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TRAFFIC CALMING

Contents

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Traffic Calming

Safety on roads has become a major concern. Mobility is drawing a heavy toll in terms of loss of life and limbs. It is an unacceptably high price to pay. There are several dimensions to the problem. Hitherto, the attempt has been to control the speed of the vehicular traffic. The concept of traffic calming takes cognizance of other aspects as well. It, thus, helps to create a safe environment for road users. The benefits to the society are immense.

This issue of the journal presents articles from leading practitioners around the world, summarising the experiences with traffic-calming techniques in different geographical and socio-economic environments. Ralf Risser makes a strong case for introducing traffic-calming techniques in order to provide multiple functions that often roads are expected to serve in urban areas. This has a direct bearing on the quality of life of all urban residents. P van Vliet and G Schermers present a summary of the efforts going on in the Netherlands to achieve sustainable safety. The principles outlined by the sustainable safety approach have since become the basis for the design and layout of Dutch road infrastructure. However, sustainable safety means more than that. It is an integrated approach and includes aspects related to the human, vehicles, land use planning, and mobility. Traffic-calming techniques play a central role in achieving sustainable safety in the Netherlands.

Dinesh Mohan summarises the relationship between speed and injuries and highlights the need to manage speed in urban and rural areas by design. In the Poland case study, Lidia Zakowska lays emphasis on another aspect of traffic-calming techniques – the road signage. This study evaluates the scope of the problem by comparing sign comprehension of different driver groups in Poland, using signs from four countries, one each from four continents. The study demonstrates the urgent need for greater uniformity in highway sign design among countries, and greater emphasis on ergonomic principles in the design of new signs and redesigning of existing signs.

Tom Opiyo presents a summary of implementing traffic-calming techniques in East African cities. The similarity of issues between Indian case studies and African cities is striking. Both emphasise the complexity of safety issues on intercity highways, which cannot be made limited access as in the West; hence, the need to calm down motorised traffic. D P Gupta presents the research digest on traffic calming. This is based on international literature and understanding gained from the Indian experiments in the field of traffic calming. Michael King has compiled efforts going on in the US to institutionalise traffic-calming techniques. Some states in the US are in the process of preparing design manuals that can be used by the local engineer at the time of construction or improvement projects.

Thus, the articles contained in this volume cover different aspects of traffic-calming techniques. This compilation has been done with the object of sharing experiences from different settings with practitioners and policymakers. We hope this issue would generate further interest in concept of sustainable road safety and the measures to achieve it.

Geetam Tiwari
Guest Editor

PHILOSOPHY OF TRAFFIC CALMING

Ralf Risser*

In the densely inhabited areas of industrial countries, many functions that urban areas are supposed to perform are impeded by fast-moving motor-vehicle traffic. In the cities of the developing countries, on the other hand, there is generally 'a severe crisis with respect to the conditions of transport of persons. In spite of all attempts made, these conditions remain unsatisfactory for the majority, especially for those who have no access to private transport: The large cities in the developing countries provide a very low level of service of public transport, an unequal distribution of accessibility, elevated traffic accident rates (mainly involving the most vulnerable road users like pedestrians and cyclists), queues, environmental pollution, and intrusion into the residential space and the living areas by inappropriate traffic' (ICTCT, 2000). This requires the laying of a better infrastructure for pedestrians and cyclists travelling long distances, apart from creating conditions for cheap and affordable public transport. It also calls for greater control of motor-vehicle traffic, i.e. for measures that in the widest sense will constitute traffic-calming measures.

At the ICTCT workshop in India, it was reported that residents in several Indian towns and villages had put up humps on bigger roads without securing the approval of the concerned authorities and without any help from experts. This was because there had been too many road casualties, the victims being mainly children. One of the objectives of the workshop was to generate ideas on helping the residents of towns and villages. Some of the recommendations that arose out of the discussions at the workshop would clearly be effective. Indeed, they form part of a broader discussion dealing with the question as to how motor-vehicle traffic could and should be calmed in order to improve interactions between cars and road users, which are probably the most common and at the same time most dangerous in densely inhabited areas.

WHY TRAFFIC CALMING?

This section offers explanations as to why traffic-calming measures are called for. In densely inhabited areas – whether in villages, towns, or cities – roads

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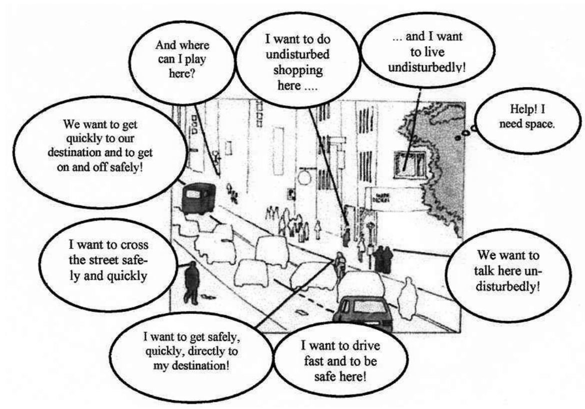
and the adjoining public space are required to perform more functions than just provide mobility. Figure 1 shows these functions. As would be seen, the mix of travel modes causes conflicts of interests. Because of different speeds of different types of modes, one road user may consider others as obstacles (see Figure 1). An important aspect is that car traffic impairs or disturbs all other functions reflected in the figure. Vehicle speed puts other road users to danger and makes road use difficult for pedestrians and cyclists, apart from causing general discomfort, air and noise pollution, and so on.

Nicole Muhlrad, in her contribution to the New Delhi workshop mentioned above demonstrated with examples that car traffic caused problems for other road users. The reason for this is that, for long, road plans were biased in favour of the car, neglecting many other facilities that need to be provided in densely inhabited areas.

Figure 1: Functions of the Road Space



Source: www.vsm.bv.tum.de/vsm/lehre/uebungen_gf/ue_vb/folie10.html, Website of the Technical University of Munich, German text translated into English by Ralf Risser.

On the website of the Technical University of Munich, from which the above figure has been taken, following concrete goals of traffic calming are shown with the help of digital photographs:

– Car speed should be reduced;
– Through-traffic should be reduced;
– Noise and air pollution should be less;
– There should be fewer parked cars in the streets;
– The portion of sealed areas should not be increased or reduced;
– More space should be given to pedestrians and cyclists;
– There should be more shopping complexes; and
– There should be more greenery.

In view of the above, one could say that traffic-calming activities were ‘invented’ in densely inhabited areas. What was to be calmed was not traffic generally, but motor-vehicle traffic. The reason for this was that motor-vehicle traffic was more and more felt to be disturbing the other functions that roads in urban areas are required to fulfil.

In order to perform these other functions, the speed of motor vehicles has to be reduced, smooth driving has to be practised, and, to some extent, walking and cycling, along with public transport need to replace journeys by motor vehicles. Data from Europe suggest this is possible. According to a study done in the frame of the EU-project WALCYNG (Hydèn, *et al*, 1997), 50 per cent of all trips in Europe are shorter than 5 km (requiring 10-15 minutes by bike), and 15-20 per cent are shorter than 1 km (requiring 10-15 minutes on foot). From this perspective, the outcome of traffic-calming measures could be even an increase in the total traffic. However, they are to be based on transportation modes more efficient than cars, causing less air and noise pollution and posing less danger for other road users like the pedestrians and cyclists.

Relationship between traffic calming and the quality of life

Less noise and pollution are in many cases achieved through traffic-calming measures, which non-motorised road users and residents appreciate the most (Risser and Wunsch, 2003). Moreover, such measures can lead to different uses of road space. Car drivers concur that after traffic calming roads become aesthetically more attractive than before (see Falk, *et al,* 2003). All the variables mentioned are related to life quality (Ausserer and Risser, 2003). Thus, traffic calming improves life quality, in spite of certain handicaps for car drivers.

What is life quality? It is a concept that contains many subjective elements. A focused study by Hakamies-Blomqvist and Jutila (1996) gave the following results: When people assess their living conditions in relation to traffic preconditions, they consider, among other things, social values (contacts, relationships, transactions), health, comfortable walks, protection against adverse weather, safety preconditions (reflecting most of all the feeling of safety), mobility, and aesthetics. In the following, these aspects, which are intimately related to any assessment of life quality, are discussed vis-à-vis traffic-calming measures.

Social values: One problem, consciously or unconsciously experienced by non-motorised road users and residents, is the low status of these traffic modes, especially in comparison to the car which symbolises such concepts as power, prestige, freedom, and status. Traffic calming officially lays more emphasis on walking and cycling. Furthermore, the nature of interaction between different road users influences the feelings of self-assuredness. Traffic calming produces fairer preconditions for interaction. Also, the feeling of safety is largely affected by the nature of this interaction.

Health: Walking and cycling are good for health. Calculations made by the Finland ministry of transport and communications demonstrated that if cycling in Finland were to double in terms of time and length, the savings in health costs and road upkeep would outweigh the costs on account of accident treatment. As compared to the gains the problems are minor and are mostly related to adverse health effects of polluted air or noise.

Road facilities: Benches, bins, finger-posts, shelters, public toilets, cafès, kiosks and restaurants, etc. are essential on roads. Bad pavement conditions affect non-motorised road users. Bad road surface adds to discomfort.

Safety: Cycles and cars should be segregated and made to run on different tracks. Also, there is need for better lighting as poor road illumination leads to security problems, especially for women.

Mobility: Non-motorised road users face two problems in the main which need to be addressed: one is narrow pavements or no pavements at all, and the other is difficulties in crossing roads where there is heavy traffic. In addition, smooth road surface and better markings on roads are required. Also, it would be a great improvement if traffic lights controlled the movements of motorised and non-motorised vehicles by apportioning time for them on a more scientific basis.

Aesthetics: This may not be an issue with car drivers and car passengers who find little time to observe beauty, but pedestrians and cyclists get closely related to the environment.

Conflicting interests of different road-user groups

Here, I do not want to discuss extensively why car drivers are 'against' traffic calming. It can, however, be assumed that the main problem for car drivers is one of frustration – the car gives them the chance to go fast, but traffic-calming measures deprive them of that opportunity. According to the theory of frustration and aggression (Dollard, *et al,* 1939), such frustration leads to aggression.

In connection with a larger road in the Swedish town of Eskilstuna that was redesigned and calmed, it was brought out that arterial roads could be changed to have a more friendly character. Their function as a barrier for all road users who want to cross such roads can be reduced, their aesthetic features can be improved, etc., without the car drivers really getting aggressive or frustrated. Falk, *et al* showed that the assessment of a calmed arterial road was somewhat more negative than that of others, but not totally negative. Quite a large proportion of car drivers feel that there are advantages of such a measure; the most important dimension in this respect is aesthetics.

In order to find out what people like or dislike, one has to apply appropriate methods –interviews, surveys, systematic observations, case studies, best-practice catalogues, etc. There can be conflicts between individual and society, individual and individual, and even within the individual himself. These conflicts have to be studied while discussing traffic-calming measures.

Marketing approach

The marketing approach comprises product policy and communication policy.

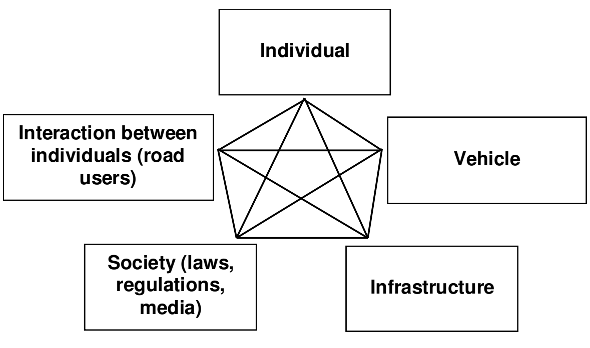
Product policy: 'Product policy' refers to societal, legal and physical features of a product –for example, the preconditions for road use. This is often called the product sector. When implementing traffic-calming measures, one has to think of adequate sites – places where there are noise problems, where implementation is easiest, where many road users can see and experience the 'product', i.e. the new measure.

