stepped-down speed was used in only two of the seven cases, and a description of the measures implemented was provided for only three of the case studies. All of the described treatments consisted of implementation of additional traffic control devices, and are as follows:

- Additional speed limit and advance alert signs on opposite side of road

- Approximately 500 ft (152 m) in advance of speed limit sign a large R2-4 [Ca.] 25 mph (40 km/h) Zone Ahead sign was placed. Then the actual speed limit, then approximately 250 ft (76 m), W11-2 on a fluorescent yellow-green sign was placed.
- Installed intermediate speed limit of 40 mph (64 km/h).

CHAPTER FOUR

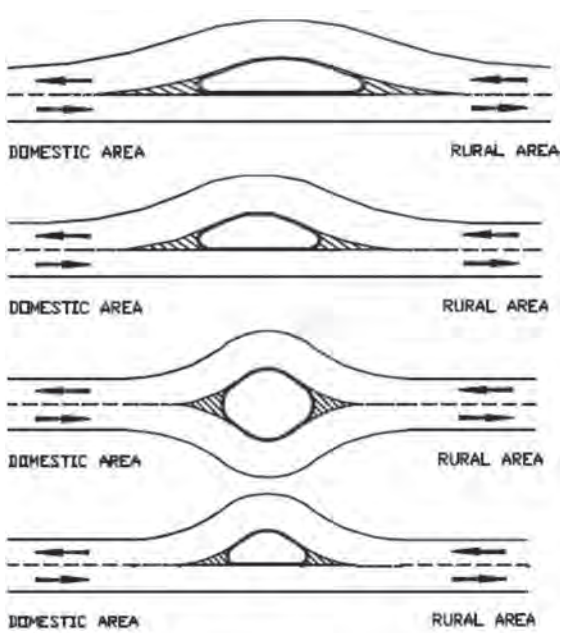
# HIGH-TO-LOW SPEED TRANSITION TOOLBOX

An array of engineering and infrastructure measures are available to practitioners for implementation in rural high-to-low speed transitions. This section of the synthesis identifies all of the measures that have been found in the conduct of this study and are in service. Each measure is described as follows:

- Which jurisdictions are known to use this measure
- Whether the measure is experimental, tested, or proven effective in transitioning speeds (and if proven, results will be provided)
- The relative cost of implementation (i.e., high, moderate, low)
- Possible impacts and cautions concerning the measure
- Basic literature references.

It is noted that in most cases where measures are implemented in the transition zone (as opposed to throughout a rural area or at the start of the urban area), road authorities tended to use multiple measures rather than relying on one measure (e.g., dragon's teeth, a median island, and roadside signs to create a gateway feature).

| **TREATMENT** | |
|---|---|
| Central Islands/Raised Medians | |
| **CATEGORY**<br>Geometric design | **COST**<br>High for physical medians<br>Low for painted medians |
| **DESCRIPTION**<br>Narrow islands that are located either mid-block or at intersections and are placed between travel lanes. Median islands can be used to create a shift/deflection in the travel path of vehicles, or they may simply be used to narrow the "optical width" of the roadway by dividing the traveled way. | |




Source: Berger and Linauer (1998)

*Continued on page 57*

*Continued from page 56*

**EFFECTIVENESS**

Medians have been shown to be very effective in lowering operating speeds, particularly when they create a deflection in the vehicle path. Berger and Linauer (1998) developed the following speed prediction models:

Metric:

$V_{85} = 14.797 \mathrm{Ln}(L/2d) + 19.779$

$V_m = 12.907 \mathrm{Ln}(L/2d) + 17.753$

Where: $V_{85}$ = 85th percentile speed (km/h)

$V_m$ = mean speed (km/h)

$L$ = length of island + length of both tapers (m)

$d$ = lateral deflection of lane (m)

U.S. Customary:

$V_{85} = 9.194 \mathrm{Ln}(L/2d) + 12.290$

$V_m = 8.020 \mathrm{Ln}(L/2d) + 11.031$

Where: $V_{85}$ = 85th percentile speed (mph)

$V_m$ = mean speed (mph)

$L$ = length of island + length of both tapers (ft)

$d$ = lateral deflection of lane (ft)

Charlton and Baas (2006), in an assessment of the effects of speed management measures, determined that median islands reduce speeds by about 9%. Hallmark et al. (2007) studied the effects of a painted median in the transition zone and found no significant reduction in operating speed. However, a median created with tubular markers yielded up to a 5 km/h reduction in operating speed. In simulator studies, Dixon et al. (2008) found up to a 15.5 km/h reduction in the 85th percentile speed.

| JURISDICTIONS WHERE USED | POTENTIAL IMPACTS |
|---|---|
| Iowa, Hamilton (Ontario), United Kingdom, Austria, New Zealand, Denmark, Germany | If the median island is used to create a lateral deflection, then attention needs to be given to the severity of the deflection to achieve speed reduction without compromising the motorist's ability to navigate the transition.<br>The raised island is a fixed obstacle that may increase the potential for single motor vehicle crashes. |

**REFERENCES**

Berger W.J. and M. Linauer, "Raised Traffic Islands at City Limits—Their Effect on Speed," *Proceedings of 1998 Meeting of the International Cooperation on Theories and Concepts in Traffic Safety*, Budapest, 1998.

Dixon, K., H. Zhu, J. Ogle, J. Brooks, C. Hein, P. Aklluir, and M. Crisler, *Determining Effective Roadway Design Treatments for Transitioning from Rural Areas to Urban Areas on State Highways*, Final Report , FHWA Report No. FHWA-OR-RD-09-02, Federal Highway Administration, Washington, D.C., Sep. 2008.

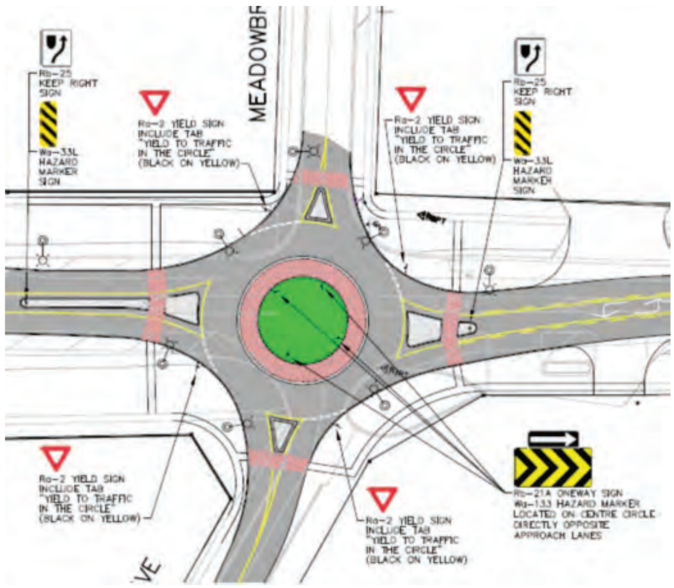
Hallmark, S.L., E. Peterson, E. Fitzsimmons, N. Hawkins, J. Resler, and T. Welch, *Evaluation of Gateway and Low-Cost Traffic-Calming Treatments for Major Routes in Small, Rural Communities*, Final Report No. CTRE Project 06-185, IHRB Project TR-523, Center for Transportation Research and Education, Iowa State University, Ames, Nov. 2007.

**TREATMENT**
Roundabout

| **CATEGORY** | **COST** |
|---|---|
| Geometric design | High |

**DESCRIPTION**

A one-way circular intersection that is characterized by a splitter island on all approaches and entering motorists yielding the right-of-way to motorists already on the circular roadway.




**EFFECTIVENESS**

Rodegerdts et al. (2007) developed speed prediction models for roundabout entries and exits as follows:

Metric:

$$V_{exit} = MIN\left( a\,R_3^b \;;\; 3.6\sqrt{\left(\frac{a\,R_2^b}{3.6}\right)^2 + 4.2d_3} \right)$$

$$V_{enter} = MIN\left( a\,R_1^b \;;\; 3.6\sqrt{\left(\frac{a\,R_2^b}{3.6}\right)^2 + 2.6d_1} \right)$$

Where: $V_{exit}$ = the predicted exit speed for the roundabout (km/h)

$R_1$ = path radius on entry to the roundabout (m)

$R_2$ = path radius on the circulating roadway (m)

R3 = path radius on exit from the roundabout (m)

*a*, *b* = see Table 13

$d_3$ = distance between the midpoint of the path on the circulating roadway and the point of interest on the exit (m)

$V_{enter}$ = the predicted entry speed for the roundabout (km/h)

$d_1$ = distance between the point of interest on the entry and the midpoint of the path on the circulating roadway (m)

*Continued on page 59*

*Continued from page 58*

**U.S. CUSTOMARY:**

$$V_{exit} = MIN\left( a R_3^b \; ; \; \frac{1}{1.47}\sqrt{\left(1.47 a R_2^b\right)^2 + 13.8 d_3} \right)$$

$$V_{enter} = MIN\left( a R_1^b \; ; \; \frac{1}{1.47}\sqrt{\left(1.47 a R_2^b\right)^2 + 8.4 d_1} \right)$$

Where: $V_{exit}$ = the predicted exit speed for the roundabout (mph)

$R_1$ = path radius on entry to the roundabout (ft)

$R_2$ = path radius on the circulating roadway (ft)

$R_3$ = path radius on exit from the roundabout (ft)

*a, b* = see Table 13

$d_3$ = distance between the midpoint of the path on the circulating roadway and the point of interest on the exit (ft)

$V_{enter}$ = the predicted entry speed for the roundabout (mph)

$d_1$ = distance between the point of interest on the entry and the midpoint of the path on the circulating roadway (ft)

**Table 13: Speed Prediction Parameters for Roundabouts**

| | **Metric** | | **US Customary** | |
|---|---|---|---|---|
| | **e = +0.02** | **e = -0.02** | **e = +0.02** | **e = -0.02** |
| a | 8.7602 | 8.6164 | 3.4415 | 3.4614 |
| b | 0.3861 | 0.3673 | 0.3861 | 0.3673 |

d2 = distance between the point of interest on the entry and the midpoint of the path on the circulating roadway (m)

The predicted speeds are independent of the approach speeds and are determined by the geometry of the circulating roadway.

**JURISDICTIONS WHERE USED**

United States, Canada, Europe, Australia

**POTENTIAL IMPACTS**

Roundabouts with higher design speeds for the circulating roadway may require more property for construction.

**REFERENCES**

Rodegerdts, L., M. Blogg, E. Wemple, E. Myers, M. Kyte, M. Dixon, G. List, A. Flannery, R. Troutbeck, W. Brilon, N. Wu, B. Persaud, C. Lyon, D. Harkey, and D. Carter, *NCHRP Report 572: Roundabouts in the United States*, Transportation Research Board of the National Academies, Washington, D.C., 2007.

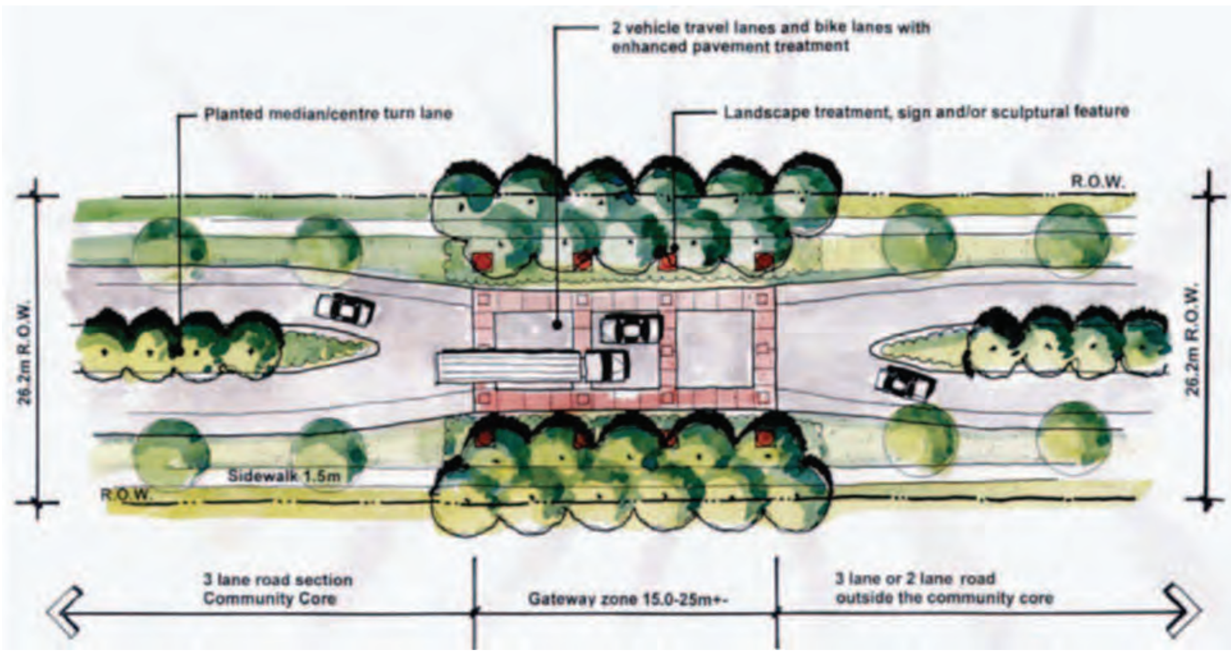
**TREATMENT**

Road or Lane Narrowings

| **CATEGORY** | **COST** |
|---|---|
| Geometric design | High |

**DESCRIPTION**

Any form of narrowing the road platform, including lane narrowing from the road edges or through the introduction of a raised or painted median.




**EFFECTIVENESS**

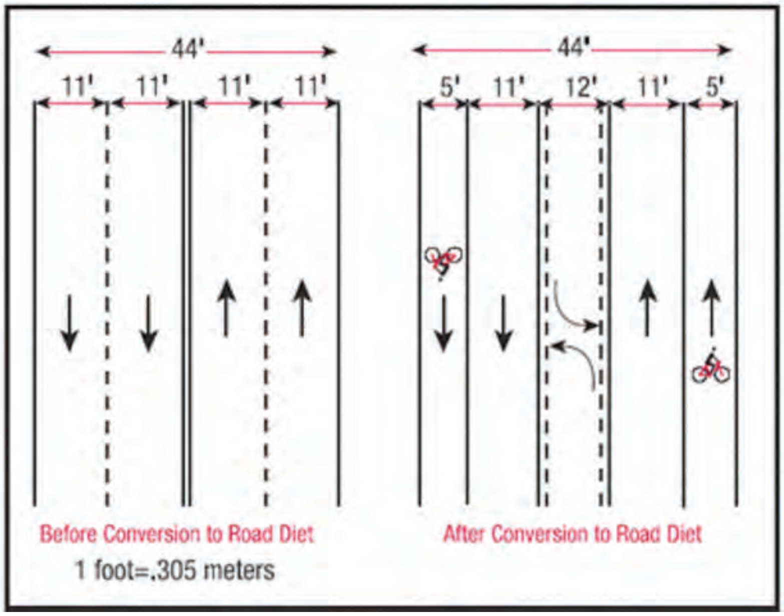
Charlton and Baas (2006) report an 11% to 20% reduction in operating speed as a result of visually narrowing the road in transition zones

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
|---|---|
| United Kingdom, Denmark, Netherlands, Ireland, New Zealand | Narrowings must take into account the number and classification of vehicles using the facility. Frequent use by large commercial vehicles or agricultural equipment may require wider pavements than otherwise. |

**REFERENCES**

Charlton, S.S. and P.H. Baas, *Speed Change Management for New Zealand Roads*, Land Transport New Zealand Research, Report 300, Wellington, New Zealand, 2006, 144 pp.

| **TREATMENT** | |
|---|---|
| Road Diets | |
| **CATEGORY**<br>Geometric design/traffic control | **COST**<br>Medium to High |
| **DESCRIPTION**<br>A reduction in the number of travel lanes for motorized traffic, with the excess road space generally reallocated to bicycle lanes, painted medians, or center turn lanes. | |




Source: http://www.tfhrc.gov/safety/hsis/pubs/04082/index.htm

| **EFFECTIVENESS** | |
|---|---|
| Knapp and Rosales (2007) reviewed a number of studies on road diets and found speed reductions of 5 mph (8 km/h) or less, but up to a 70% reduction in excessive speeding. Crash reductions are generally expected, with 20 to 40% reductions experienced. | |
| **JURISDICTIONS WHERE USED**<br>United States, Canada | **POTENTIAL IMPACTS**<br>The road diet may reduce the capacity of a facility depending on the number and types of turns, the presence of heavy vehicles, and the number and frequency of transit stops. |
| **REFERENCES** | |

Knapp, K.K. and J.A. Rosales, “Four-Lane to Three-Lane Conversions: An Update and a Case Study,” Proceedings of the 3rd Urban Street Symposium, Seattle, Washington, June 2007, http://www.urbanstreet.info/3rd_symp_proceedings/Four-Lane%20to%20Three-Lane.pdf, accessed on August 31, 2009.

**TREATMENT**

Chicanes or Horizontal Deflections

| **CATEGORY** | **COST** |
| --- | --- |
| Geometric design | Medium to High |

**DESCRIPTION**

Introducing horizontal deflections and shifts in the alignment of the road that require motorists to slow down as they negotiate the road.

Source: San Francisco Municipal Transportation Agency
(www.sfmta.com/cms/ocalm/13567.html)

**EFFECTIVENESS**

Chicanes or horizontal deflections have not been tried in transition zones as an isolated measure; they are typically installed in conjunction with other devices. The effects of horizontal deflections on speed are directly proportional to the severity of the deflection, with greater deflections generally producing greater speed reductions. However, Lamberti et al. (2009) tested a gateway treatment with and without a horizontal deflection and found speed reductions of the same magnitude for both. This indicates that the gateway signing and pavement markings may be sufficient to slow traffic without having to introduce horizontal deflection elements.

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
| --- | --- |
| United Kingdom, Italy | The chicane or horizontal deflection is a physical obstruction in the traveled way, so approaching motorists need clear visibility and adequate warning of the chicane so as to safety traverse it. Chicanes may increase the incidence of single vehicle collisions. |

**REFERENCES**

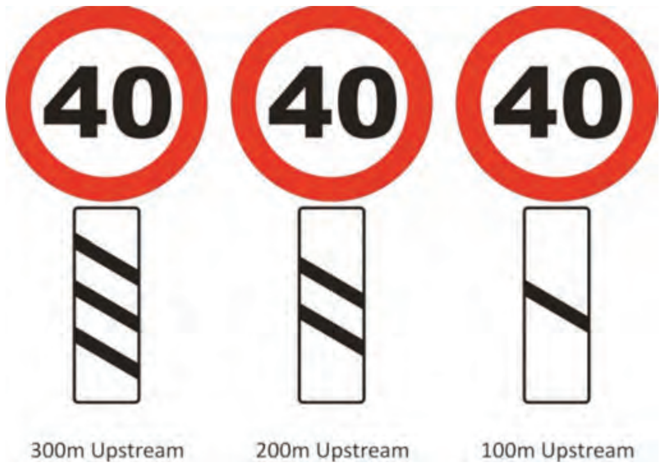
Lamberti, R., D. Abate, M.L. De Guglielmo, G. Dell’Acqua, T. Esposito, F. Galante, F. Mauriello, A. Montella, and M. Pernetti, “Perceptual Measures and Physical Devices for Traffic Calming Along a Rural Highway Crossing a Small Urban Community: Speed Behavior Evaluation in a Driving Simulator,” TRB Annual Meeting CD-ROM, Transportation Research Board, Washington, D.C., 2009.

**TREATMENT**

Countdown Speed Signs/Markers

| **CATEGORY** | **COST** |
|---|---|
| Traffic control devices | Low |

A longitudinal series of three traditional speed limit signs that are complemented with rectangular signs mounted below the speed limit signs. The complementary sign is a white background with one, two, or three diagonal slashes. The sign furthest upstream has the three diagonal slashes, followed by the sign with two slashes and then the sign with one slash, forming a non-numeric countdown.




Direction of travel →

(NOTE: European style speed limit sign shown)

**EFFECTIVENESS**

Barker and Helliar-Symons (1997) found no significant effect on mean speeds when countdown markers were used on the approaches to villages.

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
|---|---|
| United Kingdom | The countdown intended to be conveyed to the motorist by this signing method is done so using non-numeric, coded information. Therefore, public education and repeated exposure to the sign would be necessary for this sign to deliver any significant results. |

**REFERENCES**

Barker, J. and R.D. Helliar-Symons, "Countdown Signs and Roundel Markings Trails," *TRL Report 201,* Transport Research Laboratory, Crowthorne, U.K., 1997.

**TREATMENT**
Speed Feedback Signs

| **CATEGORY** | **COST** |
|---|---|
| Traffic control devices | Medium |

**DESCRIPTION**

Electronic signs placed at the roadside are connected to a device that measures the speed of approaching vehicles and displays the actual travel speed to motorists.


Source: Richard Drdul

**EFFECTIVENESS**

Donnell and Cruzado (2008) used speed feedback signs in transition zones, which showed mean speed reductions of approximately 6 mph (10 km/h) at the speed feedback sign and downstream of the sign. This effect was present only while the signs were in place, and mean speeds rebounded to before levels in the week after sign removal.

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
|---|---|
| Texas, Pennsylvania, United Kingdom | The cost of installation could be much higher than expected if a source of electricity is not readily available at the sign placement. Solar power is an option, but the solar panels are subject to theft. |

**REFERENCES**

Donnell, E.T. and I. Cruzado, *Effectiveness of Speed Minders in Reducing Driving Speeds on Rural Highways in Pennsylvania*, Final Report, The Thomas D. Larson Pennsylvania Transportation Institute, Pennsylvania State University, June 2008.

**TREATMENT**

Speed-Activated Speed Limit Signs

| **CATEGORY** | **COST** |
|---|---|
| Traffic control devices | Medium |

**DESCRIPTION**

Electronic signs placed at the roadside that are connected to a device that measures the speed of approaching vehicles. Should the measured speed exceed the legal speed limit, then the electronic sign is activated to display the legal speed limit. The speed limit may be accompanied by a “SLOW DOWN” message.


Source: Winnett and Wheeler (2002)

**EFFECTIVENESS**

Winnett and Wheeler (2002) produced up to an 80% change in the percentage of vehicles exceeding the speed limit using vehicle-activated speed signs on the approaches to villages.

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
|---|---|
| Iowa, Washington (Tacoma, Redmond), Maryland (Anne Arundel County), Canada (Ontario, Alberta, and British Columbia), United Kingdom | The cost of installation could be much higher than expected if a source of electricity is not readily available at the sign placement. Solar power is an option, but the solar panels are subject to theft. |

**REFERENCES**

Winnett, M.A. and A.H. Wheeler, “Vehicle-Activated Signs; A Large Scale Evaluation,” *TRL Report 549,* Transport Research Laboratory, Crowthorne, U.K., 2002.