Communication policy: This part of marketing is related to arguments and dialectics, i.e. addressing conflicts.

HOW CAN TRAFFIC BE CALMED?

In principle, this can be done in different sectors of the total traffic system. Figure 2, where five different sectors are displayed, reflects this.

Figure 2: The traffic system (the 'diamond')



All these sectors influence human behaviour. Many traffic experts give importance to individual features and communication between individuals by arguing that 'traffic calming begins in the minds of people.' In their evaluation, planners and road users should see more clearly the advantages that traffic calming has for society, and thus in the long run for themselves.

Speed and strength influence a car driver's behaviour. A famous study in Germany in the beginning of the 1990s demonstrated that the stronger and faster the cars were, the greater was the frequency of accidents. This refers especially to severe accidents (Arand, *et al,* 1992; OECD, 1990). Göran Nilsson showed the following relationship between speed and accidents.

Exponential model by G Nilsson

(v_1/v_2) *number of accidents*

$(v_1/v_2)^2 \longrightarrow$ *number of injured road users*

$(v_1/v_2)^3 \longrightarrow$ *number of severely injured road users*

$(v_1/v_2)^4 \longrightarrow$ *number of killed road users*

The above model reflects the empirical relationship between average speed and accidents. A change in real average speed where v_1 is the original average speed and v_2 is the new average speed is followed by a proportional change in the number of accidents; the number of injured road users changes by the square of the ratio v_1/v_2, and so on.

An Australian study (Kloeden, *et al*) showed results that supported such a strong relationship between speed- and alcohol-related accidents (see Table 1).

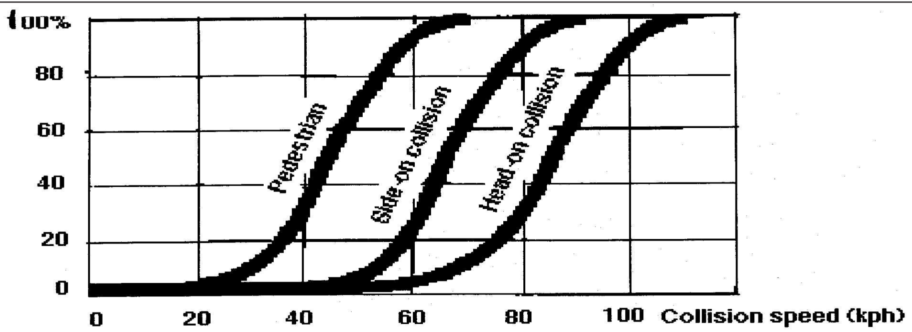
However, the findings of Gunnarsson show clearly that a speed upwards of 30 km per hour sharply increases the chance of fatal accidents (Fig. 3).

Table 1: Speed- and alcohol-related accidents

Speed (km/h)	Speed Rel. Risk	Alcohol (g/100ml)	Alcohol Rel. Risk
60	1.0	Zero	1.0
65	2.0	0.05	1.8
70	4.2	0.08	3.2
75	10.6	0.12	7.1
80	31.8	0.21	30.4

In some countries, Intelligent Speed Adaptation (ISA) projects have been started (Varhelyi, 2002). ISA refers to systems where an electronic map in a car

Figure 3: Relation between speed and fatal accident probability



is connected to a GPS. With the help of this communication, the car knows all along what the speed limit is. Different types of mechanisms can then give feedback to the driver: warnings leading to voluntary reactions by the driver via the optical, acoustic or haptic channel; or more active influence for example with the help of a so-called active gas pedal that produces increasing resistance against being pressed when the speed-limit is reached. Theoretically, ISA-like mechanisms can be adapted in a very detailed way so that speed can be kept even lower in the vicinity of schools, hospitals, etc.

Last but not the least, infrastructure-based measures may be mentioned which can efficiently be installed at critical sites. When we talk of traffic calming, infrastructure measures are usually the ones we think of first.

TRAFFIC CALMING IMPROVES LIFE QUALITY AND SAFETY

Though there is no decisive proof that traffic calming improves life quality, the available results, data and arguments lead to this conclusion. Some results from the Swedish towns of Lund and Malmö, where traffic-calming measures were introduced, may be recounted here.

Safety is considered an important factor contributing to life quality (Risser, *et al,* 2003). In Malmö, two roads have been compared with reference to this criterion (see Table 2). Möllevångsvägen is an urban road where many traffic-calming measures have been implemented, whereas Rådmansgatan has a more 'conventional' layout. Moreover, all the 30-km-per-hour sections have been taken together (most of them are on Möllevångsvägen), and compared to the

Table 2: Indexes for subjective risk for different groups in Malm

Assessment of risk	D*O	Total	V30	V50	MÖLLEV	RADMAN	S in
3,7	v4*5_1	11,8	9,7	12,6	10,1	13,6	c.d. do n good tim
3,8	v4*5_2	11,4	11,5	11,9	11,0	12,3	They driv
3,8	v4*5_3	12,5	12,2	12,7	11,8	12,9	They driv
4,4	v4*5_4	14,5	15,0	14,8	13,5	15,6	Too fast
4,2	v4*5_5	14,7	12,1	15,2	13,4	15,4	They do pedestria
4,0	v4*5_6	13,6	12,1	14,0	12,2	14,6	They try
3,7	v4*5_7	11,5	10,9	11,9	10,8	12,5	Turn left pedestria
3,7	v4*5_8	13,0	12,0	13,4	11,0	15,0	Neglect
4,4	v4*5_9	14,1	12,1	14,7	12,2	15,8	They are
4,0		13,0	12,0	13,5	11,8	14,2	Average

50-km-per-hour sections. The data were collected verbally. Residents and road users (randomly chosen for road-side interviews) were asked in the first round about the nature of their interactions with car drivers. The replies were then put in standardised questionnaires. The levels of danger (D) and the frequencies at which such occurrences (O) took place were assessed on a five-grade scale. And the product of the two (D*O) should, according to our hypothesis, reflect what affects people's perceived safety concerns. In order to compare different groups of people in Malmö, we decided to use the average severity assessment (D) of the total sample and to look separately only at the frequency assessments of different groups.

A significance test (non-parametric: Man-Whitney U-test) showed that the index D*O is significantly higher on Rådmansgatan than on Möllevångsvägen. It is also significantly higher in 50-km-per-hour areas than in 30-km-per-hour areas.

In other words, according to this analysis, subjective safety is lower on Rådmansgatan than on Möllevångsvägen. The perceptions are that car drivers do not slow down in good time, that they drive past too fast and too near, that they do not stop at pedestrian crossings, that they try to be ahead (i.e. to pass before the vulnerable road users can cross), that they neglect the speed limit, and that they are ruthless.

In 30-km-per-hour areas, the situation is significantly better than in 50-km-per-hour areas. It can be concluded that life quality is better there.

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INSTITUTIONALISING TRAFFIC CALMING IN THE UNITED STATES

Michael King, et al*

Three (of the 50) states in the United States have been or are in the process of incorporating traffic-calming (TC) design standards within their statewide design manuals: Delaware, Vermont, and New Jersey. We look at these efforts to see how they are proceeding. One state, Oregon, is seen as progressive in transportation circles, but has so far not adopted a formal traffic-calming policy. We look at this tactic to explore how a jurisdiction might obtain some goals of traffic calming informally.

Evidence of the institutionalisation of traffic calming (or any subject) can be found when it is incorporated into the 'manual'. Many states have had traffic-calming precepts and policies in planning documents for a number of years. These usually involve 'tool boxes' and 'where-when' charts to help guide the decision-making process. Yet these are generally not prescriptive. At the end of the day, the engineer decides how the roadway will be built, and if a particular TC device is not in the design manual as a state standard, it will not be on the road. This is especially true for small-town or consulting engineers who rely on state manuals for guidance.

I. DELAWARE DEPARTMENT OF TRANSPORTATION (DelDOT)

Delaware was the first state in the country to adopt traffic-calming standards as part of its state roadway design manual. This effort began in 1999 with the hiring of Rummel, Klepper and Kahl and Dr Reid Ewing as the principal author. The manual was completed in 2001 and may be downloaded from *http://www.deldot.net/static/publications_forms.html*

Delaware is one of the smallest states and most of its streets are under state jurisdiction. This is unusual in the United States where most streets are under local control. The state legislators are intimately involved in every aspect of their respective communities. It was, therefore, recognised that legislative support was

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* *The article has been compiled and edited by Michael King, Principal Traffic Calmer, Brooklyn, New York. Each individual section of the article has been prepared by a different author – (i) Michael Somers: Delaware Section; (ii)James W. Ford: Vermont Section; (iii) William Feldman: New Jersey Section; (iv) Michael Ronkin: Oregon Section; (v) Georges Jacquemart: Route 30 Section; (vi) Andrew Wisdom: Downtown Brooklyn Section.*

necessary for the successful implementation of any statewide programme. Also, DelDOT wanted to involve representatives of the various community elements that would have a vested interest. In order to do this, the manual was developed with inputs from the state and city politicians, business and community representatives, and the media. From this diverse pool of talent, a working group was formed to help identify issues, concerns and conditions unique to the state. This working group was a valuable resource and partner throughout the process.

After meetings with the working group and discussions with the agency, the consultants produced the basic elements that would be covered in the policy manual. These elements include the following:

- A discussion of the purpose of the manual;
- A summary of the manual's relationship to the statewide Long Range;
- Transportation plan;
- An explanation of the applicability of the manual;
- The manual's relationship to other departmental initiatives;
- The steps that the communities, the Department, and the legislators must take to have a project nominated, approved, developed, funded and constructed;
- The priority rating system that is intended to rank projects for funding and project development purposes.

The consultants helped the agency select measures most appropriate in the Delaware context (the 'Toolbox') and provided inputs on the impacts and applicability of the various measures. The remaining portion of the manual included explanations of the various available measures and associated geometric designs, with the final section having to do with support references, signing and marking applications. [Note that signs and markings generally must meet federal standards, as codified in the Manual for Urban Traffic Control Devices (MUTCD). Signages for some traffic-calming devices (speed humps, roundabouts) are included in the 2000 version of the manual, see *http://mutcd.fhwa.dot.gov/*.]

A primary focus of the DelDOT traffic-calming programme is the process by which the projects are implemented. In the initial phases, this was envisioned as a fairly extensive programme, but budgets being what they are, the process has been trimmed. Also, the nature of the projects has been different than originally anticipated. The steps currently undertaken are outlined below.

- All requests come to the Department via one or more legislators from the study area.
- Speed and volume data are collected, and assessments are made regarding the severity of the problem reported.

- Assuming the data show a significant problem, the programme manager meets the community to establish a working group.
- The agency presents a series of options to the working group which then accepts or rejects them. The working group can also offer its own (feasible) options.
- The options are reworked and the working group makes a final selection.
- After the working group makes its recommendations, the plan is finalised and presented to the community at a workshop.
- Shortly after the workshop, ballots are distributed to the residents in the affected area. (Petitions may be used, but ballots have proved to be more successful).
- If the plan is supported by two-thirds of the returned ballots, the plan passes.

Figure I.1: Original chicane design sketch (Delaware)

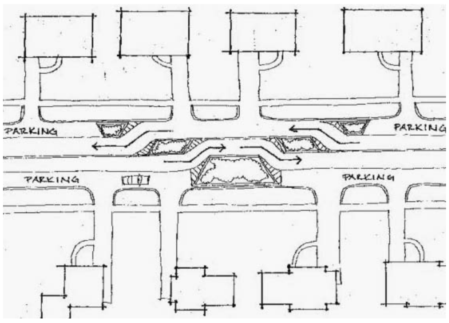


Figure I.2: Before condition (Delaware)

Figure I.3: After condition, photo montage (Delaware)

If the plan is minor in scope (no right of way, no major construction), it is submitted to the district for construction under the maintenance contracts. On the other hand, if the plan is significant in scope, it is included in the capital budget. The bulk of the construction funds for these projects comes from the money allocated by local legislators for transportation projects. Also, the agency has some funds available to augment the programme.

Harmony Road

The first traffic-calming project to be implemented via this new process was chicanes on Harmony Road, a residential street in Newark. Harmony Road is about one km long, sits off a major expressway interchange, and has a high amount of 'cut-through' traffic. The posted speed is 25 mph (40 km/h); yet the 85th percentile speed was recorded at 59 km/h. On average, 18,000 vehicles ply daily on the road, and 80 children cross the street daily on their way to school. It is about 13 metres wide and parking is allowed on both sides always.

Figure I.4: Chicane at intersection (Delaware)

The traffic-calming devices, a series of chicanes, were chosen to slow traffic such that drivers could choose the alternative route instead of driving through the neighbourhood. At the same time, accommodations had to be made for the school buses and ambulances on their way to the hospital just to the north. The number and design of the original chicanes desir were modified to accommodate these use As part of the process, renderings we produced detailing how the devices wou appear. The project was completed last

Figure I.5: Chicane at midblock (Delaware)

II. VERMONT AGENCY OF TRA

In 1999, VTrans began a progran for traffic calming in Vermont. A project management committee was created to guide the process and the consulting firm Earth Tech was retained to work out the process and produce the standards. The reasons for the initiative were simple – Vermont needed: (i) a standardised approach; (ii) a set of tools to assist communities considering traffic calming; (iii) an understanding of which devices would be approved for use on state highways, and (iv) the conditions dictating which measures would be allowed where.

Like many state agencies in the United States, VTrans had not considered traffic calming on the state highways or developed approaches that were acceptable to the agency and responsive to the communities. Vermont is a small but very pro-active state, one that strives to be responsive to its citizens. Traffic calming had become very popular with Vermont communities, and there was much confusion on the part of the local government and residents on the proper use of traffic-calming tools. The intent of the agency in initiating the project was to fill this void in knowledge and develop a set of criteria that would enable traffic calming to be deployed properly and consistently.

Traffic calming on state highways raised many issues, and new standards were needed to address both safety and maintenance concerns. State highways were intended to carry higher volumes of traffic and higher speeds than customary on local roads. Traffic calming was seen as inconsistent with this role. It was necessary to advise the stakeholders on the proper role and possibilities of traffic calming so that they could make informed decisions, especially with regard to Vermont, a mountainous state with harsh winters. This was accomplished through a series of meetings in which committee members were educated in the state-of-the-art successes and failures. The committee then adopted several guidelines for the effort including three criteria that any traffic-calming device must meet: (i) designed to be safe, (ii) maintainable in snow and ice, and (iii) responsive to a demonstrated need, such as speed or traffic diversion.

Through a number of policy meetings and device evaluations, the committee determined that a series of standards would be necessary. A matrix was then developed to show which traffic-calming devices were applicable where and under what conditions. In Vermont, state highways are classified from expressways to local roads. The objective of the matrix was to delineate these classifications and identify which traffic-calming devices could be deployed in each case. The matrix presented the pluses and minuses of each and also stated where traffic calming was not appropriate. As can be anticipated, no devices were seen as appropriate for expressways.

The matrix refers to the new traffic-calming standard devices, of which there are nine: speed hump, speed table, raised intersection, chicane, curb extension, neck down, traffic circle (for use on local streets), roundabout (for use on other streets), and raised median. Additionally, there are gateways, landscaping and enhancement treatments that may be used in combination with the devices.

The project was designed to fit in the customary process and format given by the agency and its consultants. Standard sheets were developed which had the ‘look and feel’ of other VTrans standards drawings. Agency officials recognised that for traffic calming to be accepted, standards had to be recognisable and thus enforceable. This ‘official’ status was seen as essential by VTrans. At present, the standards are in the draft form and set to be adopted through the routine process. Ultimately, they would be posted at *http://www.aot.state.vt.us/NewsPub.htm*

The project achieved its primary goal of providing VTrans with a process for considering and developing traffic calming on state projects. It dealt with the devices that could be deployed in Vermont and the conditions for deployment. The standards were not intended to determine whether traffic calming would be deployed in the state, but rather to set standards for quality and construction details for such projects.

In reviewing the project, certain ingredients of policy succeeded, as indicated below:

- VTrans is a pro-active agency that has, over the years, recognised the potential of change in serving the transportation needs of the state.
- The initial project scope recognised that the project could not establish one set of standards that would apply to all cases.
- The philosophy was adopted not to reinvent the wheel on sidewalks, pavement and drainage standards. Thus, the product remained focused on traffic calming.
- While developing the standards, the committee recognised and addressed the need for treatment details specific to Vermont, such as landscaping and village gateways.
- It is essential to assemble a stakeholders' committee that represents all constituencies likely to be affected by the standards, both inside and outside of the agency, such as the municipal and regional planning staff and emergency service providers.

In hindsight, the project was a little ambitious in that the ability to achieve consensus on tools and deployment could not be fully achieved in the time provided and with the personnel assembled. As the practice evolves, it is anticipated that the matrix and standards will need updating. Also, this project did not address the implementation process. A separate effort should be undertaken to achieve that goal since the agreement on the implementation process and methodology is not universal and is highly dependent on the community.

III. NEW JERSEY DEPARTMENT OF TRANSPORTATION (NJDOT)

The utilisation of traffic-calming measures to reduce the travel speeds of motor vehicles and to restrict traffic to appropriate roadways is growing throughout New Jersey. Until now, these measures have been implemented at the local level by municipalities on roadways under their jurisdiction, usually in response to citizens' concerns about 'cut-through' and speeding traffic on local streets. For the most part, these facilities have been designed with guidance from existing general guidelines such as those published by the Institute of Traffic Engineers (ITE). In the past, the state's transportation agency, the New Jersey Department of Transportation (NJDOT), whose practices and standards are often followed by local jurisdictions, did not exhibit interest in developing standards for or implementing traffic-calming treatments. The thinking was that the state highway system was not conducive to using traffic calming as a solution to traffic-safety problems, primarily because of high traffic volumes and greater vehicular speeds.

This situation is changing. There is increased concern for the safety and availability of non-motorised travel. A new design philosophy that embodies principles of context sensitive design (CSD) has been adopted and integrated. There is also the realisation that many miles of state system roadways serve urban and suburban areas, some acting as the "main street" of New Jersey municipalities. Because of this, the agency has initiated the development of a new section in its Roadway Design Manual on traffic-calming treatments.

The Roadway Design Manual (RDM) is one of the key baseline documents of the NJDOT. This manual was developed "to present current Department guidelines pertaining to roadway design on the State Highway System" [New Jersey Department of Transportation, NJDOT Design Manual, Roadway, Trenton, NJ, November 30, 2001, p.1-1.] The document presents both general as well as specific design guidance and details on basic geometric design elements, major cross-section elements, at-grade intersections, interchanges, guide rail and median barriers, crash cushions, drainage facilities, highway lighting systems, traffic signals, ground-mounted sign supports and traffic control plans.

The development of a section on traffic calming for the manual is integrally linked to the development of two other new RDM sections: those on bicycle facilities and pedestrian facilities. In New Jersey, the most densely populated state in the United States, many short trips could be made by bicycling and walking. Even though the state highway system consists primarily of highways with generally high functional classifications, many miles of state system roadways serve urban and suburban areas, and as noted above, as main streets. Many more miles serve rural areas where bicycle is often used for recreational touring. The RDM, however, was initially developed (as the current edition states) to provide guidance in order to develop "uniformity and safety in the design of a highway system consistent with the needs of the *motoring* public." [New Jersey Department of Transportation, NJDOT Design Manual, Roadway, Trenton, NJ, November 30, 2001, p.1-1.]

Recognising this deficiency, and in keeping with the Department's evolving policies and increased interest in addressing the needs of non-motorised traffic, the agency hired the RBA Group in 1998. Its job was to undertake a thorough review of the RDM and to recommend revisions and additions to support the development of bicycle and pedestrian accommodations. This could be accomplished by including these facilities in roadway projects as part of the general highway design process and by developing independent bicycle and pedestrian facilities projects.

As this effort was commencing, another initiative was being studied and implemented within NJDOT: context sensitive design (CSD). During the course of these workshops, the practice of traffic calming, and how the Department should deal with it was raised. For some time, NJDOT staff had been fielding questions from county and municipal transportation agencies regarding appropriate design treatments for traffic-calming installations. The Department had no formal policy or standards and had provided *ad hoc* guidance. In general, the Department's position was that traffic-calming treatments were design elements rather than traffic control devices and, as such, the design of these features could be advanced by local governments (on roadways under their jurisdiction), without the need for agency approval.

Questions from local jurisdictions persisted and it was noted that the neighbouring state of Delaware had developed a set of traffic-calming guidelines. Ultimately, it was decided that in addition to developing new bicycle and pedestrian design sections, a third section should be developed: traffic calming. This would serve as a resource to the agency staff in designing traffic-calming treatments on state system highways, and for responding to local requests for information on traffic calming. The RBA Group was retained for this further work with Michael King as the principal author.

Initial drafts of the sections were prepared and submitted to the Department for internal review by a Technical Advisory Committee (TAC) in 2001. The primary concern expressed by the TAC was that the new sections contained too much information. A request was made that major revisions be made, which included the elimination of 'planning' language related to determining where and when these facilities were appropriate, and the elimination of discussions on design treatments that were not in general use in the United States. In addition, in a significant shift in thinking, the TAC requested that discussions of any bicycle, pedestrian and traffic-calming design treatments that pertained to design elements covered in the pre-existing sections of the RDM (e.g. medians) should be moved and incorporated in those pre-existing sections.

Extensive revisions were made and resubmitted in 2002. Although considerably pared down, there were still many comments that recommended the transfer of more material to the pre-existing sections. In addition, there were comments requesting the removal of discussions of traffic-calming treatments that were not likely to be used on the state highway system. This reflected further changes in thinking, particularly on the purpose of the traffic-calming section.

The process of addressing these comments and preparing a final submission for internal review through the baseline document adoption process has been a protracted one. This was primarily due to the need for extensive discussions within the Department to resolve conflicting comments. The third and final submission is to be made in 2003.

This final draft will now be subject to the Department's baseline document review process for official adoption. Internal differences on some issues remain, and must ultimately be resolved during the internal baseline document review process. When completed, they would be posted at *http://www.state.nj.us/transportation/cpm/RoadwayDesignManualEnglish/RoadwayDesignManualEnglish.html*. Other documents may be found at *http://www.state.nj.us/transportation/publicat/index.htm*.

As currently drafted, the Traffic-Calming Chapter includes an introductory section with:

(i) a brief policy statement: Traffic calming will be considered for Department-administered or -financed projects in accordance with the guidelines and requirements contained in this Section (Section 17) on roadways:
  - with an existing or proposed speed limit of 35 mph or below,
  - where the speed limit transitions to 35 mph or below, and/or
  - for segments of roadway that exhibit or are zoned such that they are proposed to exhibit attributes that would characterise them as "main streets," such as pedestrian use, building setback and streetscape.

(ii) the Department's new Statement of Design Philosophy that holds "in conceiving, scoping and designing projects. The NJDOT will consider the needs of all road users and neighbours. This includes pedestrians, bicyclists and neighbours such as residents and businesses…" The Statement also notes that a wide range of options are available to accomplish this, "including some that fall under the umbrella 'traffic calming'."

(iii) definitions and references, and

(iv) principles to be kept in view when considering traffic-calming treatments.

Specific design standards are discussed in two major sections – one on Traffic-Calming Design *Controls* (design speed, design vehicle, design offset, clear zone and streetscape elements, signs and markings); and, Traffic-Calming Design *Standards* covering volume-control devices, vertical speed-control devices, horizontal speed control devices, other devices and combination treatments.