**TREATMENT**

Transitional Speed Limits (or Stepped-Down Speed Limit)

| **CATEGORY** | **COST** |
|---|---|
| Traffic control devices | Low |

**DESCRIPTION**

Provision of an intermediate or stepped-down speed limit to ease the transition from a high-to-low speed area. For example, a short section of 40 mph speed zone inserted between a 55 mph rural speed zone and a 30 mph urban speed zone.


**EFFECTIVENESS**

Hildebrand et al. (2004) tested stepped-down speed limits at seven high-to-low speed transitions that were 25 mph (40 km/h) or more, and found that inserting a transitional speed limit had no significant effect on mean speed, speed dispersion, or the percentage of motorists exceeding the speed limit.

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
|---|---|
| United States, Canada, United Kingdom, Australia, Europe | None identified. |

**REFERENCES**

Hildebrand, E.D., A. Ross, and K. Robichaud, “The Effectiveness of Transitional Speed Zones,” *ITE Journal*, Vol. 74, No. 10, Institute of Transportation Engineers, Washington, D.C., 2004, pp. 30–38.

| | |
|---|---|
| **TREATMENT**<br>Removal of Pavement Markings | |
| **CATEGORY**<br>Traffic control devices | **COST**<br>Medium |
| **DESCRIPTION**<br>Removing the directional dividing line and/or the edge lines from the pavement surface to create discomfort for motorists, causing them to slow down commensurately. | |

***Before***


***After***

Source: Kennedy (2005)

| | |
|---|---|
| **EFFECTIVENESS**<br>Removal of the directional dividing lines in two cases in the United Kingdom resulted in as much as a 7 mph (11 km/h) reduction in speed (Quimby and Castle 2006). | |
| **JURISDICTIONS WHERE USED**<br>United Kingdom | **POTENTIAL IMPACTS**<br>This measure has been used in villages, and may not be suitable for transition zones. Longitudinal pavement markings play an important role in lane keeping and reducing crashes that result from lane departures (head-on collisions, sideswipe collisions, or run-off-road collisions). This measure is not suitable for areas where the forward visibility of the road ahead is restricted and motorists rely on the longitudinal markings to maintain lateral position. |
| **REFERENCES**<br>Quimby, A. and J. Castle, *A Review of Simplified Streetscape Schemes*, Project Report PPR292, TRL Limited, Crowthorne, U.K., Jan. 2006. | |

**TREATMENT**

Optical Speed Bars

**CATEGORY**

Traffic control devices

**COST**

Low

**DESCRIPTION**

Transverse markings placed in and across the travel lane with the intent of increasing the optical flow of information and creating a sense of increasing speed. The speed bars may be evenly spaced or exponentially spaced with a decreased spacing as one travels downstream.


Source: Arnold and Lantz (2008)

**EFFECTIVENESS**

Arnold and Lantz (2008) tested optical speed bars on the approach to a rural village and found a 3 to 9.5 mph (5 to 15 km/h) reduction in speed. It is unknown whether this effect can be sustained over time. Fitch and Crum (2007) found only a 1.0 mph (1.6 km/h) reduction in the 85th percentile speed when testing optical speed bars at four towns in Vermont.

**JURISDICTIONS WHERE USED**

Virginia, Vermont

**POTENTIAL IMPACTS**

Transverse pavement markings increase maintenance costs if they are placed in the wheel paths of vehicles. Also, pavement markings are not visible from significant distances upstream, so placement requires careful consideration.

**REFERENCES**

Arnold, E.D. and K.E. Lantz, *Evaluation of Best Practices in Traffic Operations and Safety: Phase I: Flashing LED Stop Sign and Optical Speed Bars, Final Report*, Virginia Transportation Research Council, Charlottesville, June 2007.

Fitch, J. and N. Crum, *Dynamic Striping in Four Towns Along Vermont Route 30—Final Report*, Report No. 2007-14, Vermont Agency of Transportation, Montpelier, Oct. 2007.

**TREATMENT**

Speed Humps, Raised Crosswalks, Raised Intersections, and Vertical Deflections

| **CATEGORY** | **COST** |
|---|---|
| Surface treatment | Medium to High |

**DESCRIPTION**

A relatively abrupt change in the elevation of the road surface so as to create an uncomfortable feeling for motorized traffic when the feature is traversed at a high speed.

Source: Richard Drdul

**EFFECTIVENESS**

Vertical deflections at high-to-low speed transitions have not been used extensively in practice because the profession is wary of the potential for vehicle damage and lost control crashes resulting from a motorist striking the deflection at full speed. Nonetheless, Charlton and Baas (2006) report speed cushions and speed humps in transition zones could reduce speeds by 9% and 21%, respectively.

| **JURISDICTIONS WHERE USED** | **POTENTIAL IMPACTS** |
|---|---|
| United Kingdom | Vertical measures are particularly troubling if motorists are not provided with sufficient warning of the deflection. Traversing these features at high operating speeds may cause vehicle damage and cause a motorist to lose control of the vehicle. |

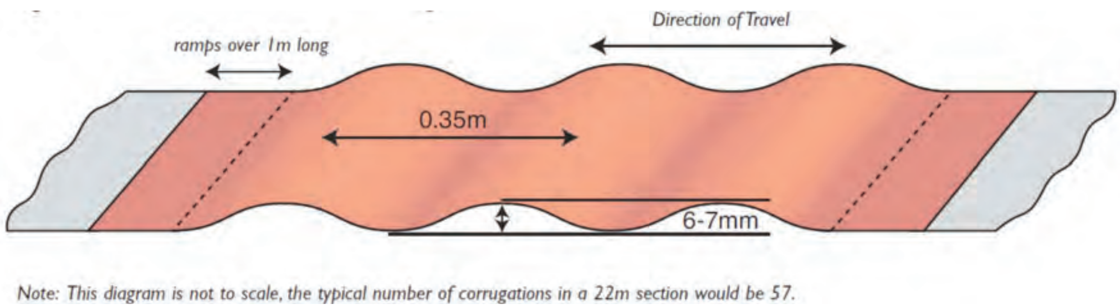
**REFERENCES**

Charlton, S.S. and P.H. Baas, *Speed Change Management for New Zealand Roads*, Report 300, Land Transport New Zealand Research, Wellington, 2006, 144 pp.

| TREATMENT | |
|---|---|
| Rumblewave Surfaces | |
| **CATEGORY**<br>Pavement surface treatment | **COST**<br>Medium to high |

**DESCRIPTION**

An undulating road surface that resembles a series of closely spaced speed humps using a sinusoidal profile. The amplitude of the waves are about one quarter of an inch, and the wavelength is in the order of 1.1 feet.




Source: Department for Transport (2005)

**EFFECTIVENESS**

At seven pilot locations, rumblewave surfaces produced reductions in both the mean and 85th percentile speeds from 1% to 6% (Department for Transport, 2005).

| JURISDICTIONS WHERE USED | POTENTIAL IMPACTS |
|---|---|
| United Kingdom | Rumblewave surfaces are experimental. They may cause some maintenance concerns, particularly where snow and ice build-up may cause winter weather hazards. |

**REFERENCES**

Department for Transport, *Rumblewave Surfacing, Traffic Advisory Leaflet 1/05*, Department for Transport, London, United Kingdom, Jan. 2005, 6 pp.

**TREATMENT**

Gateway

**CATEGORY**

Roadside features

**COST**

Low to High

**DESCRIPTION**

Measures and elements that are placed at the urban/rural threshold and collectively present a visual cue to the driver that this is the point of change in roadway character.

Gateways can consist of a simple sign at the roadside, a raised island, or an elaborate collection of measures including freestanding structures placed over/across the traveled way, colored pavement, and pavement markings.


Source: Veneziano et al. (2009)


Source: Andersson et al. (2008)

**EFFECTIVENESS**

Andersson et al. (2008) analyzed the safety performance of 251 town gates across Denmark and found that overall town gates increased the number of property damage only collisions by 34% and did not have any significant effect on personal injury crashes. If the gates are broken down by those with physical measures, those with visual measures, and those with combined physical and visual measures—the combined measures gates performed the best, yielding a 28% decrease in injury collisions and a 36% increase in property damage collisions. Also, the researchers found that gates in transition zones where the difference in the posted speed limit is less than 20 mph (30 km/h) perform better than gates in zones with speed differences of 20 mph (30 km/h) or more.

Veneziano et al. (2009) reviewed seven gateways constructed in California that consisted solely of freestanding structures and roadside signs, and found that they are not detrimental to safety.

**JURISDICTIONS WHERE USED**

California, United Kingdom, Denmark

**POTENTIAL IMPACTS**

Gateways become fixed objects at the roadside and may increase the severity of run-off-road crashes. Gateways need to be conspicuous to be effective, but should blend in with the surrounding environment (particularly in historic areas). Gateways should be visible over at least the stopping sight distance to avoid surprising the driver.

**REFERENCES**

Veneziano, D., Z. Ye, J. Fletcher, J. Ebeling, and F. Shockley, *Evaluation of the Gateway Monument Demonstration Program: Safety, Economic and Social Impact Analysis*, Western Transportation Institute, College of Engineering, Montana State University, Sep. 2009, 141 pp.

Andersson, P.K., B. la Cour Lund, P.V. Greibe, and L. Herrstedt, *Byporte: de trafiksikkerhedsmaessige efffeckter*, Trafitec Scion-DTU, July 2008, 116 pp [Online]. Available: http://www.trafitec.dk/pub/byporte%20notat.pdf [accessed Sep. 3, 2009].

CHAPTER FIVE

# CONCLUSIONS

The North American experience with high-to-low speed transition zones is generally disjointed and fairly limited. More than one-half of state and provincial respondents to the state-of-the-practice survey indicated that they do not have a standard method of treating transition zones, and those that do are relying on standard traffic signs as specified in the *MUTCD*. The experience from overseas is more robust, and the lessons learned from foreign testing might be used as a starting point for developing a North American effort into this important area of research.

Measures that have been implemented in transition zones fall into four broad categories: geometric design changes, traffic control devices, road surface treatments, and roadside features. The effectiveness of the various measures is generally determined through the impact these measures have on operating speed or crash risk. Testing methodologies include both driving simulator studies and field experiments. The general trend with these studies is that all but the most aggressive transition zone measures have little or no effect on operating speed, but the effect on crash risk is generally positive. However, these transition zone studies show a significant degree of inter-study variation, which draws into question the transferability of any of results. The variation might be explained by differences in the applied treatment (e.g., "gateways" having different designs in different studies), and recording speeds/crashes at different points or over different sections of road.

Only a handful of studies examined the long-term or habituation effects of high-to-low speed transition treatments. It has long been recognized that change creates uncertainty, and uncertainty may result in lower operating speeds. However, whether the change is sustained over the long term requires further investigation. At the end of the day, the profession requires a more rational approach to experimenting and gathering data on the effectiveness of transition zone measures than the somewhat disjointed trial-and-error method currently being used.

The design guidance that is available on transition zones from the literature review for this project (see chapter two) is generally consistent in providing the following information:

- More extensive and aggressive measures tended to produce greater reductions in speed and crash occurrence than less extensive and passive measures.
- There needs to be a distinct relationship between a settlement speed limit and a change in the roadway character.
- There is not one particular measure that is appropriate for all situations. Each settlement must be assessed and treated based on its own characteristics and merits.
- To maintain a speed reduction downstream of the transition zone, it is necessary to provide additional measures through the village. Otherwise, speeds may rebound to previous levels as soon as 820 ft (250 m) from the start of the lower speed zone.

With respect to the design of transition zones, there needs to be greater attention to treating the transition zone as a length of highway upstream of the rural to urban threshold, rather than as a specific point (i.e., the threshold itself). A good deal of emphasis has been placed on creating a gateway to address transition zone issues, and placing the gateway at the location where the character of the road changes from rural to urban in order to build credibility with motorists. However, this places the gateway at the downstream end of the transition zone, which leaves the transition zone—the length of road where the speed change is expected to occur—essentially untreated except for advance speed limit signs or a stepped-down speed limit.

In designing and selecting transition zone measures, the ultimate goal is to have motorists traveling at the lower speed limit at the start of the settled area, and to have the speed reduction occur in the transition zone. This places the transition zone in the rural area, and requires the designer to use a variety of techniques to achieve the goal. Because physical measures are the most effective in reducing speed but are the most perilous if traversed at high speed, it may be helpful to recognize that an approach zone is required upstream of the transition zone to warn motorists. The transition zone and approach zone concept are shown in Figure 39.

The basic principle is that motorists are first provided with warning devices and psychological measures in the approach zone, and are faced with physical measures in the transition zone. This approach to transition zone design is intended to better satisfy driver expectations, and to avoid the abrupt appearance of a gateway feature or a physical calming feature.

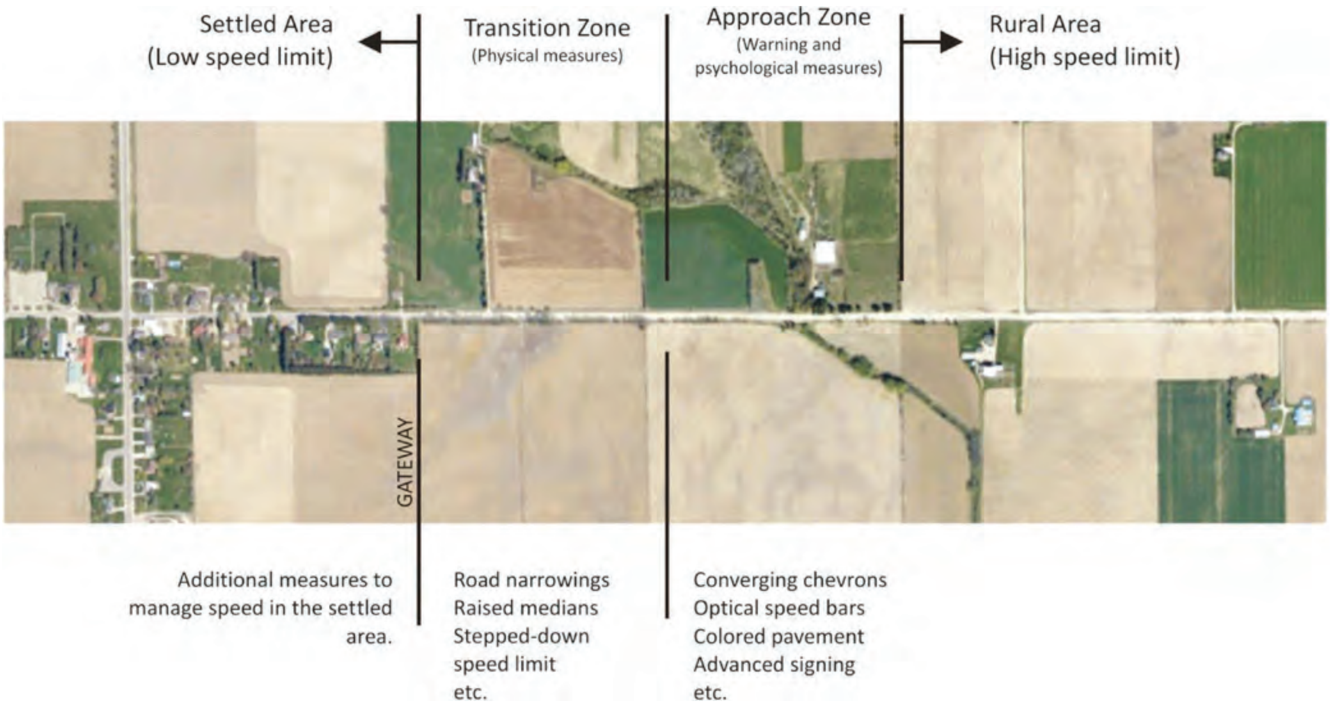



FIGURE 39 Transition zone and approach zone concepts.

Having stated that, the speed adaptation phenomenon makes any attempt at transitioning drivers from high to low speeds difficult at best. Because speed adaptation is a carryover effect from a previously traversed high-speed area, it is unlikely that infrastructure changes in the transition zone will ameliorate this effect. Moreover, as motorists underestimate their operating speeds in these situations, it may be beneficial to use speed feedback signs at the upstream end of the transition zone. These signs provide more reliable information on current operating speeds than the drivers own senses, and can assist motorists in slowing to an appropriate speed.

Most of the guidelines and recommendations for transition zones rely on horizontal deflections and narrowings to achieve speed reductions, and specifically recommend against any vertical deflections (i.e., speed humps and raised crosswalks) in the transition area. When using an approach zone and a transition zone, vertical deflections, which tend to be the most effective measures in managing speeds, may be considered at the downstream end of the transition zone.

Finally, at the present time there is an interesting bifurcation between the North American and European approaches to speed management and road safety in small towns, settlements, and villages. The European community is currently experimenting with minimizing and removing traffic control and design features that physically separate road user types (e.g., removal of directional dividing lines). This is an attempt to create a measure of uncertainty in the driving environment that reduces operating speeds and requires motorists to pay closer attention to the driving task and to communicate (i.e., make eye contact) with other road users. This approach has not been specifically linked to transition zones, but it is in stark contrast to the North American approach to speed management, which has been to add measures. The results of these experiments are very preliminary, but should be monitored.

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# GLOSSARY OF TERMS

Combs: Rhomboid pavement markings placed adjacent to the edges of the travel lane. The combs visually reduce lane width and increase the optical flow for drivers.

Converging chevrons: A series of pavement markings where chevrons (with the point oriented in the direction of travel) are marked along a section of road where the spacing between successive markings decreases as one moves downstream.

Countdown markers: A series of consecutive signs (usually three) that are posted beneath a primary sign that is used to convey the message to the driver of an impending downstream condition. The countdown markers are generally rectangular with the height of the sign greater than the width. The marker has a geometric symbol (usually a "slash") across the sign; the upstream sign has three slashes separated vertically, the next sign has two slashes, and the final sign has one slash. The reduction in the number of slashes is coded information intended to resemble a countdown.

Dragon's teeth: Pavement markings placed adjacent to both edges of the travelled lane and directly opposite for any length of roadway such that they resemble a row of teeth. Also known as shark's teeth.

Gateway: Any device or change in the road character or installation, located at the threshold between the high speed and low speed areas, that is meant to inform the driver of the speed reduction.

Hamlet: A community of people usually smaller than a village, but often used interchangeably with small town, village, or settlement.

Optical flow: The pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer (the driver) and the scene (the road).

Optical speed bars: Transverse pavement markings placed in or across a lane that are intended to increase the flow of information in the visual field and cause drivers to slow down. Speed bars may be placed at a uniform spacing or may use an exponential spacing where the distance between successive bars decreases as one travels downstream, creating a sense of increasing speed.

Optical width: The relation of the height of the vertical elements at the roadside to the distance between the vertical elements on opposite side of the road when measured in cross-section. When the distance between the vertical elements exceeds the height of the vertical elements, the optical width is large, and promotes faster operating speeds.

Portal: See gateway.

Psychological traffic calming: Calming measures that aim to increase the mental load on drivers and thereby encourage them to reduce speed. This is in contrast to physical traffic calming measures that require drivers to slow down in order to safely negotiate the measure. For example, a speed hump is physical traffic calming; optical speed bars are psychological traffic calming.

Speed roundel: A pavement marking symbol that shows the speed limit (expressed as a numeral without units of measure) in a concentric ring.

Wundt illusion: An optical illusion in which the lane/edge line markings or pavement edges appear to converging when chevrons pointed in the direction of travel are marked in the lane.

# APPENDIX A
# Survey Questionnaire

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

**NCHRP Synthesis 40-08: Effective Speed Reduction Techniques for Rural High to Low Speed Transitions**

Over the years road authorities throughout the United States and Canada have employed a variety of engineering and infrastructure techniques to reduce vehicle speeds at transitions from high-speed rural areas to small towns, residential settlements, or community areas. However, limited research has been conducted on the subject so there is no existing toolbox on how to reduce traffic speeds in these transition areas. The purpose of this survey is to collect information on, and document the state of the practice concerning infrastructure-based speed reduction techniques for rural high-to-low speed transitions. We would appreciate your participation in this survey.

This survey should be completed by the person(s) in your jurisdiction who is (are) most familiar with speed reduction measures at rural high-to-low speed transitions. All responses will be included in a final study report, including the names of the responding agencies, and the name of the primary respondent. However, personal contact information will not be shared with anyone except the study team.

Please return the completed questionnaire by Tuesday, March 31, 2009 to:

*Gerry Forbes*
*Intus Road Safety Engineering Inc.*
*2606 Bluffs Way, RR 2, Milton, Ontario, L9T 2X6, CANADA*
*e: gerry@intus.ca f: 905.332.9777*

If you have questions, please contact the Principle Investigator, Gerry Forbes via e-mail (gerry@intus.ca) or telephone (905-332-9470).

Your participation is appreciated.

## PART 1: CONTACT INFORMATION

1. Please provide your contact information.

Name:

Title:

Agency:

Address:

Telephone:

Fax:

E-mail:

## PART 2: STANDARD APPROACH

*The focus of this survey is on* ***infrastructure-based or engineering measures*** *for rural high-to-low speed transitions. These measures include traffic control devices (i.e., traffic signs, traffic signals, and pavement markings), roadside treatments, road surface treatments, and modifications to roadway geometrics. While generally considered an important part of road safety management, education, encouragement, or enforcement techniques are not the focus of this survey.*

2. Does your agency have a standard approach to treating rural high-to-low speed transitions in new construction or complete reconstruction?

☐ Yes, I can provide a URL (web address) with the details: ____________________________
☐ Yes, I will mail or e-mail the details
☐ Yes, I can describe the approach
☐ No, we do not have a standard approach

*If you are* ***not*** *describing your standard approach for high-to-low speed transitions in new construction, please go to Question 4.*

3. You indicated that you have a standard approach to rural high-to-low speed transitions in new construction of these areas. Please provide a detailed description of the standard treatments.

Roadway (geometric) design ________________________________________

Traffic control devices ________________________________________

Road surface treatments ________________________________________

Off road treatments ________________________________________

4. Does your agency have a standard approach to treating rural high-to-low speed transitions in retrofit situations?

☐ Yes, I can provide a URL (web address) with the details: ______________________
☐ Yes, I will mail or e-mail the details

☐ Yes, I can describe the approach
☐ No, we do not have a standard approach

*If you are not describing your standard approach for high-to-low speed transitions in retrofits, please go to Question 6.*

5. You indicated that you have a standard approach to rural high-to-low speed transitions in retrofits of these areas. Please provide a detailed description of the standard treatments.

Roadway (geometric) design ______________________________

Traffic control devices ______________________________

Road surface treatments ______________________________

Off road treatments ______________________________

6. Which of the following measures, if any, do you consider ***inappropriate*** for treating rural high-to-low speed transitions [Check all that apply]?