IV. OREGON DEPARTMENT OF TRANSPORTATION (ODOT)

Oregon's Department of transportation is known around the country as fairly progressive, yet they have no formal traffic-calming policy. It is felt that traditional traffic-calming measures applicable to local streets would often not be acceptable on state highways, especially features such as speed humps. But other more subtle driver clues to slow down can be incorporated into the design of a project, without calling them "traffic calming." These include on-street parking, curb extensions, narrowing travel lanes, and landscaping. When used in appropriate situations, these measures represent effective and context-sensitive designs. Therefore, these kinds of tools can be integrated into design projects using existing standards without the need for a separate body of traffic-calming specific guidelines.

ODOT, however, does have formal bicycle and pedestrian policies and has become a nationally recognised leader in implementing progressive planning and design for pedestrians. One example is the enviable bicycle and pedestrian plan, available on the web at *http://www.odot.state.or.us/techserv/bikewalk/planimag/toc-imag.htm*. On that website are posted several traffic-calming designs as a resource for information only, no official endorsement. *http://www.odot.state.or.us/techserv/bikewalk/planimag/II1e.htm*, "Other Innovative Practices."

Oregon DOT has found that the most effective way to further traffic-calming principles within their state's highway road design is not to label it as such specifically, but rather by using its fundamental precepts to guide good and smart design. This enables several traffic tools to be deployed with minimal backlash from state transportation officials.

Other state departments of transportation have worked very hard to identify and codify traffic-calming devices and the processes by which to deploy them. Oregon has achieved greater success by more stealthily integrating these precepts into overall design. Their philosophy is that good road design accommodates pedestrians and bicyclists without unduly impeding traffic flow. Good traffic-calming practices don't punish good drivers. The secret is to make sure to look at the big picture: access, safety and comfort for all users.

Cities

At the local level, many cities in the country have active and extensive traffic-calming programmes and policies. Seattle WA has been installing mini-roundabouts for two decades now. Portland OR and Cambridge MA have very active programmes and are considered leaders. New York City developed standards for speed humps and curb extensions in the mid-1990s. Numerous other cities have active programmes, policies and design standards: Sacramento CA, Alexandria VA, Charlotte NC, San Antonio TX. Many of these have been documented in Reid Ewing's book Traffic Calming: State of the Practice, published by the Institute of Transportation Engineers in 1999 (*www.ite.org*). We look at two efforts that, while not being official policies or standards shed light on the implementation of traffic-calming programme at the local level. The first is a generally positive effort, while the second has met many obstacles.

V. VERMONT ROUTE 30

This project extends over a 39-mile stretch of a two-lane state highway between the city of Brattleboro in southeastern Vermont and the town of Winhall near the Stratton Mountain ski resort. Route 30 traverses five towns northwest of Brattleboro punctuated by typical old northeastern villages. In September 1999, the Windham Regional Commission (WRC) completed the Vermont Route 30 Corridor Management Study working with the five towns along Route 30. The Corridor Management Study identified many issues in the corridor, but traffic volumes and speed were mentioned as consistent problems. The study called for a systematic and thematic approach to traffic calming along this road. The Route 30 Traffic-Calming Project, conducted by the firm Buckhurst, Fish & Jacquemart, provided the next steps towards reaching that goal.

The project included a very comprehensive community participation programme, involving a survey that was sent to town officials, businesses, schools, fire, police and road commissions in the study area, two public workshops and four meetings with the Route 30 Implementation Committee. The workshops were well advertised and were structured such that the consultants were able to obtain useful information from the participants. Workshop I focused on the conceptual framework for traffic calming, and Workshop II focused on the preliminary traffic-calming concepts.

Traffic volumes along the Route 30 corridor range between 3,100 and 10,000 AADT. The highest traffic volume was seen at the southern end of Route 30 (10,000 AADT) near Brattleboro and the lowest traffic volume (3,100 AADT) was observed west of Bondville.

Speed surveys were undertaken along Route 30 to quantify the speeding problem. These surveys showed that the most significant speeding occurred in the villages where the speed limits are either 30 or 35 mph (48 or 56 km/h). Typically, the 85th percentile speeds were about 16 km/h over the speed limit, and between 75 and 85 per cent of the traffic drove faster than the speed limit.

Crash data show that crash locations mostly cluster along developed sections of Route 30. The crash analysis shows that 55 per cent of the crashes involved property damage only, 42 per cent involved injuries/fatalities, while 3 per cent involved either pedestrian or bicycle crashes. The 5 pedestrian/bicycle crashes (over a 3-year period) occurred in village settings including one each in Brattleboro, Newfane, Townshend, Jamaica, and Rawsonville, indicating a need to improve safety for the more vulnerable users in the village areas.

The first phase of work focused on developing the framework for the traffic-calming effort: what are the conditions that warrant traffic calming, where should traffic-calming devices be built, and where should they not be built? This phase of work developed a recognisable and systematic traffic-calming scheme concentrating on those areas that warrant traffic calming, not only because of safety reasons, but also because of quality-of-life reasons. The study focused on villages as target areas where traffic calming should occur and as the only areas along Route 30 where traffic calming is warranted. Any safety problems identified along open stretches of Route 30 were just those warranting safety solutions, not traffic-calming solutions. For instance, a dangerous curve along a rural stretch of Route 30 could be improved through reduced speeds or through a realignment of the highway.

Traffic calming should only be applied to a village as defined by the State of Vermont. The stretches of state highways to be calmed should be kept to a minimum and should not include any areas that would not satisfy the village definition. The expectation is that if traffic calming is restricted to the village areas, and if it is recognisable by the driver, it will be more effective in terms of speed reduction. By clearly recognising the village entry or ‘gateway’, it will also help strengthen the villages, one of Vermont’s great assets. Hopefully, this process will help in slowing down growth spreading along state highways outside of the villages. This phase of work produced a profile showing desirable speed limits along Route 30, as expressed by the study participants. This speed profile was translated into a map for each village showing the transition zones, village boundaries and desirable speeds for each.

One of the objectives of the Route 30 Traffic-Calming project was to institute a regular and recognisable traffic-calming programme along Route 30. This led to the desire to have a consistent prototype throughout the corridor and to have consistent speed limits. Figure V.1 shows the prototypical traffic-calming scheme adopted by the Committee.

The rural or open section of the state highway would not have any calming devices, with a higher design speed, e.g. 80 km/h as a main objective. The beginning of the transition zone is the location where the speed limit is reduced from the rural highway speed to a transition speed to facilitate the gradual slowing down to the village speed. It would be marked by a sign 'Approaching Village of XX', with dynamic striping and a 40 mph (64 km/h) speed-limit sign. Dynamic striping consists of a series of painted stripes along the travel lane and perpendicular to the travel direction that are spaced increasingly closer giving the impression to the driver that his speed is increasing.

The gateway treatment announces the entry into the village area. For the village gateway, a physical traffic-calming device is recommended. This can also act as an entry symbol, clearly marking a change in character: either a roundabout, a median island forcing a deflection on traffic and representing an opportunity to install a village sign in the median, or a neckdown (midblock neckdown), also representing an opportunity for signage indicating the village entry. Attention needs to be paid to the signage in that it satisfies the requirements of the Manual of Uniform Traffic Control Devices (MUTCD) or that an exception be requested for demonstration purposes. Within the village area, the speed limit would be a consistent 30 mph (48 km/h), and additional traffic-calming devices could be installed, such as neckdowns, curb extensions, medians, and on-street parking.

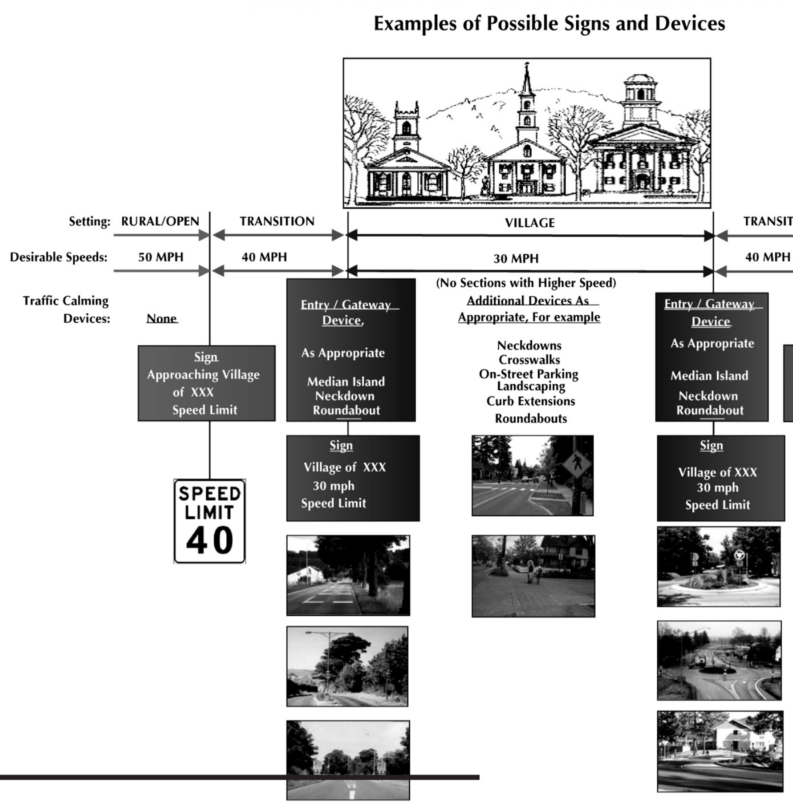
Following the first workshop, the consultant team developed conceptual traffic-calming schemes for each village. These schemes were then reviewed by the study participants and were revised to address community concerns. The maintenance of the traffic-calming devices was an important subject of the second workshop. Are the towns and villages prepared to maintain all or part of the new devices? The towns and villages did not feel that they have the resources to increase maintenance liabilities to any significant degree. It was pointed out that maintenance agreements would have to be signed similar to those that the state requires to build sidewalks in a town.

In general, the conceptual designs for the four villages along Route 30 adhere to the *Traffic-Calming Standards,* prepared by the State of Vermont Agency of Transportation and to the *Vermont State Standards for the Design of*

Transportation Construction, Reconstruction and Rehabilitation on Freeways, Roads and Streets. Traffic signs marking the village entrances and dynamic striping may be exceptions to this and may require a special permission for demonstration purposes. The traffic-calming measures employed in the conceptual designs include pavement markings, gateways, medians, signage, neckdowns/roadway narrowing, curbing, sidewalks, curb extensions, and on-street parking. As the traffic-calming measures are proposed in a village setting, all of the proposed traffic measures adhere to the state's traffic-calming standards.

The Vermont State design standards allow for reductions in the standard dimensions to accommodate such issues as historic and archaeological resources, natural resources, recreational resources, scenic resources, village or city entrance considerations, and economic vitality considerations. These allow for a mechanism for justifying reductions in the design standards based on specific site conditions. The reduced widths at the gateways to the villages fall in this category. The gateways will need to be so designed as to accommodate the large trucks (lumber

Figure V.1: Prototype traffic calming devices (Route 30)



trucks) and snow plows in a safe manner, but they may not be able to satisfy the extra widths required for bicycles either in a shared-use curb lane (13 feet) or on a shoulder (3 to 4 feet). Providing the extra width at this location may eliminate the desired path deflection and may defeat the purpose of the gateway-calming device. During the final design phase, special consideration will need to be given to the short gateway sections to accommodate bicyles in a safe manner. Depending on the prevailing speeds, volumes, and sight distances, one could assume that bicycles take over the travel lane (as in other traffic-calmed situations). Alternatively, short bypass paths could be built alongside the gateway section to accommodate bicycles. As bicycles approach the village gateway, presumably on the highway shoulder, they would transition on to the path on the right side of the gateway treatment. Once they pass the gateway, they would transition back on to the highway.