**Geometric Design**

☐ Chicanes or increasing road curvature
☐ Bulb-outs, neckdowns, chokers, road narrowings
☐ Central islands/raised medians
☐ Traffic circle
☐ Roundabout
☐ Road diet, reduction in the number of through lanes
☐ Adding bicycle lanes
☐ Adding sidewalks or pedestrian paths
☐ None of the above
☐ Other (please specify): ____________

**Surface Treatments**

☐ Speed humps
☐ Raised intersections or speed tables
☐ Speed cushions or road studs
☐ Pedestrians crosswalks
☐ Transverse Rumble strips
☐ Centreline or shoulder rumble strips
☐ Colored or textured pavement
☐ None of the above
☐ Other (please specify): ____________

**Traffic Control Devices**

☐ Enhanced speed limit signs and/or markings
☐ Add standard warning signs
☐ Unique (non-MUTCD) traffic control signs
☐ All-way stop control
☐ Amber flashing beacons
☐ Speed sensitive signals
☐ Variable message signs other than speed trailers
☐ Marked no-passing zones
☐ Transverse pavement markings, chevrons, or dragon's teeth
☐ Removal of all pavement markings
☐ Removal of most traffic signs
☐ Transitional/stepped-down speed limit

- [ ] Village information signs
- [ ] Speed cameras
- [ ] Speed trailers/radar message boards
- [ ] None of the above
- [ ] Other (please specify): ______________

**Roadside Features**

- [ ] Gateway/entrance features
- [ ] Landscaping changes
- [ ] Street furniture
- [ ] Introduce/alter street lighting
- [ ] None of the above
- [ ] Other (please specify): ______________

7. Does your agency have any other documentation (i.e., policies, handbooks, manuals, guidelines, etc.) concerning rural high-to-low speed transitions?

- [ ] Yes, I here is the URL (website address) ______________________________________
- [ ] Yes, I will mail or e-mail the documentation
- [ ] Yes, please contact me for details
- [ ] No, there is no other documentation

## PART 3: ENHANCED TREATMENTS

*In this section, please consider rural high-to-low speed transitions where you implemented infrastructure measures that were **more than required by your standard approach.** If you do not have a standard approach, then please consider your standard approach as the minimum requirements as specified by your MUTCD.*

*We are interested in engineering measures you have tried, even if they were unsuccessful and/or subsequently removed.*

8. Which factors may influence a decision to implement enhanced rural high-to-low speed transition measures?

- [ ] Significant drop in posted speed limit (Specify minimum drop: ______ mph)
- [ ] High operating speeds in the village
- [ ] Poor crash record
- [ ] Functional classification of the road
- [ ] Driveway/access density
- [ ] Public opinion/concerns
- [ ] Pedestrian/cyclist volumes
- [ ] ADT
- [ ] Minimum size of settlement
- [ ] Other (please specify): ________________________________________

If you did not select "Minimum size of settlement" in Question 8, please go to Question 10.

9. If you indicated that minimum size of settlement is a factor in deciding when to implement enhanced high-to-low speed transition measures (Question 8), please describe what is meant by minimum size? [Check all that apply.]

- [ ] Population of settlement

- ☐ Length of development fronting on the main street
- ☐ Presence of certain amenities (i.e., school, church, local store, etc.)
- ☐ Other (please specify): ______________________________

10. Which of the following measures are not part of your standard approach and have been tried in any enhanced rural high-to-low speed transitions on your roads?

**Geometric Design**

- ☐ Chicanes or increasing road curvature
- ☐ Road diet, reduction in the number of through lanes
- ☐ Bulb-outs, neckdowns, chokers, road narrowings
- ☐ Adding bicycle lanes
- ☐ Central islands/raised medians
- ☐ Adding sidewalks or pedestrian paths
- ☐ Traffic circle
- ☐ None of the above
- ☐ Roundabout
- ☐ Other (please specify): ____________

**Surface Treatments**

- ☐ Speed humps
- ☐ Centreline or shoulder rumble strips
- ☐ Raised intersections or speed tables
- ☐ Colored or textured pavement
- ☐ Speed cushions or road studs
- ☐ None of the above
- ☐ Pedestrians crosswalks
- ☐ Other (please specify): ____________
- ☐ Transverse Rumble strips

**Traffic Control Devices**

- ☐ Enhanced speed limit signs and/or markings
- ☐ Variable message signs other than speed trailers
- ☐ Add standard warning signs
- ☐ Marked no-passing zones
- ☐ Unique (non-MUTCD) traffic control signs
- ☐ Transverse pavement markings, chevrons, or dragon's teeth
- ☐ All-way stop control
- ☐ Removal of all pavement markings
- ☐ Amber flashing beacons
- ☐ Removal of most traffic signs
- ☐ Speed sensitive signals
- ☐ Transitional/stepped-down speed limit
- ☐ Village information signs
- ☐ None of the above
- ☐ Speed cameras
- ☐ Other (please specify): ____________
- ☐ Speed trailers/radar message boards

**Roadside Features**

- ☐ Gateway/entrance features
- ☐ Introduce/alter street lighting
- ☐ Landscaping changes
- ☐ None of the above
- ☐ Street furniture
- ☐ Other (please specify): ____________

## PART 4: CASE STUDIES

In this section you are requested to provide detailed information (or links to information) for up to 3 rural high-to-low speed transitions where you implemented an enhanced engineering measure or measures.

*If you do not have any case studies to report, please go to Question 40.*

11. Are the details of the first transition treatment documented and available to the research team?

- ☐ Yes, I can provide a URL (website address) ______________________
- ☐ Yes, I will e-mail or mail the information
- ☐ Yes, but I will describe the details now
- ☐ No, there is no documentation

*If you provided a URL, or stated that you would mail or e-mail information in Question 11, please go to Question 16.*

12. What were the speed limits before implementation of the enhanced measures?

| Speed Limit (mph) | In the high speed (rural) area | In the transition zone | In the low speed (village) area |
|---|---|---|---|
| 20 | ☐ | ☐ | ☐ |
| 25 | ☐ | ☐ | ☐ |
| 30 | ☐ | ☐ | ☐ |
| 35 | ☐ | ☐ | ☐ |
| 40 | ☐ | ☐ | ☐ |
| 45 | ☐ | ☐ | ☐ |
| 50 | ☐ | ☐ | ☐ |
| 55 | ☐ | ☐ | ☐ |
| 60 | ☐ | ☐ | ☐ |

13. How many through lanes (for both directions combined) were present before implementation of the enhanced measures?

| | In the high speed (rural) area | In the low speed (village) area |
|---|---|---|
| 2 lanes | ☐ | ☐ |
| 3 lanes | ☐ | ☐ |
| 4 lanes | ☐ | ☐ |
| > 4 lanes | ☐ | ☐ |

14. What type of median was present before implementation of the enhanced measures?

| | In the high speed (rural) area | In the low speed (village) area |
|---|---|---|
| Undivided (No median) | ☐ | ☐ |
| Painted median | ☐ | ☐ |
| Two-way left-turn lane | ☐ | ☐ |
| Depressed median | ☐ | ☐ |
| Raised median | ☐ | ☐ |

15. Please describe all of the measures implemented in this transition including the location of the measures in relation to the start of the low speed limit (e.g., a 6 foot wide raised median that is 30 feet long, at the start of the low speed zone)

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

16. Did you evaluate this treatment?

☐ Yes, I can provide a URL (website address): ______________________
☐ Yes, I will mail or e-mail the information
☐ Yes, I can provide the details now
☐ No, there is no evaluation

*If you are **not** providing details now (Question 16), please go to Question 20.*

17. Please provide traffic operations and safety data gathered for the evaluation(s)

| | Before Study | After Studies 1 | After Studies 2 | After Studies 3 |
|---|---|---|---|---|
| No. of months after installation | N/A | | | |
| ADT | | | | |
| Capacity (vph) | | | | |
| 85th Percentile speed (mph) | | | | |
| Mean speed (mph) | | | | |
| % Exceeding the speed limit | | | | |
| No. of fatal crashes | | | | |
| No. of personal injury crashes | | | | |
| No. of damage only crashes | | | | |
| No. of months of crash data | | | | |

18. Please describe the results of your evaluation on the following (Enter "DNE" for did not evaluate):

Public Opinion ______________________________

Emergency Service Response ______________________________

Noise ______________________________

Maintenance ______________________________

Access to adjacent properties ______________________________

19. What was the cost of treating this high-to-low speed transition?

a. Initial cost of installation $ ____________
b. Change in annual maintenance cost $ ____________

20. Do you want to describe a second high-to-low speed case study?

☐ Yes
☐ No

If you answered "No" to Question 20, please go to Question 40.

21. Are the details of the second transition treatment documented and available to the research team?

☐ Yes, I can provide a URL (website address) ____________________
☐ Yes, I will e-mail or mail the information
☐ Yes, but I will describe the details now
☐ No, there is no documentation

*If you provided a URL, or stated that you would mail or e-mail information in Question 21, please go to Question 26.*

22. What were the speed limits before implementation of the enhanced measures?

| Speed Limit (mph) | In the high speed (rural) area | In the transition zone | In the low speed (village) area |
|---|---|---|---|
| 20 | ☐ | ☐ | ☐ |
| 25 | ☐ | ☐ | ☐ |
| 30 | ☐ | ☐ | ☐ |
| 35 | ☐ | ☐ | ☐ |
| 40 | ☐ | ☐ | ☐ |
| 45 | ☐ | ☐ | ☐ |
| 50 | ☐ | ☐ | ☐ |
| 55 | ☐ | ☐ | ☐ |
| 60 | ☐ | ☐ | ☐ |

23. How many through lanes (for both directions combined) were present before implementation of the enhanced measures?

| | In the high speed (rural) area | In the low speed (village) area |
|---|---|---|
| 2 lanes | ☐ | ☐ |
| 3 lanes | ☐ | ☐ |
| 4 lanes | ☐ | ☐ |
| > 4 lanes | ☐ | ☐ |

24. What type of median was present before implementation of the enhanced measures?

| | In the high speed (rural) area | In the low speed (village) area |
|---|---|---|
| Undivided (No median) | ☐ | ☐ |
| Painted median | ☐ | ☐ |
| Two-way left-turn lane | ☐ | ☐ |
| Depressed median | ☐ | ☐ |
| Raised median | ☐ | ☐ |

25. Please describe all of the measures implemented in this transition including the location of the measures in relation to the start of the low speed limit (e.g., a 6 foot wide raised median that is 30 feet long, at the start of the low speed zone)

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

26. Did you evaluate this treatment?

☐ Yes, I can provide a URL (website address): ______________________
☐ Yes, I will mail or e-mail the information
☐ Yes, I can provide the details now
☐ No, there is no evaluation

*If you are **not** providing details now, please go to Question 30.*

27. Please provide traffic operations and safety data gathered for evaluation(s)

| | Before Study | After Studies 1 | 2 | 3 |
|---|---|---|---|---|
| No. of months after installation | N/A | | | |
| ADT | | | | |
| Capacity (vph) | | | | |
| 85th Percentile speed (mph) | | | | |
| Mean speed (mph) | | | | |
| % Exceeding the speed limit | | | | |
| No. of fatal crashes | | | | |
| No. of personal injury crashes | | | | |
| No. of damage only crashes | | | | |
| No. of months of crash data | | | | |

28. Please describe the results of your evaluation on the following (Enter "DNE" for did not evaluate):

Public Opinion ________________________________

Emergency Service Response ________________________________

Noise ________________________________

Maintenance ________________________________

Access to adjacent properties ________________________________

29. What was the cost of treating this high-to-low speed transition?

a. Initial cost of installation $ ________________
b. Change in annual maintenance cost $ ________________

30. Do you want to describe a third high-to-low speed case study?

☐ Yes
☐ No

If you answered "No" to Question 30, please go to Question 40.

31. Are the details of the third transition treatment documented and available to the research team?

☐ Yes, I can provide a URL (website address) ____________________
☐ Yes, I will e-mail or mail the information
☐ Yes, but I will describe the details now
☐ No, there is no documentation

*If you provided a URL, or stated that you would mail or e-mail information in Question 31, please go to Question 36.*

32. What were the speed limits before implementation of the enhanced measures?

| Speed Limit (mph) | In the high speed (rural) area | In the transition zone | In the low speed (village) area |
|---|---|---|---|
| 20 | ☐ | ☐ | ☐ |
| 25 | ☐ | ☐ | ☐ |
| 30 | ☐ | ☐ | ☐ |
| 35 | ☐ | ☐ | ☐ |
| 40 | ☐ | ☐ | ☐ |
| 45 | ☐ | ☐ | ☐ |
| 50 | ☐ | ☐ | ☐ |
| 55 | ☐ | ☐ | ☐ |
| 60 | ☐ | ☐ | ☐ |

33. How many through lanes (for both directions combined) were present before implementation of the enhanced measures?

| | In the high speed (rural) area | In the low speed (village) area |
|---|---|---|
| 2 lanes | ☐ | ☐ |
| 3 lanes | ☐ | ☐ |
| 4 lanes | ☐ | ☐ |
| > 4 lanes | ☐ | ☐ |

34. What type of median was present before implementation of the enhanced measures?

| | In the high speed (rural) area | In the low speed (village) area |
|---|---|---|
| Undivided (No median) | ☐ | ☐ |
| Painted median | ☐ | ☐ |
| Two-way left-turn lane | ☐ | ☐ |
| Depressed median | ☐ | ☐ |
| Raised median | ☐ | ☐ |

35. Please describe all of the measures implemented in this transition including the location of the measures in relation to the start of the low speed limit (e.g., a 6 foot wide raised median that is 30 feet long, at the start of the low speed zone):

______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

36. Did you evaluate this treatment?

- ☐ Yes, I can provide a URL (website address): ____________________
- ☐ Yes, I will mail or e-mail the information
- ☐ Yes, I can provide the details now
- ☐ No, there is no evaluation

*If you are **not** providing details now, please go to Question 40.*

37. Please provide traffic operations and safety data gathered for evaluation(s).

| | Before Study | After Studies 1 | After Studies 2 | After Studies 3 |
|---|---|---|---|---|
| No. of months after installation | N/A | | | |
| ADT | | | | |
| Capacity (vph) | | | | |
| 85th Percentile speed (mph) | | | | |
| Mean speed (mph) | | | | |
| % Exceeding the speed limit | | | | |
| No. of fatal crashes | | | | |
| No. of personal injury crashes | | | | |
| No. of damage only crashes | | | | |
| No. of months of crash data | | | | |

38. Please describe the results of your evaluation on the following (Enter "DNE" for did not evaluate):

Public Opinion ______________________________
Emergency Service Response ______________________________
Noise ______________________________
Maintenance ______________________________
Access to adjacent properties ______________________________

39. What was the cost of treating this high-to-low speed transition?

    a. Initial cost of installation $ ______________________
    b. Change in annual maintenance cost $ ______________________

## PART 5: GENERAL IMPRESSIONS AND INFORMATION

40. Based on your experience what are the key elements of a successful rural high-to-low speed transition? (Enter "No opinion" if you do not have an opinion, or do not wish to answer this question.)

    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________

41. What research is needed concerning rural high-to-low speed transitions? [Enter "No opinion" if you do not have an opinion or do not wish to answer.]

    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________

42. Do you have any other comments concerning rural high-to-low speed transitions, including the names of other individuals or agencies who you may have additional information?

    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________
    ______________________________________________________________________

**END OF QUESTIONNAIRE.**

Thank you for your participation!

Please return the completed survey to:

**Gerry Forbes**
**Intus Road Safety Engineering Inc.**
**2606 Bluffs Way, RR 2**
**Milton, Ontario L9T 2X6**
**CANADA**

**E: gerry@intus.ca**
**F: 905.332.9777**

# APPENDIX B
## Survey Responses

### PART 1: CONTACT INFORMATION

Agencies that responded to the survey:

| STATES/PROVINCES | COUNTIES |
|---|---|
| ***United States Respondents*** | |
| Alabama Department of Transportation | Alameda County, CA |
| Arkansas State Highway and Transportation Department | Allegany County, MD |
| Arizona Department of Transportation | Benton County, WA |
| California Department of Transportation | Buchanan County, IA |
| Colorado Department of Transportation | Coconino County, AZ |
| Connecticut Department of Transportation | Decatur County, IA |
| Delaware Department of Transportation | Dubuque County, IA |
| Illinois Department of Transportation | Ford County, KS |
| Iowa Department of Transportation | Fresno County, CA |
| Hawaii Department of Transportation | Graham County, AZ |
| Kansas Department of Transportation | Hamilton County, OH |
| Kentucky Transportation Cabinet | Ionia County, MI |
| Louisiana Department of Transportation and Development | Johnson County, IA |
| Maine Department of Transportation | Kent County, MI |
| Maryland State Highway Administration | Lake County, OH |
| Massachusetts Department of Transportation | Linn County, IA |
| Minnesota Department of Transportation | Louisa County, IA |
| Mississippi Department of Transportation | Lucas County, OH |
| Missouri Department of Transportation | Marion County, IA |
| Nebraska Department of Roads | Montgomery County, IA |
| Nevada Department of Transportation | Polk County, OR |
| New Jersey Department of Transportation | Riverside County, CA |
| New York Department of Transportation | San Bernardino County, CA |
| North Carolina Department of Transportation | Solano County, CA |
| North Dakota Department of Transportation | Washington County, OR |
| Oklahoma Department of Transportation | Washtenaw County, MI |
| Oregon Department of Transportation | Yakima County, WA |
| Pennsylvania Department of Transportation | |
| South Carolina Department of Transportation | |
| South Dakota Department of Transportation | |
| Tennessee Department of Transportation | |
| Texas Department of Transportation | |
| Vermont Agency of Transportation | |
| West Virginia Department of Transportation | |
| Wisconsin Department of Transportation | |
| Wyoming Department of Transportation | |
| ***Canadian Respondents*** | |
| Manitoba Infrastructure and Transportation | |
| Nova Scotia Transportation and Infrastructure | |

*The reader is cautioned that the county responses include a disproportionate number of responses from California and Iowa counties, and the results may not be representative of the national state of the practice.

## PART 2: STANDARD APPROACH

Does your agency have a standard approach to treating rural high-to-low speed transitions in new construction or complete reconstruction?

| | State/Province Responses | | County Responses | |
|---|---|---|---|---|
| | *N* = 36 | | *N* = 27 | |
| | Number of Responses | Percentage | Number of Responses | Percentage |
| Yes, I can provide a URL (web address) with the details: | 1* | 3 | 0 | 0 |
| Yes, I will mail or e-mail the details | 3 | 8 | 2 | 7 |
| Yes, I can describe the approach | 11 | 31 | 7 | 26 |
| No, we do not have a standard approach | 19 | 53 | 18 | 67 |

*Reference provided to state *MUTCD* website.

You indicated that you have a standard approach to rural high-to-low speed transitions in new construction of these areas. Please provide a detailed description of the standard treatments.

Roadway (geometric) design:

- Typical roadway cross-section changes from rural to urban-type roadway
- Transition from rural to urban cross section
- Channelization through marking patterned islands; roundabouts
- IDOT Standard
- County uses AASHTO Geometric Design as a reference

Traffic control devices:

- Use W3-5a SPEED REDUCED AHEAD signs and post new speed per ADOT PGP 311. Usual practice is to drop speeds in 10 mph increments at transitions, but 10 mph drops are not required.
- Standard signing in accordance with *MUTCD*.
- W3-5, followed by upsized R2-1 (30x36). If speed reduction is greater than 10 mph will typically have 2/10 mile transition zone (i.e., 50-40-35-40-50). Will include a second W3-5 if the second reduction is 10 mph but optional for a 5 mph speed reduction. We would still provide upsized lead speed limit sign for the second speed drop.
- Speed limit signs
- Standard speed reduction signing and marking techniques; accentuated markings; HIBs
- Speed zones are established to be a transition zone between the high and low. Each speed zone has Reduced Speed Ahead Warning signs W3-5
- We use a black and white sign that says REDUCE SPEED followed by a line that shows a speed—say 30—and the last line shows a distance—say 750
- We use advance speed reduction signing unless the situation is such we need to further address safety concerns. We generally use "reduced speed ahead" warning signs to warn the driver of the speed reduction.
- Utilization of W3-5 or W3-5a signs in accordance with the state *MUTCD*.
- Reduce speed limits in increments (50 to 35 and then 35 to 25)
- State DOT Standard
- We place signs alerting traffic to the reduced speed and the community. This is typically done with cooperation from the community. "Reduced speed ahead" sign is placed per *MUTCD*. The speed limit is generally set and posted by the city. We post "Resume Speed" sign as you leave the

city as the speed limit returns to Iowa code prescribed speed. We post city name at corporation line with their speed limit in white on green destination sign.

- County uses the *MUTCD* as a reference
- Transition speed zones are posted
- "Reduced Speed Ahead" sign followed by a new posted speed limit sign
- Based on location by location review, we will establish transitional speed zones, at least 0.25 mile in length. We install Reduced Speed Zone Ahead signs (W3-5) and speed limits signs (R2-1)
- Reduce the speed in 10 mph increments
- Stepped-down speed limit in appropriate increments

Road surface treatments:

- Rumble strips (considering tactile and subtle noise surface treatment)
- No additional treatment unless there is an accident history.
- State standard
- None—we do typically select different surfacing for our projects from that selected by the city. A discerning motorist may pick up on this change.
- No standard treatment—occasionally at points of concern raised buttons are used to alert drivers.

Off road treatments:

- None—although many communities have placed city identification structures at major road entrances
- Marginally maintained and signed roads are labeled as Primitive Roads.
- Signage

Does your agency have a standard approach to treating rural high-to-low speed transitions in retrofit situations?

| | **State/Province Responses** | | **County Responses** | |
|---|---|---|---|---|
| | ***N* = 36** | | ***N* = 26** | |
| | **Number of Responses** | **Percentage** | **Number of Responses** | **Percentage** |
| Yes, I can provide a URL (web address) with the details: | 1* | 3 | 0 | 0 |
| Yes, I will mail or e-mail the details | 2 | 6 | 2 | 8 |
| Yes, I can describe the approach | 11 | 31 | 8 | 31 |
| No, we do not have a standard approach | 22 | 61 | 16 | 62 |

*Reference provided to state *MUTCD* website.

You indicated that you have a standard approach to rural high-to-low speed transitions in retrofits of these areas. Please provide a detailed description of the standard treatments.