VI. DOWNTOWN BROOKLYN

Brooklyn, being a borough of New York City, is part of the most densely populated city in the United States. Downtown Brooklyn sits at the confluence of two bridges and one tunnel leading into Manhattan. As such, it faces a daily onslaught of vehicular traffic on the expressways spilling off on to the local streets. The fact that the bridges do not connect directly to the expressways is a fundamental flaw in the system and one of the major reasons for such traffic.

For decades, local activists, city planners, business interests, community organisers and politicians have advocated for a solution to the traffic problem in the area. In 1998, the Downtown Brooklyn Traffic Calming Study (DBTCS) was created through a financial partnership of the New York City Department of Transportation (NYCDOT), Brooklyn Borough President, and members of the City Council and State Assembly, in response to strong community concern about the impacts of traffic on life in Downtown Brooklyn. The funding for the study was approximately $1.5 million.

As the scope of the study was developed, the high level of community interest in the project was acknowledged. NYCDOT agreed to divert from usual practice and have three neighbourhood representatives—as designated by the Borough President and the City Council – serve as voting members of the Selection Committee, along with four NYCDOT members. That Selection Committee hired the firm of Ove Arup to undertake the study. Arup was assisted by several other firms and consultants on the project. A community-based Task Force convened by the Brooklyn Borough President monitored the study. NYCDOT chaired a Technical Advisory Committee, which consisted of interested government agencies, elected officials, and community boards.

The study team confronted a number of challenges. These included:

Conflicts between the stakeholders: Notwithstanding the partnership approach used to develop the study's scope and to select the consultant, a strong history of conflict exists among the various stakeholders. Strained relations between the then Brooklyn Borough President and the then Mayor led to stiffness between the Brooklyn Borough President's office and NYCDOT. Moreover, a good deal of mistrust existed between community groups and NYCDOT. Finally, the appointment of a consultant experienced elsewhere but unknown to many stakeholders caused some nervousness and suspicion.

Such conflicts made early progress on the study difficult. A successful traffic-calming strategy must reflect local community aspirations. As not all aspirations can be fully met in a congested environment such as Downtown Brooklyn's, the development of a traffic-calming strategy depends on a fruitful dialogue between all stakeholders committed to a common overall goal and willing to discuss issues in good faith.

Unstated traffic management goals: A traffic-calming study is customarily undertaken in an environment in which traffic management goals have been clearly defined. However, such was not the case for this study. No goals had been developed for managing Downtown Brooklyn's streets, other than the implicit one of maximising traffic capacity in this heavily congested area.

Undifferentiated existing traffic management approach: NYCDOT's management approach has historically been to do everything possible to smoothen the flow of traffic through all streets in the apparent hope of minimising congestion and the impact of the pervasive traffic. Such an approach may meet the goal of moving as much traffic as possible through the area, but certainly is ineffective in meeting other community goals for use of streets. This problem is reflected in the groundswell of discontent that gave rise to this study.

Unrealistic and conflicting expectations: A number of community stakeholders came to the study expecting that it would provide the means to solve all traffic-related problems in Downtown Brooklyn. Traffic calming is not a universal panacea and so such inflated expectations were doomed to remain unsatisfied.

Belief that the pilot programme would be the strategy: Some stakeholders believed that the demonstration projects implemented as part of the study's pilot programme would serve as a surrogate for Downtown Brooklyn's broad traffic-calming strategy. This was completely unfeasible. Yet the limited scope of the pilot programme and lingering confusion in some quarters about the difference between pilot programme and the strategy yielded initial dismay in some quarters at the time of implementation of the pilot programme.

Belief that traffic problems can be solved by piecemeal treatments: Many community stakeholders came to the study with ideas on individual treatments that they felt could solve traffic problems at individual locations. Experience around the world has demonstrated that individual treatments can only be effective when implemented in the framework of a broad and coordinated strategy.

The study team's response to the challenges presented to it can be summarised as under:

Education: The consultant had to educate the various stakeholders on what traffic calming could and could not achieve. Some members of the community came to the project believing a traffic-calming programme would remove traffic from Downtown Brooklyn and solve all the area's traffic problems and that an uncoordinated and piecemeal set of treatments would achieve a useful result. Some members of the affected agencies such as NYCDOT, NYPD (New York Police Department) and FDNY (Fire Department of New York) believed that traffic calming would prevent Downtown Brooklyn's street network from performing its necessary role.

Elements of the education programme ranged from broad background material such as a review of the possible approaches to traffic management and the place of traffic calming in the traffic manager's armory, to detailed information on what can and cannot be achieved by traffic calming. It also looks at the place of the pilot programme in the overall traffic-calming strategy. This information was delivered both as formal briefing notes and presentations and as background messages included in all verbal and written material.

Traffic-management framework: The consultant had to create a traffic-management framework for the area within which the traffic-calming strategy could fit. The consultant created an innovative street classification framework that better matches streets' management needs than a conventional road hierarchy. The study demonstrated that it was possible to define a range of goals for streets and that different streets could be managed according to different goals.

Importantly, the strategy takes account of the needs of all users of street space, rather than focusing primarily on the needs of drivers of motor vehicles. This represents a major shift in thinking about New York's streets as it includes all activities between property lines, rather than just the space between curb lines, and addresses the needs of everyone that uses this space rather than just those who travel on the roads. This approach ensures that the needs of shoppers, pedestrians, cyclists, bus riders and residents in Downtown Brooklyn are considered along with those of drivers.

Localising traffic-calming practice: Traffic-calming measures from around America and the world had to be modified to suit New York's conditions. Representative measures were implemented as part of the project. This required careful shepherding of the original ideas through the NYCDOT design groups more used to designing roads to a different set of objectives, their careful implementation in the field, and thorough review. This process has been effective in reducing concerns held by affected agencies about the impact of traffic calming on their operations.

NYPD, FDNY and the Department of Sanitation initially had reasonable fears that aggressive traffic-calming treatments could compromise their ability to work effectively. Through close consultation, field-testing of prospective designs before implementation, and careful monitoring of the operations of treatments implemented in the pilot programme, the consultant was able to build confidence in these agencies about how traffic-calming treatments affected traffic operations and also about the impact such treatments would have on the agencies' operations.

Placing outreach at the centre of the process and creating ownership of the programme: The effectiveness of the traffic-calming programme will be reflected in its implementation in the years to come. Complete implementation and ongoing refinement of the plan can only occur if the various stakeholder groups take responsibility of the outcome of the study. The consultant had worked hard to gain consensus on a useful and achievable programme acceptable to all stakeholders. A significant element of the consultant's strategy involved placing outreach at the centre of the study, in general, and the strategy development process, in particular. The final strategy reflects the choices made by each of the directly affected community boards from the options presented and discussed by the consultant. That the strategy reflected the aspirations of the community boards and proved acceptable to NYCDOT and other related agencies is a measure of how the consultant was able to moderate the initial combative environment through out the course of the study.

Honesty and fair dealing: The success of the programme depended on acceptance by all stakeholders that the consultant at all times acted fairly and honestly. While it may seem odd that the achievement of this objective is counted as a success, the atmosphere of conflict that had pervaded the project's inception meant that the consultant's credentials were at no time assured. However, through the course of the project, the consultant was able to develop good relations with all stakeholders on a sound footing of honesty and professionalism that helped maintain dialogue even during times of disagreement. The Downtown Brooklyn Traffic-Calming Study can be downloaded from: *http://www.transalt.org/campaigns/brooklyn/dbtc/index.html*.

Figure VI.1: Typical arterial (Downtown Brooklyn)

Figure VI.2: Typical commercial street (Downtown Brooklyn)

Figure VI.3: Large truck on narrow street (Downtown Brooklyn)

Figure 4: New curb extension as part of project (Downtown Brooklyn)

TRAFFIC CALMING MEASURES ON NATIONAL AND STATE HIGHWAYS

Indian Case Studies

Geetam Tiwari*

In India, national highways (NHs) and state highways (SHs) together carry more than 70 per cent of the total road traffic. Safety has become a major concern on these roads. The problem is especially serious when these highways pass through villages and towns. During day, local traffic and activities around the highways cause congestion and become a bottleneck for fast through traffic. However, at night when the volume of traffic is low, these sections become a safety hazard. Since these highways are not limited access roads, they are intersected by other categories of roads forming intersections on them. Networks of national and state highways are expected to carry a substantial volume of the inter-city long-distance traffic. Therefore, network upgrading demands that the needs of long-distance traffic be addressed along with the needs of local traffic, which comprise slow-moving vehicles, such as bicycles, animal carts, tractors, and pedestrians.

Traffic-calming techniques have emerged primarily as society's response to safety concerns. In Western countries, they have been implemented in residential areas and cities because inter-city highways and freeways are relatively safe. It is well recognised by experts that variations in speed, direction, and/or quantum of vehicles usually make a difference as to the number and severity of road accidents. In the West, freeways are rated highly safe. On such freeways, driving speeds are the highest but relatively uniform and there is much less variation in direction and vehicle mass. However, residential areas and inner cities have become safer in the last 25 years because of 30-km-per-hour zones in residential areas, despite considerable variation in the direction and vehicles using them. Traffic-calming techniques have played an important role in achieving safety by ensuring low driving speeds and smaller speed differences among different road users.

The general experience of different European countries indicates that speed-limit signs and other visual measures *alone* are not sufficient to make the drivers choose an appropriate speed. However, when used in combination with other physical speed-reducing measures, significant results can be achieved.

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European measures have been based largely on traffic systems in which cars are the dominant mode. However, this is not the case in India. Here we have a much more varied mix of traffic. (Table 1 gives a broad comparison of the traffic situation in India and OECD (Organisation for European Cooperation and Development) countries.

Table 1: Traffic in India vs traffic in OECD countries

Feature	India	OECD countries
Modal mix of traffic in urban areas	Two-wheelers, three-wheelers and non-motorised traffic comprise a much larger share of traffic than cars	Cars are the dominant mode
Modal mix on inter-city roads	Trucks and buses constitute a larger share than cars on most highways. Presence of tractors and non-motorised traffic. Large variation in speeds.	Cars are the dominant mode. No tractors and non-motorised traffic. Little variation in speeds.
Highways passing through townships	Almost all inter-city roads pass through townships and villages. Therefore, all inter-city traffic has to interact with local traffic when passing through these areas. This situation is likely to remain the same for quite some time.	The extensive network of limited access highways ensures that most long-distance traffic uses this network. Traffic on inter-city roads passing through townships is generally not long-distance and hence has slightly different characteristics and needs.
Vehicle characteristics	Suspension systems of vehicles and their sizes vary greatly. Thus, horizontal traffic-calming measures like lane narrowing and staggering would have to be re-explored to deal particularly with narrow vehicles. Vertical measures like humps (speed-breakers) would affect cars, motorcycles, trucks and buses differently.	Since the vast majority of vehicles are cars or even bigger than cars, horizontal measures are effective. Vertical measures which have to be tailored to suit cars, buses, trucks, and two-wheelers are not a major issue in this case.
Traffic segregation	At present, roads in India have very little segregation of traffic. Traffic-calming measures here should include segregation as one of the important measures.	A large proportion of roads in Europe have segregation of traffic particularly due to the provision of bicycle lanes. This makes traffic-calming measures easier to implement.

This paper presents a summary of the pilot projects carried out on select sites to evaluate the effectiveness of traffic-calming measures on national highways and state highways. Eleven select sites provided a range of traffic-calming measures that had been constructed at the instance of local residents. They mostly constituted speed humps or rumble strips not conforming to any standards. The pilot projects were designed to carry out comparisons of the effectiveness of existing traffic-calming measures with the proposed measures. The proposed measures were developed on the basis of local traffic needs and international experience. These measures could be implemented at four sites only which provided before-and-after data for evaluation.

Discussions with local residents to understand their concerns and support for the proposed comprehensive measures brought out that: (i) safety concern is very high among the local community; (ii) increasing traffic and highway construction (improvement) are often perceived as a threat to local safety; (iii) engineers and highway authorities are often seen as being not sensitive to their needs; and (iv) local community leaders do not hesitate in defying the authorities.

Meetings with policymakers brought out a different set of concerns. These were:

- Efficiency of motorised traffic on the highway must be given primary importance.
- The growing number of accidents on highways is a major concern. Villagers must be taught/educated to behave on the road since the road is designed primarily for through traffic and this has to be honoured.
- General understanding of safety measures is very poor among the decision-makers. The relationship between speed and fatalities is not well understood. Often Indian highways are compared to limited-access highways of the West. Local concerns for mobility and safety are dismissed.

Following sites were selected for implementing the proposed traffic-calming measures:

- Kheri village, km 66, NH 10.
- Sampla Bypass, km 58-59, NH 10.
- Checkpost at km 42, NH 10.
- Bhondsi Village, SH 13.
- Meerut Railway level crossing, NH 58.

The study team visited the sites, traffic data were gathered, and the site inventory was completed. The concerned personnel in the state PWD were briefed through the officials of the Ministry of Road Transport and Highways. They gave support throughout the study and also assisted by undertaking civil works on the stretches.

Data collection

Both primary and secondary data were collected for the identified sites. In addition to the detailed inventory of the site recording geometric characteristics and land-use details, the data types are speed, volume, and accident records. Primary data for speed and classified volume were collected with the help of a lidar gun and by using videography techniques. The traffic was videotaped from a pre-selected spot to record the maximum interaction of vehicles in the traffic stream for at least 25-30 metres of the road length. The traffic flow was videotaped for at least four durations of an hour each. This was done to capture the speed and volume at different times during the day. The tapes were analysed to estimate: (i) classified counts, and (ii) space mean speed.

Methodology for obtaining spot speeds of vehicles using lidar gun

ProLaser gun was used to measure both the range and velocity of selected vehicles. The advanced technology on which the ProLaser gun is based provides pinpoint-aiming capability, allowing the operator to isolate a single vehicle out of a group.

The proposal for intervention at each site was discussed with the local PWD officials and detailed plans were handed over to the PWD for execution.

Traffic Calming at Kheri Village, NH 10

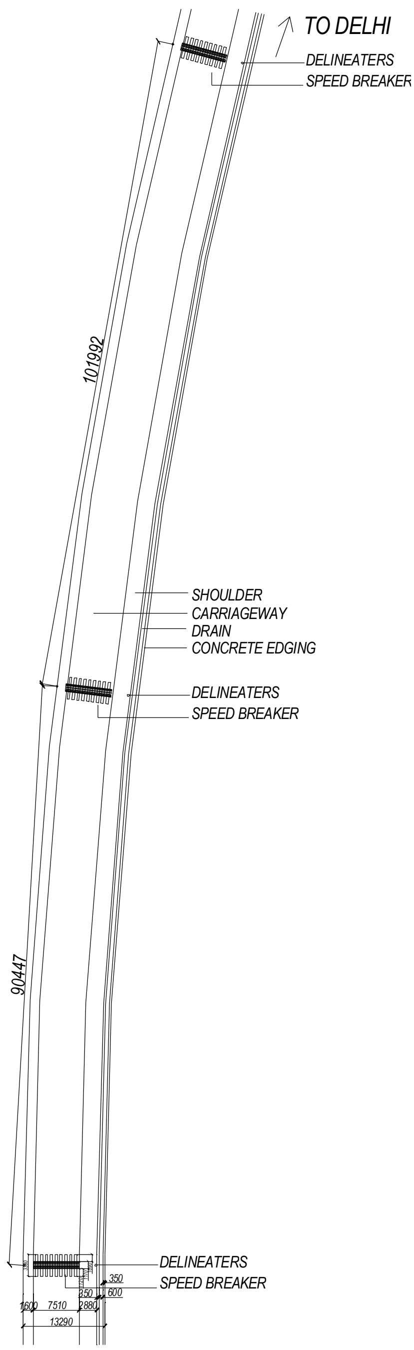
Location

Kheri village is located near Rohtak at a distance of 66 km from Delhi on National Highway 10.

Background

The national highway which passes through the village is a two-lane undivided road with unpaved shoulders. There are three speed-breakers each at an approximate interval of 100 metres. There is high-density residential development on both sides of the undivided carriageway. The local residents

Figure 1: Kheri Village, km 66, NH 10



reported a sharp decline in serious accidents after the construction of the speed-breakers. As such, they resisted proposals to remove the speed-breakers. They also did not like the study team's carrying out experiments despite persuation by state PWD officials.

Classified traffic volume

Tables 2 and 3 show the classified traffic volume at Kheri village before and after the implementation of the proposed traffic-calming measures.

Table 2: Classified traffic volume at Kheri village

Time	Morning (1110 hrs to 1310 hrs)			Afternoon (1420 hrs to 1520 hrs)			Evening (1650 hrs to 1750 hrs)			Evening (2150 hrs to 2255 hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	36	32	68	24	37	61	57	24	81	39	32	71
LCV	63	49	112	31	48	79	35	35	70	17	12	29
Car 1	172	128	299	152	130	282	177	151	328	22	45	67
Car 2	63	51	114	48	42	90	59	51	110	4	8	12
2-wh	85	65	150	72	58	130	69	81	150	4	6	10
3-wh	28	26	54	32	22	54	28	18	46	2	0	2
Tractor	7	9	15	11	10	21	13	10	23	5	4	8
NMV	36	18	54	17	20	37	35	36	71	2	3	5

Table 3: Classified traffic volume at Kheri village after implementing the proposed traffic-calming measures

Time	Afternoon (1245 hrs to 1415 hrs)			Afternoon (1530 hrs to 1700 hrs)			Evening (1700 hrs to 1830 hrs)			Evening (1945 hrs to 2115 hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	40	43	83	37	27	64	33	27	60	42	36	78
LCV	39	23	62	37	25	62	17	52	69	28	30	58
Car 1	114	101	214	129	103	232	113	94	207	42	86	128
Car 2	40	34	74	44	37	80	26	38	64	15	27	43
2-wh	69	72	141	81	70	151	70	52	122	23	11	34
3-wh	34	29	63	39	21	60	29	13	42	3	5	8
Tractor	9	9	17	13	8	21	10	5	15	2	1	3
NMV	38	24	62	58	40	98	76	45	121	11	1	13

Note: (i) "1 to 2" stands for Delhi to Rohtak.
(ii) "2 to 1" stands for Rohtak to Delhi.

Vehicle Coding:

HV – Chartered bus, Blueline bus, DTC bus, school bus and trucks
LCV – Mini Truck, Tempo, Mini bus and RTV.
Car 1– Maruti 800, Esteem, Cielo, Honda City, Lancer, Mercedes, Ford, WagonR, Santro, Indica, Ambassador, Fiat, Contessa, Opel, Safari, Tata Estate, Tata Sierra, Escort and other cars.
Car 2 – Sumo, Qualis, Mahindra, Jeep and Gypsy
2-wh Scooters, Motorcycles and Moped
3-wh Three-wheelers
NMV – Bicycles and pedal-rickshaws; Human carts and animal carts

Major problem

This corridor's major problem seems to be sudden speed reduction at the periphery of the village. The vehicles on the highway encounter speed-breakers without any prewarning and are forced to apply the brakes suddenly.

Intervention

To counter the problem of sudden slowing down of the vehicles, following pre-warners, signages and tactile traffic-calming measures were proposed from a distance of 270 metres from the entry of the village on one side (Rohtak side):

– Chicane on the Rohtak end of the village
– Speed table on the Delhi end of the village
– Rumble strips before both the above measures
– Signage (conforming to IRC 67:2001) before the chicane, the speed tables and the rumble strips.

Construction of traffic-calming measures at Kheri village

A chicane, a trapezoidal hump, and rumble strips along with suitable signages were to be constructed at the site. The speed-table was supposed to replace one of the speed-breakers at the farthest end of the village (towards Delhi). However, from their experience in the past, the villagers knew that getting a traffic-calming measure implemented by authorities was not easy, and the speed-breakers that were installed had been very effective in slowing the speed of vehicles. They could not believe that something better could replace them and that the same could be constructed within a short span of time. So, they were opposed to the idea of intervening with any existing speed-breaker and put up a strong resistance against the local public works department officials, who abandoned the plan. Several efforts were made informally through public meetings. Some time was lost in the process, despite the efforts of the state PWD officials and the project team. However, after consistent efforts, the following were constructed.

– Chicane (towards Rohtak)
– Delineators for the chicane
– Rumble strips while approaching chicane
– Signages (IRC 67: 2001) pre-warning the above-mentioned traffic-calming measures.

Observations from data collected by lidar gun and videography

1. The pattern followed by the different vehicle types – Car 1, Car 2, and LCVs –showed a significant fall in the number of people driving

above 60 km per hour after the first rumble strip. There is a further fall, although not so sharp, in the number of people driving above 60 km per hour after the second rumble strip. Correspondingly, there is an increasing tendency for people to drive between 60 km per hour and 30 km per hour. However, after the chicane, there is a rise in the proportion of people driving above 60 km per hour. Consequently, there is a drop in the percentage of vehicles driving between 60 km per hour and 30 km per hour. It is to be noted that the percentage of vehicles moving below 30 km per hour drops more sharply than that of those driving below 60 km per hour but above 30 km per hour.

2. The pattern followed by two-wheelers and heavy vehicles shows that most of them move between 30 and 50 km per hour. However, there is a tendency to speed up right after the chicane when there is a rise in the number of vehicles moving above 60 km per hour.

3. There is also a tendency for vehicle types Car 1, Car 2, heavy vehicles, three-wheelers, and tractors to speed up *as they near* the chicane and for two-wheelers to speed up immediately *after* the chicane. It is felt that the drivers of the former group of vehicles are not able to judge the adequacy of the road space from a distance. They have a better judgement regarding its negotiability as they approach the chicane when they speed up. Two-wheelers, on the other hand, are 'squeezed' between the bigger vehicles and would prefer to drive slow while within the chicane.

Conclusions

1. Rumble strips are effective deterrents for Car 1 type vehicles.
2. Chicane is a less effective deterrent than rumble strip.
3. Vehicles have a tendency to speed up after the chicane. Hence, steps have to be taken to curb this tendency. This may require either the lengthening of the chicane and/or introduction of other traffic-calming measures within the close vicinity of the chicane.
4. A modified design of the chicane has been suggested to address the two-wheelers' problems. It consists of providing a cycle lane on the side.
5. Rumble strips should be painted to reinforce their visibility.

Traffic-calming at Bhondsi village – Sohana-Gurgaon Highway, State Highway 13, Haryana

Location

Bhondsi village is located at a distance of 12 km from Gurgaon on State Highway 13. The Highway passes through the village. It is a two-lane undivided road with unpaved shoulders.

Background

The Sohna-Gurgaon Highway (on State Highway 13) carries a heavy load of truck traffic. On local residents' demand, four speed-breakers were constructed on the highway as it passed through Bhondsi. These speed-breakers are at regular intervals, and *prima facie* they appear to be effective in reducing and maintaining the reduced speed of traffic through the village. The speed-breakers have been denoted through proper signage and delineators although they are no longer visible. Tables 4 and 5 show the classified traffic volumes at Bhondsi village.

Problems

Initial data collected show that there is a drop in the maximum speed of each vehicle category within the village where the speed-breakers are located. However, the slowing down begins only after one enters the village. So one approaches the village at a high speed of 60–70 km per hour. This may be hazardous to vehicles, especially two-wheelers at night, and also to pedestrians near the first speed-breaker where the approach speeds may still be high.