Roadway (geometric) design

- Typical roadway cross-section changes from rural to urban-type roadway
- Transition from rural to urban cross section
- Ditto new
- *MUTCD* portable stop
- See previous page
- Same

Traffic control devices

- Use W3-5a SPEED REDUCED AHEAD signs and post new speed per ADOT PGP 311. Usual practice is to drop speeds in 10 mph increments at transitions, but 10 mph drops are not required.
- Standard signing in accordance with *MUTCD*
- W3-5 followed by upsized R2-1 (30x36). If speed reduction is greater than 10 mph will typically have 2/10 mile transition zone (i.e., 50-40-35-40-50). Will include a second W3-5 if the second reduction is 10 mph, but optional for a 5 mph speed reduction. We would still provide upsized lead speed limit sign for the second speed drop.
- Speed limit signs
- Ditto new
- Speed zones are established to be a transition zone between the high and low. Each speed zone has Reduced Speed Ahead Warning signs, W3-5
- Same as previous page
- Advance speed reduction signs.
- Utilization of W3-5 or W3-5a signs in accordance with the State *MUTCD*.
- Reduce speed in increments (50 to 35 and 35 to 25)
- Iowa *MUTCD* portable stop for pavement patching
- Same as new construction
- See previous page
- Same
- We have no standard policy established, but we are typically consistent with our responses, but they do vary by road classification. When the regulatory speed changes from high to low we either sign with a stepped-down speed zoning or with a warning sign for the upcoming lowered speed zone. When the reduction is from a high speed area to a low speed section of curves or to a stop control we use a variety of tools starting with standard signing and proceed with increasingly expensive measures. We start with supplementing the required signing. If problems continue after signs are installed we typically install a series of transverse rumble strips and if they are not sufficient we have in some places installed warning beacons on top of the warning signs. On local and neighborhood route roads we have used radar equipped signs for education. We currently have not permanently installed any of these but rotate them around to problem locations. We also use a radar trailer and non-standard educational signs both of which are temporarily used and rotated. At entrances to neighborhoods we have installed neighborhood identification signing above the street name sign but this is typically at stop controlled locations.
- Based on location by location review, we will establish transitional speed zones, at least 0.25 mile in length. We install Reduced Speed Zone Ahead signs (W3-5) and speed limits signs (R2-1)
- Reduce the speed limit in 10 mph increments
- Stepped-down speed limit in appropriate increments

Road surface treatments

- Ditto new
- None unless there is an accident history
- *MUTCD*
- See previous page
- Same
- We have no standard policy established but we are typically consistent with our responses. A series of transverse rumble strips are used if problems persist after signing is installed.

Off road treatments:

- State *MUTCD*
- See previous page
- Same

- We have no standard policy established but we are typically consistent with our responses. In instances where signing and rumble bars do not appear to alleviate crashes we have installed roadside delineators in low speed curves in high speed areas.
- Signage

Which of the following measures, if any, do you consider *inappropriate* for treating rural high-to-low speed transitions?

| | State/Province Responses (*N*=38) | | County Responses (*N*=28) | |
|---|---|---|---|---|
| | Number of Responses | Percentage | Number of Responses | Percentage |
| **Geometric Design** | | | | |
| Chicanes or increasing road curvature | 19 | 50 | 15 | 54 |
| Bulb-outs, neckdowns, chokers, road narrowings | 10 | 26 | 13 | 46 |
| Central islands/raised medians | 7 | 18 | 12 | 43 |
| Traffic circle | 18 | 47 | 12 | 43 |
| Roundabout | 6 | 16 | 3 | 11 |
| Road diet, reduction in the number of through lanes | 9 | 24 | 11 | 39 |
| Adding bicycle lanes | 16 | 42 | 7 | 25 |
| Adding sidewalks or pedestrian paths | 13 | 34 | 7 | 25 |
| None of the above | 7 | 18 | 3 | 11 |
| Other | 1 | 3 | 1 | 4 |
| **Surface Treatments** | | | | |
| Speed humps | 32 | 84 | 21 | 75 |
| Raised intersections or speed tables | 27 | 71 | 15 | 54 |
| Speed cushions or road studs | 27 | 71 | 15 | 54 |
| Pedestrians crosswalks | 24 | 63 | 13 | 46 |
| Transverse rumble strips | 8 | 21 | 3 | 11 |
| Centerline or shoulder rumble strips | 7 | 18 | 4 | 14 |
| Colored or textured pavement | 10 | 26 | 3 | 11 |
| None of the above | 1 | 3 | 2 | 7 |
| Other | 1 | 3 | 0 | 0 |
| **Traffic Control Devices** | | | | |
| Enhanced speed limit signs and/or markings | 1 | 3 | 0 | 0 |
| Add standard warning signs | 0 | 0 | 0 | 0 |
| Unique (non-*MUTCD*) traffic control signs | 24 | 63 | 14 | 50 |
| All-way stop control | 26 | 38 | 13 | 46 |
| Amber flashing beacons | 4 | 11 | 3 | 11 |
| Speed sensitive signals | 6 | 16 | 5 | 18 |
| Village information signs | 9 | 24 | 5 | 18 |
| Speed cameras | 15 | 39 | 10 | 36 |
| Speed trailers/radar message boards | 5 | 13 | 2 | 7 |
| Variable message signs other than speed trailers | 6 | 16 | 4 | 14 |
| Marked no-passing zones | 6 | 16 | 4 | 14 |
| Transverse pavement markings, chevrons, or dragon's teeth | 6 | 16 | 5 | 18 |

| | | | | |
|---|---|---|---|---|
| Removal of all pavement markings | 29 | 76 | 22 | 79 |
| Removal of most traffic signs | 29 | 76 | 21 | 75 |
| Transitional/stepped down speed limit | 1 | 3 | 0 | 0 |
| None of the above | 1 | 3 | 2 | 7 |
| Other | 2 | | 0 | 0 |
| **Roadside Features** | | | | |
| Gateway/entrance features | 6 | 16 | 7 | 25 |
| Landscaping changes | 3 | 8 | 0 | 0 |
| Street furniture | 9 | 24 | 9 | 32 |
| Introduce/alter street lighting | 5 | 13 | 2 | 7 |
| None of the above | 14 | 37 | 13 | 46 |
| Other | 0 | 0 | 0 | 0 |

Other Geometric Design:

- State—I do think many of options listed (such as bike lanes, sidewalks, etc.) should not be constructed just to slow down vehicles. They should be warranted on their own merits.
- County—No real experience utilizing these measures.

Other Road Surface:

- State—I think geometric options such as speed humps and raised intersections/speed tables are inappropriate if talking about transition from rural-high to urban-low speed

Other Traffic Control Devices:

- State—Some options (such as all-way stop, no-passing zone, etc.) should not be considered unless warranted on own merits.
- Speed cameras are not legal in our state; any unwarranted traffic controls, such as all way stops, should be avoided

Does you agency have any other documentation (i.e., policies, handbooks, manuals, guidelines, etc.) concerning rural high-to-low speed transitions?

| | State/Province Responses (*N*=36) | | County Responses (*N*=27) | |
|---|---|---|---|---|
| | **Number of Responses** | **Percentage** | **Number of Responses** | **Percentage** |
| Yes, I here is the URL (web address) | 2 | 6 | 0 | 0 |
| Yes, I will mail or e-mail the documentation | 3 | 8 | 1 | 4 |
| Yes, please contact me for details | 3 | 8 | 1 | 4 |
| No, there is no other documentation | 28 | 78 | 25 | 93 |

## PART 3: ENHANCED TREATMENTS

Which factors may influence a decision to implement enhanced rural high-to-low speed transition measures?

| | State/Province Responses (*N*=37) | | County Responses (*N*=28) | |
|---|---|---|---|---|
| | **Number of Responses** | **Percentage** | **Number of Responses** | **Percentage** |
| Significant drop in posted speed limit * | 25 | 68 | 11 | 39 |
| High operating speeds in the village | 20 | 54 | 9 | 32 |
| Poor crash record | 31 | 84 | 12 | 43 |

| | | | | |
|---|---|---|---|---|
| Functional classification of the road | 10 | 27 | 10 | 36 |
| Driveway/access density | 26 | 70 | 12 | 43 |
| Public opinion/concerns | 26 | 70 | 18 | 64 |
| Pedestrian/cyclist volumes | 16 | 43 | 12 | 43 |
| ADT | 11 | 30 | 15 | 54 |
| Minimum size of settlement | 2 | 5 | 4 | 14 |
| Other** | 0 | 0 | 3 | 11 |

*Significant speed drops specified were:

- State—Four states mentioned 10 mph, eight states mentioned 15 mph, eight states mentioned 20 mph, one state mentioned 30 mph, and one state mentioned greater than 30 mph.
- County—One county mentioned 5 mph, four counties mentioned 10 mph, four counties mentioned 15 mph, one county mentioned 20 mph, and one county mentioned 30 mph.

**Other:

- Presence of agricultural equipment
- We are very rural no money
- Some towns in the County do this.

If you indicated that minimum size of settlement is a factor in deciding when to implement enhanced high-to-low speed transition measures (Question 8), please describe what is meant by minimum size?

| | State/Province Responses (*N*=2) | | County Responses (*N*=4) | |
|---|---|---|---|---|
| | Number of Responses | Percentage | Number of Responses | Percentage |
| Population of settlement | 1 | 50 | 2 | 50 |
| Length of development fronting on the main street | 1 | 50 | 3 | 75 |
| Presence of certain amenities (i.e., school, church, local store, etc.) | 1 | 50 | 3 | 75 |
| Other | 0 | 0 | 0 | 0 |

Which of the following measures are not part of your standard approach and have been tried in any enhanced rural high-to-low speed transitions on your roads?

| | State/Province Responses (*N*=36) | | County Responses (*N*=28) | |
|---|---|---|---|---|
| | Number of Responses | Percentage | Number of Responses | Percentage |
| **Geometric Design** | | | | |
| Chicanes or increasing road curvature | 5 | 14 | 6 | 21 |
| Bulb-outs, neckdowns, chokers, road narrowings | 9 | 25 | 5 | 18 |
| Central islands/raised medians | 6 | 17 | 4 | 14 |
| Traffic circle | 4 | 11 | 5 | 18 |
| Roundabout | 7 | 19 | 5 | 18 |
| Road diet, reduction in the number of through lanes | 6 | 17 | 4 | 14 |
| Adding bicycle lanes | 6 | 17 | 6 | 21 |
| Adding sidewalks or pedestrian paths | 6 | 17 | 5 | 18 |
| None of the above | 15 | 42 | 14 | 50 |
| Other | 0 | 0 | 0 | 0 |
| **Surface Treatments** | | | | |

| | | | | |
|---|---|---|---|---|
| Speed humps | 8 | 22 | 6 | 21 |
| Raised intersections or speed tables | 5 | 14 | 5 | 18 |
| Speed cushions or road studs | 7 | 19 | 6 | 21 |
| Pedestrians crosswalks | 4 | 11 | 5 | 18 |
| Transverse rumble strips | 9 | 25 | 7 | 25 |
| Centerline or shoulder rumble strips | 4 | 11 | 2 | 7 |
| Colored or textured pavement | 4 | 11 | 4 | 14 |
| None of the above | 15 | 42 | 11 | 39 |
| Other | 1 | 3 | 0 | 0 |
| **Traffic Control Devices** | | | | |
| Enhanced speed limit signs and/or markings | 9 | 25 | 10 | 35 |
| Add standard warning signs | 8 | 22 | 7 | 26 |
| Unique (non-*MUTCD*) traffic control signs | 5 | 14 | 6 | 21 |
| All-way stop control | 6 | 17 | 6 | 21 |
| Amber flashing beacons | 15 | 42 | 4 | 14 |
| Speed sensitive signals | 4 | 11 | 3 | 11 |
| Village information signs | 3 | 8 | 5 | 18 |
| Speed cameras | 7 | 19 | 4 | 14 |
| Speed trailers/radar message boards | 15 | 42 | 8 | 29 |
| Variable message signs other than speed trailers | 8 | 22 | 4 | 14 |
| Marked no-passing zones | 4 | 11 | 3 | 11 |
| Transverse pavement markings, chevrons, or dragon's teeth | 6 | 17 | 2 | 7 |
| Removal of all pavement markings | 5 | 14 | 6 | 21 |
| Removal of most traffic signs | 5 | 14 | 5 | 18 |
| Transitional/stepped down speed limit | 10 | 28 | 5 | 18 |
| None of the above | 6 | 17 | 4 | 14 |
| Other | 2 | 6 | 1 | 4 |
| **Roadside Features** | | | | |
| Gateway/entrance features | 9 | 25 | 6 | 21 |
| Landscaping changes | 8 | 22 | 3 | 11 |
| Street furniture | 5 | 14 | 6 | 21 |
| Introduce/alter street lighting | 5 | 14 | 4 | 14 |
| None of the above | 18 | 50 | 17 | 61 |
| Other | 0 | 0 | 0 | 0 |

Other Road Surface:

- Centerline rumble stripes.