Intervention

To tackle the problem of sudden slowing down, following measures were proposed:

1. A series of pre-warners and signages conforming to IRC: 67-2001 were installed from a distance of 792 metres from the entry into the village on one

Figure 2: Speed Breakers on Sohna Gurgaon, SH 13

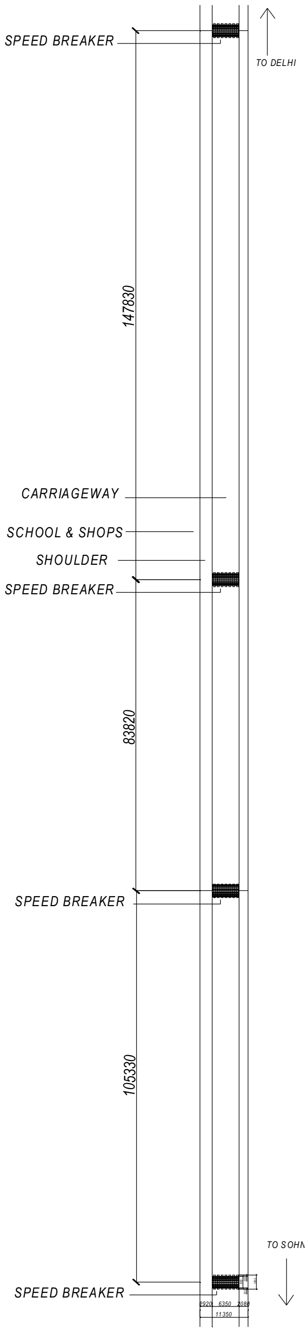


Table 4: Classified traffic volume at Bhondsi village, speed-breaker 1

Time	Morning (1000 hrs to 1200 hrs)			Afternoon (1355 hrs to 1440 hrs)			Evening (1645 hrs to 1745 hrs)			Evening (2150 hrs to 2250 hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	79	78	157	113	77	190	91	71	162	6	16	22
LCV	20	21	41	23	21	44	25	20	45	1	0	1
Car 1	71	73	144	56	57	113	69	94	163	2	3	5
Car 2	29	27	56	33	29	63	17	24	41	0	0	0
2-wh	109	91	200	92	69	161	76	82	158	1	2	3
3-wh	6	4	10	4	0	4	2	3	5	0	0	0
Tractor	4	6	10	7	4	11	2	5	7	0	0	0
NMV	16	15	31	23	11	33	41	45	86	0	0	0

Table 5: Classified traffic volume at Bhondsi village after implementing the traffic-calming measures

Time	Morning (1005 hrs to 1255 hrs)			Afternoon (1430 hrs to 1550 hrs)			Evening (2020 hrs to 2150hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	96	79	174	94	82	176	77	108	185
LCV	18	19	37	26	23	49	8	17	25
Car 1	84	69	153	70	71	141	20	26	46
Car 2	36	31	67	37	32	68	10	11	20
2-wh	113	112	225	91	86	177	11	7	18
3-wh	5	4	8	4	7	11	0	0	0
Tractor	7	6	13	8	6	14	2	1	3
NMV	27	31	58	30	44	74	5	2	7

Note: (i) "1 to 2" stands for Gurgaon to Sohna.
(ii) "2 to 1" stands for Sohna to Gurgaon.
(iii) For vehicle coding: see Table 3.

side (Sohna side). They were designed to reduce the speed at the rate of 2.54 m/s^2 (which is around 0.2g – a comfortable rate of deceleration).

2. The entire highway within the village boundaries was painted with diagonal strips 25 cm wide, with the object of alerting drivers. The idea was to change the visual environment suddenly and assess the impact it had on the driver.

Observations on data collected at Bhondsi

Graphs of speed vs distance from the speed-breaker, and the 85th percentile speed of vehicles vs distance for different vehicle categories before and after the traffic-calming interventions have been analysed:

1. The pattern followed by the vehicle types – Car 1, Car 2, and LCVs – shows that there is a significant fall in the number of people driving above 60 km per hour after the 60-km-per-hour mark. There is a

further fall, although not so sharp, in the number of people driving above 60 km per hour after the 50-km-per-hour mark. Correspondingly, there is an increasing tendency for people to drive between 60 km per hour and 30 km per hour. However, after the 30-km-per-hour speed-warning and before the speed-breakers (which are 139 metres apart), there is a sharp drop in the number of cars moving at the speed of above 60 km per hour and a sharp rise in people driving below 30 km per hour.

2. All vehicles show a sharp drop in speed to around or below 30 km per hour, as they approach a speed-breaker.
3. The pattern followed by two-wheelers and heavy vehicles shows that most of them move between 40 and 60 km per hour.

Road-users survey at Bhondsi village

Drivers of various types of vehicles were surveyed in Bhondsi to assess their reactions to the traffic-calming measures provided there. Three questions were asked:

- Did they see the road signages (on road markings and signboards)?
- What meaning did they convey to them?
- What purpose was served by the series of lines marked across the carriageway along the entire village?

The survey was conducted to find whether drivers responded to the three-pronged efforts at limiting the vehicle speed to 30 km per hour while moving on the highway within the village limits. Although 40 per cent of the drivers of Car 1 vehicles saw speed markings, only 20 per cent felt that they should slow down. Car 2 drivers were not very sure, although they were less dismissive of the exercise. In all, car drivers were neither attentive to the presence of road signs, nor were they keen to follow the speed limits even after the meaning of the signs was explained to them.

Eighty-three per cent of heavy vehicle drivers saw either the road markings or the signboards. Fifty per cent felt that they should slow down on seeing such signs; thirty-three per cent felt that the hatching should make them drive slowly. In fact, drivers of all goods vehicles, including LCVs and trucks, noticed the signs as well the 45-degree hatching and felt that they should slow down. The reason may be that they are fearful of disobeying rules.

Although two-wheeler drivers saw the road signs, it seemed they were not sure about their purpose. However, hatching was clearly a message to slow down.

Findings from the user survey

1. Drivers did not notice the traffic-calming devices. Hence, the devices need to be made more conspicuous and frequent (as distinct from installing them at points where they may elude drivers moving at a high speed).
2. Speed-breaker is a more effective option in controlling the speed of vehicles than traffic-calming measures.
3. From other sites, it is observed that the rumble strip is a more effective instrument in alerting a driver. So the signage needs to be combined with rumble strips.

Sampla Bypass, km 58-59, NH 10

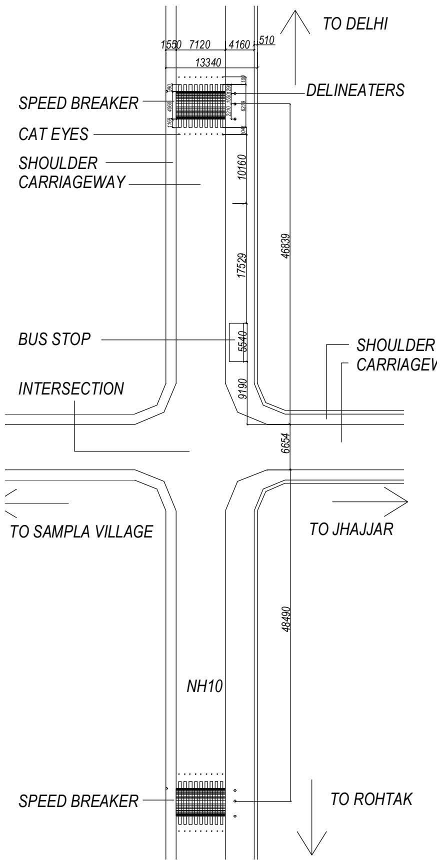
Location

The Sampla bypass, at 58-59 km, is at a junction where a minor road joining Sampla village and Jhajjar village meets NH10.

Background

There were speed-breakers on both sides of the junction on NH10. However, there were no speed-breakers on the minor road. Signboards indicating the presence of speed-breakers which were located as shown in the figure. There is a bus stop at this junction. The minor road carries fair amount of village traffic. Tables 6 and 7 show the classified traffic volumes at Sampla Bypass.

Figure 3: Sampla Bypass, Bahadurgarh, NH 10



Proposed traffic-calming measures

At the Sampla bypass, following traffic-calming measures were suggested:

– Surmountable road divider on the national highway to discourage overtaking.
– Rumble strips on the highway as a prewarner to the traffic-calming measures ahead.

Table 6: Classified traffic volumes at Sampla bypass

Time	Morning (1045 hrs to 1243 hrs)			Afternoon (1635 hrs to 1740 hrs)			Evening (2150 hrs to 2250 hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	39	36	75	45	31	76	32	38	70
LCV	39	19	57	33	42	75	17	21	38
Car 1	110	93	203	105	95	200	6	30	36
Car 2	23	14	37	26	21	47	2	7	9
2-wh	22	24	45	16	14	29	0	1	1
3-wh	2	1	3	0	2	2	0	0	0
Tractor	6	4	10	10	12	22	5	0	5
NMV	1	2	3	1	1	2	0	0	0

- Road signs on the highway warning of the above measures lying ahead.
- Speed-breaker and rumble strips on the minor road crossing the highway.
- Signages.

Table 7: Classified traffic volume at Sampla bypass

Time	Morning (1100 hrs to 1340hrs)			Afternoon (1615hrs to 1850 hrs)			(2120h
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2
HV	31	27	58	30	29	59	32
LCV	18	19	36	22	28	50	18
Car 1	92	90	182	130	106	237	12
Car 2	18	20	38	18	18	36	6
2-wh	23	29	51	25	21	46	0
3-wh	2	2	3	2	2	3	0
Tractor	1	4	5	2	2	3	1
NMV	1	1	2	2	2	4	0

Note: (i) 1 to 2 stands for Rohtak to Delhi.
(ii) 2 to 1 stands for Delhi to Rohtak
(iii) Vehicle coding: see Table 3.

Observations

- The speed-breakers disappeared after the bypass was repaired.
- The measures proposed above were not fully implemented by the state PWD except the painting of the edge of the carriageway and provision of rumble strips.

Findings

- Painting the edge of the carriageway did not make a perceptible difference in the speed profile of the vehicles.

– The non-implementation of rumble strips and effective speed-breakers on the minor roads hampered the desired speed management at such intersections.

Traffic-calming at Railway Level Crossing on NH 58

Location

This is a grade railway line crossing on the National Highway 58 (Meerut Bypass) near Meerut.

Background

It is a two-lane undivided road with 1.5-metre wide unpaved shoulders. During initial visits, vehicles were seen moving at a fairly high speed. There were rumble strips on the road on both sides of the railway line slowing down traffic at the gates. However, the rumble strips were not laid according to the IRC code, and their height exceeded 125 mm, making them effectively a cluster of speed-breakers. Tables 8 and 9 show the classified traffic volumes at the Meerut railway crossing.

Table 8: Classified traffic volume at Meerut railway crossing

Time	Morning (1028 hrs to 1136 hrs)			Afternoon (1412 hrs to 1512 hrs)			Afternoon (1555 hrs to 1652 hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	54	38	92	55	46	101	48	35	83
LCV	18	27	45	23	29	52	20	29	49
Car 1	80	82	162	80	81	161	99	97	196
Car 2	29	24	53	17	29	46	22	38	60
2-wh	63	82	145	66	44	110	65	66	131
3-wh	0	1	1	2	3	5	18	30	48
Tractor	6	5	11	8	1	9	0	0	0
NMV	25	18	43	13	14	27	27	20	47

Table 9: Classified traffic volume at Meerut railway crossing

Time	Afternoon (1225 hrs to 1353 hrs)			Afternoon (1520 hrs to 1620 hrs)			Evening (2005 hrs to 2140 hrs)		
	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total	1 to 2	2 to 1	Total
HV	57	44	101	53	61	114	46	39	85
LCV	22	18	40	17	19	36	11	15	26
Car 1	59	69	129	61	77	138	53	28	81
Car 2	18	15	33	12	24	36	13	9	23
2-wh	71	65	137	78	80	158	22	14	37
3-wh	3	1	4	1	0	1	0	0	0
Tractor	5	5	10	7	1	8	1	0	1
NMV	29	31	60	34	29	63	9	6	16

1. 1 to 2 stands for Ghaziabad to Meerut.
2. 2 to 1 stands for Meerut to Ghaziabad.