Other Traffic Control Devices:

- Driver Feedback Signs (Your Speed Is signs)
- Colored pavement markings.

## PART 4: CASE STUDIES

Are the details of the transition treatment documented and available to the research team?

| | *N* = 2 | |
|---|---|---|
| | Number of Responses | Percentage |
| Yes, I can provide a URL (web address) with the details: | 0 | 0 |
| Yes, I will mail or e-mail the details | 1 (Kansas) | 50 |
| Yes, I but I will describe the approach now | 0 | 0 |
| No, there is no documentation | 1 (Iowa) | 50 |

The Iowa case study was described as follows:

- An undivided, two-lane facility with a 55 mph speed limit, transitions to an undivided two-lane and four-lane facility with a 30 mph speed limit. A stepped down speed limit of 45 and 35 mph was the traditional treatment. The DOT implemented a speed display trailer as a speed management measure in the transition zone. Evaluations were not undertaken.

The Kansas case study referred to a report titled "Mitigating Crashes at High-Risk Rural Intersections with Two-Way Stop Control" [Russell and Godavarthy (2010)], which is described in detail in the Literature Review section of this NCHRP Synthesis report.

## PART 5: GENERAL IMPRESSIONS AND INFORMATION

Based on your experience what are the key elements of a successful rural high-to-low speed transition?

State/Province Responses:

- Adequate signing
- Consistent approach that is easily understood and recognized by the motorists.
- The motorist must feel the natural inclination to slow down. The appearance of "Changed Conditions" must be prevalent to get compliance.
- A visible change in environment
- The roadway context has to be carefully considered during the design stage and the principals of context sensitive solutions have to be applied.
- Land use; change in the roadway cross-section
- That the roadway looks and feels different then the higher speed roadway. There needs to be significantly more development, more driveways and more traffic.
- Using a device that catches driver's attention
- Get drivers attention
- Getting drivers' attention, get drivers to recognize changed area, altering driver behavior
- Getting driver attention and compliance to traffic control devices
- Enhanced step-down signing
- The geometrics have to physically slow down the traffic speeds. Signs, colored pavement and other things may be used, but they are only perceptual and don't have a lasting effect.
- Treatments that give the driver a sense that the road is getting narrow and the urge to slow down. Neck downs, raised median islands and bike lanes are examples that seem to have worked.

- The highway design and traffic control measures have to work together to present subconscious message to the driver that a speed adjustment is required.
- Giving adequate warning to motorists and other highway users.
- Informing drivers, step down speeds, and larger signs
- Posted speed limits need to be reasonable and close to the 85th percentile speed limit. Design speed of highway should approximate expected operating speed.
- Reduced operating speeds, fewer motor vehicle crashes, pedestrian crashes, and /or bicycle/vehicle crashes.
- 1. Locals must accept the treatment and believe it provides them benefits (slows drivers, improves the image of their community, makes it safer, etc.).
  2. Safety of the roadway must not be negatively impacted.
  3. Cost needs to be reasonable.
  4. Motorists must feel the treatment is reasonable.
  5. Day to day and long term maintenance of the device/system must be reasonable.
  6. Finally, the actual ability of the system to reduce the speed of approaching drivers...this one may be the least important one of all the key elements.
- While we don't have a policy to deliberately enhance the hi-lo transition, my opinion is the following elements should be successful: roadway width, sidewalks, bike lanes, parking, roadside character, speed-feedback signs with photo enforcement. However, photo enforcement is unlikely in most of the "cowboy" rural areas of the U.S. Too many conservative paranoiacs brainwashed by to the anti-government rhetoric of the corporate-sponsored talk shows.
- Adequate signage and/or warning, voluntary conformance to the appropriate speed based on the roadway environment (with a speed limit based on the driving environment, i.e., not a blanket statutory speed limit for an urban area)
- Gradual reduction in speed and adequate visibility to changes.
- Roadway geometric features are an important part of any speed transition - if the features do not indicate that there is a drop in speed, drivers will drive at the speed they feel is most comfortable given the circumstances. Roadway features can vary from shoulder to curb and gutter to change in access to land use, etc.
- The transition has to be visible and the reason has to be apparent and understandable to drivers.
- Consistent law enforcement and use of W3-5 signs

County Responses:

- Accident data, terrain/physical features, speed data
- Speed study to determine if the speed transition is justified, or if the speed limit should be raised
- Change in roadside features, coupled with clear change in adjacent land use are the key elements that inform motorists a lower speed is appropriate.
- Provide adequate information to the driver
- Force actions from the driver, they do not want to slow down.
- Respect from motorists
- Presence of side friction naturally causes reduced speed. Drivers reduce speed when presented with what appears to be a more complex set of driving conditions. This typically happens in cities with their lower speed limits and numerous entry points. Slowing traffic in advance of the community to assure that traffic is slowed before reaching the residential area is ineffective.
- *MUTCD* compliance, public input, enforcement
- Reasonable speeds in low speed areas.
- Long term effectiveness with familiar drivers.
- Clear message to drivers that they are entering a populated area. On occasion follow up with law enforcement and radar message boards.
- *MUTCD*
- Enforcement is a key element in any effective speed reduction.
- I believe it depends on the ADT. Higher #s seem harder to calm driver habits.
- Education and enforcement

- Signing
- Need some enforcement to be effective

What research is needed concerning rural high-to-low speed transitions?

State/Province Responses:

- Effectiveness of other measures such as message signs.
- Best practices
- We are interested in research on this topic
- Research projects need to be set up carefully so that results are valid.
- What does the driver need to see to make a decision to slow down?
- Collect field data
- Measured reactions to combinations of tools
- Effects of pavement texture, effects of other treatments
- Evaluation on traffic control versus road surface conditions
- It is hard to get before/after studies where only one treatment has been added and thus get a true measure of effectiveness. This would be a big help.
- Case studies
- I believe any research on the most effective low-cost solutions is very good information.
- Speed studies related to specific methods used for speed transitions
- What roadway features/design elements actually influence prevailing speeds
- We need to find out what ideas and concepts are out there. Then the concepts can be prioritized and then actual research can be conducted on how effective the systems are (from a speed reduction standpoint) and on the items listed in question 40 above (local perception, safety, etc.)
- What are the elements that are most effective? Try some easy ones, like speed-feedback signs or rumble strips (though I'm not a fan of those)
- Is there an actual safety issue at these locations or is it just a perception. In general our experiences indicate that there is not a substantial crash problem in these transition zones unless there is a traffic signal and high volumes.
- More research on geometric features would be helpful.
- Test a variety of elements.

County Responses:

- Need to concentrate on low cost/economical alternatives; most methods used today are very costly
- Data or studies to inform practitioners the measures that are effective or proven for the subject application.
- Speed tables
- The influence of speed reduction measures on speed and crashes. Much of the signing used to reduce speed entering a community may have nothing to do with the driver reducing speed. The driver may reduce speed based upon perception of the complexity of the environment and not based upon adherence to speed limit signs.
- ADT, current speeds, roadway geometrics, accident history, complaints
- When is low speed too low and results in irritation instead of compliance. Transitions in speed made too far in advance creating the same scenario. Does compliance improve with shorten transition lengths?
- Tool box of measures and applications.
- Accident rates when speed bump/humps are used vs. other practices.
- Traffic studies, DOT's and Law Enforcement

Do you have any other comments concerning rural high-to-low speed transitions, including the names of other individuals or agencies who you may have additional information?

State/Province Responses:

- As I remind many that call and want speed limits lowered, the signs alone will not get a driver to slow down. They slow down if they feel a need to, not because the sign tells them to.
- We do not have a standard approach because we feel every situation is a little different.
- The public is always wanting speed limits lower than what a driver is willing to drive. There is a lack of enforcement.
- I am sorry that I can't provide more information. Our Highway Design Manual would probably be a good source for the information you seek regarding standards.
- Our projects are designed and evaluated in 12 District Offices throughout California. These offices are more familiar with measures implemented outside of the standard approach.
- This condition is becoming increasingly rare as our roadways are transformed from rural to urban by development of abutting lands.
- In Oklahoma, state statutes limit the reduction in speed to 10MPH increments between successive speed zones which causes speed reduction problems in rural areas.
- I would like to see research done on special landscaping and other roadway treatments that make the driver naturally feel like they need to slow down....rather than some "thing" that forces them to slow down. Some concepts may be negatively viewed by jurisdictions because of how snow, in particular blowing snow, is affected by the proposals.
- Just that mere speed limit signs do not work alone. The driver must perceive a reason to slow down—and that comes more from the character of the road than by signs.
- Connecticut adapts the specific design details to each site specific location. There are too many variables in our developed area to use the same "standard" approach for each project. Physical bumps in the pavement are not sufficiently visible and are too apt to surprise the driver. We anticipate that this type of use could create more problems than they solve. In general, we have found that any special treatment which is inserted into a project for speed reduction only has an effect for a short distance beyond the treatment. We have also found that speed reduction only has an effect for the noted short distance for a relatively short period of time until drivers get used to the treatment and it loses its intended effect.

County Responses:

- Usually we have found that the lower speed is unreasonable for conditions
- While the focus of this research is on infrastructure-based/engineering measures, enforcement to a large extent is a critical element that will make rural high-to-low speed transition work.
- Rural portable speed bumps
- Reducing speed limits because residents perceive that this results in lower travel speed may cause a false sense of security. Setting speed limits arbitrarily as many communities do to please residents may work to reduce adherence.
- In Michigan speed limits are set by the State Police and they are very strict in using the 85th percentile making transitions difficult.
- Radar message boards in conjunction with speed zone transitions have worked best for us.
- Personally, we have an understaffed CHP force in Calif. Enforcing the affected speed reduction areas and making the public aware we mean business and need a reduction to secure the safety throughout this area

Abbreviations used without definition in TRB Publications:

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|---|---|
| AAAE | American Association of Airport Executives |
| AASHO | American Association of State Highway Officials |
| AASHTO | American Association of State Highway and Transportation Officials |
| ACI–NA | Airports Council International–North America |
| ACRP | Airport Cooperative Research Program |
| ADA | Americans with Disabilities Act |
| APTA | American Public Transportation Association |
| ASCE | American Society of Civil Engineers |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| ATA | Air Transport Association |
| ATA | American Trucking Associations |
| CTAA | Community Transportation Association of America |
| CTBSSP | Commercial Truck and Bus Safety Synthesis Program |
| DHS | Department of Homeland Security |
| DOE | Department of Energy |
| EPA | Environmental Protection Agency |
| FAA | Federal Aviation Administration |
| FHWA | Federal Highway Administration |
| FMCSA | Federal Motor Carrier Safety Administration |
| FRA | Federal Railroad Administration |
| FTA | Federal Transit Administration |
| IEEE | Institute of Electrical and Electronics Engineers |
| ISTEA | Intermodal Surface Transportation Efficiency Act of 1991 |
| ITE | Institute of Transportation Engineers |
| NASA | National Aeronautics and Space Administration |
| NASAO | National Association of State Aviation Officials |
| NCFRP | National Cooperative Freight Research Program |
| NCHRP | National Cooperative Highway Research Program |
| NHTSA | National Highway Traffic Safety Administration |
| NTSB | National Transportation Safety Board |
| SAE | Society of Automotive Engineers |
| SAFETY-LU | Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005) |
| TCRP | Transit Cooperative Research Program |
| TEA-21 | Transportation Equity Act for the 21st Century (1998) |
| TRB | Transportation Research Board |
| TSA | Transportation Security Administration |
| U.S.DOT | United States Department of Transportation |

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