Problems

1. The speed-breakers were located close to the gates of the railway level crossing. As a result, there was a sudden drop in vehicular speed near the gates, which was a risky situation at night.

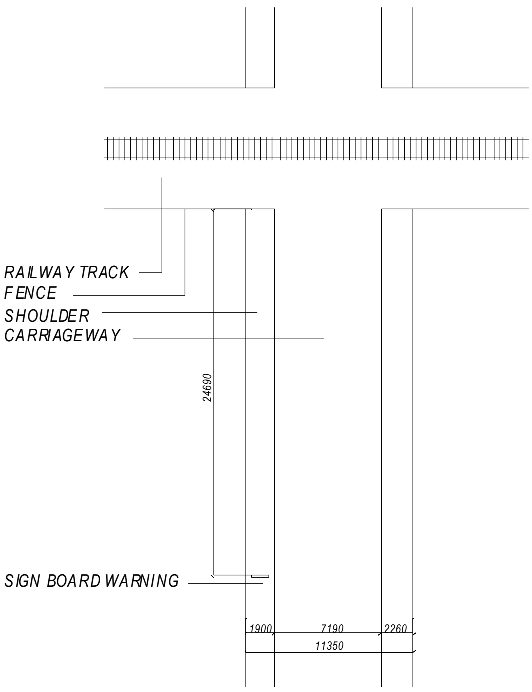
2. There was a chaotic build-up of vehicles near the gates on both sides when they were closed. Vehicles occupied both the lanes. As vehicles on either side were in conflict, it created congestion and slowed dispersal of traffic when the gates were opened.

Intervention

1. To counter the problem of sudden slowing down of vehicles, a series of prewarners and signages were suggested from a distance of 250 metres from the railway crossing.

2. A 100-mm-high (4 inches) surmountable median was constructed along the entire 250-metre length on the approach road to the crossing from the Meerut side. This was constructed to separate opposing traffic on the two lanes. This was expected to eliminate chaos when the gates were opened.

Figure 4: Railway Level Crossing, NH 58



3. Rumble strips (IRC: 39-1986) and signages (IRC 67:2001) were proposed at a suitable distance to serve as a prewarner to the traffic-calming measures lying ahead.

Construction of proposed Traffic-calming Measures at Meerut Railway Crossing

The concrete median pieces, each measuring 30 cm in width, 17.5 cm in depth and approximately 30 cm in length, were pre-cast and brought to the site in cartloads. They were, however, not laid as specified. As per the specifications, 7.5 cm of the 17.5-cm-high section were to be below the surface while only 10 cm were to be visible from outside. The idea was to put up a mountable divider. Instead, the whole of the 17.5-cm section was simply put in the middle of the carriageway and aligned manually. This had obvious disadvantages –most notable was the breaking of the alignment on one or two occasions when a vehicle grazed past it. Also by putting the whole 17.5-cm of the section over the surface, it had turned into a non-surmountable median posing as a source of damage to vehicles that hit it accidentally.

The delineator indicated the beginning and end of the median. However, the base of the delineator marking was almost 50-cm wide, much more than the median. The delineator was designed to leave a maximum possible carriageway for movement. In fact, it defeated the purpose of restricting the median width. Quite a few times, heavy vehicles grazed past, the extra few centimeters jutting out into the carriageway at the base of the delineator thereby damaging it. This prompted the site engineer to put concrete slabs on the carriageway at about 20 cm distance from the base. Such a move also added to the slowing down of the vehicles apart from measures such as rumble strips, signboards and the median itself.

The bituminous rumble strips were supposed to be laid (IRC: 39-1986) at a height of 1 inch (25 mm), but they had been laid at a height of 1.5 to 2 inches. Thus, it effectively served as a speed-breaker instead of a pre-warner to the speed-breaker. Also, as it was not constructed onto the shoulder, two-wheelers and even cars were trying to avoid it by going over the shoulders.

Conclusion

Traffic on Indian national and state highways is very different from traffic on highways in the Western countries. Often highways pass through towns and villages and therefore are required to serve the needs of fast moving traffic as well as those of local slow traffic. The limited experiments of traffic calming devices conducted on selected sites illustrate that optimal speed management of high traffic needs complete corridor planning. This includes using rumble strips as pre-warners, speed humps as speed reducing devices with appropriate signage. The existing traffic calming measures (speed humps) do not conform to standards and lack proper marking and signage. Such devices reduce vehicle speed at that spot, however, they do not result in the desired speed reduction over a corridor and are resented by the vehicle drivers. The behaviour of motorised two-wheelers, heavy vehicles (trucks and buses) and cars (passenger cars, jeeps) varies in terms of average speeds and distance from the speed hump at which these vehicles reduce their speeds. Therefore, more detailed experiments are required to evolve effective traffic calming designs suitable for the current mix of traffic present on our highways.

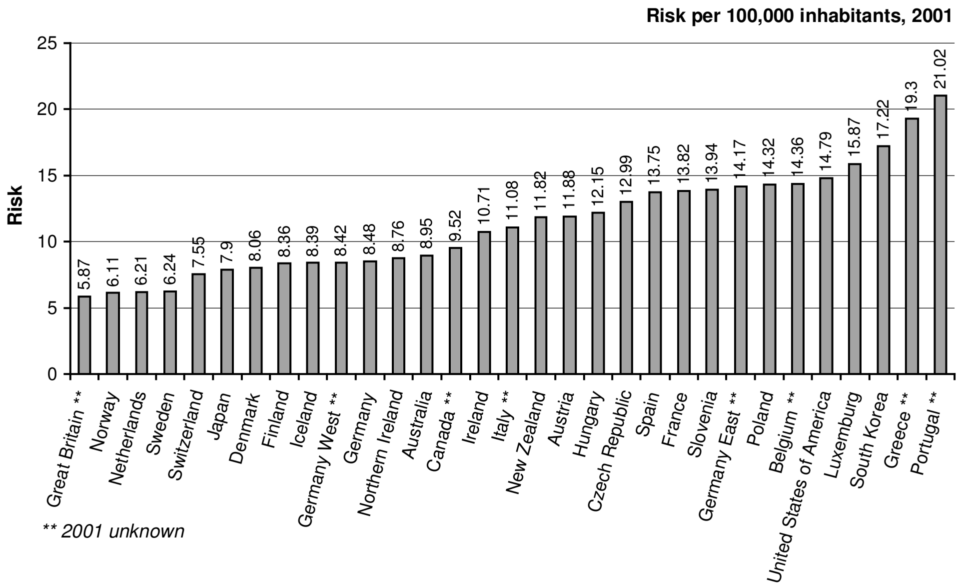
SAFER ROADS BY APPLYING THE CONCEPT OF SUSTAINABLE SAFETY

P van Vliet and G Schermers*

The Netherlands is a small, well-developed European country with an area of 33,870 sq km, located on the west coast of the North Sea. With a population of about 16 million people, it is one of the most densely populated countries in the world. The country has an extensive road network comprising a total length of some 120,000 kilometres. The road network is the responsibility of the central government (national routes), provincial governments (regional routes), local governments (local urban roads) and the Union of Waterways (mainly local rural roads).

In 2002, there were 1,066 traffic-related deaths and some 19,000 serious injuries in the Netherlands (CBS, 2003). In terms of road safety (injury-accidents per 100,000), the Netherlands rates as one of the safest countries in the world. Annually, traffic accidents cost the Dutch society some •7,5 billion (SWOV, 2000).

Figure 1: Traffic fatality rate in a number of countries per 100,000 inhabitants



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Road safety has for a long time ranked high on the political agenda. As far back as 1985, long-term road safety targets were set for 2000 and 2010. The means to achieve these were periodically reviewed, revised and documented in so-called multi-year traffic and transport plans (meerjarenplan). The target set for 2000 was a 25 per cent reduction in traffic-injury casualties, whereas the 2010 goal was a reduction of 40 per cent in traffic fatalities and of 50 per cent in serious injuries. The goal for 2000 had been achieved, and the indication is that the trend in road accident fatalities is still downward (Figure 2), while the number of serious-injury victims appears to be stabilising (Figure 3).

Figure 2: Fatal injuries (1984-2002)

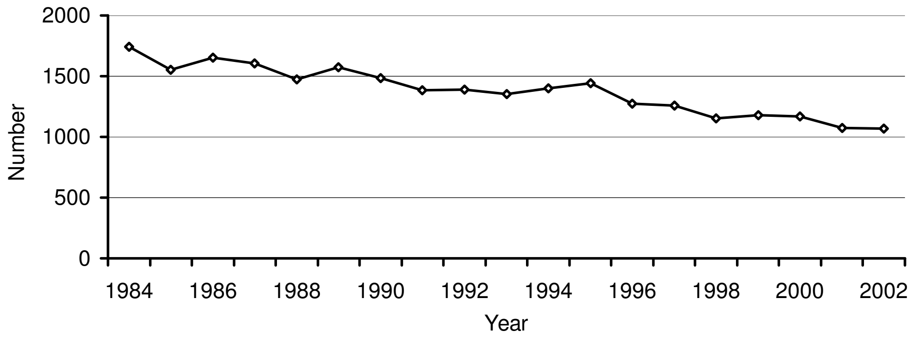
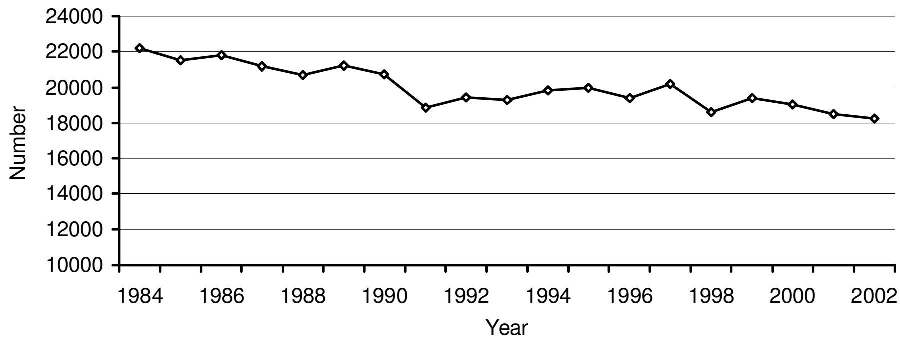


Figure 3: Serious injury victims (1984-2002)



The initial road safety policy was strongly directed at protecting vulnerable road users (logical, because cycling is a major mode of transport in the Netherlands) and hazardous locations, and reducing the most common form of accidents. Consequently, the policy focused on the following central themes (or spearpoints): the elderly, cyclists and moped riders; driving under influence of liquor; use of safety devices (mainly seatbelts, motorcycle helmets and child restraint systems); high speed; heavy goods vehicles; and hazardous locations (blackspots).

Towards the end of the 1980s, it became apparent that the spearpoint policy, although initially successful, could by itself not meet the targets set for the long term. A new strategy was needed if the downward trend in road fatalities was to continue. The Institute for Road Safety Research (SWOV) had for a number of years been analysing the road safety situation in the Netherlands and, on the basis of an in-depth analysis, the concept of sustainable safety was launched (SWOV, 1990). Although favourably received on all fronts, the implementation of the programme did not commence till 1998.

The principles outlined by the sustainable safety approach have since become the basis for the design and layout of Dutch road infrastructure. However, sustainable safety means more than road infrastructure. It is an integrated approach and includes aspects related to the humans, vehicles, land use, and mobility. Unfortunately, the approach has a drawback in that infrastructure measures are often costly and cannot always be implemented due to space constraints. Phased implementation and a degree of creativity are therefore essential.

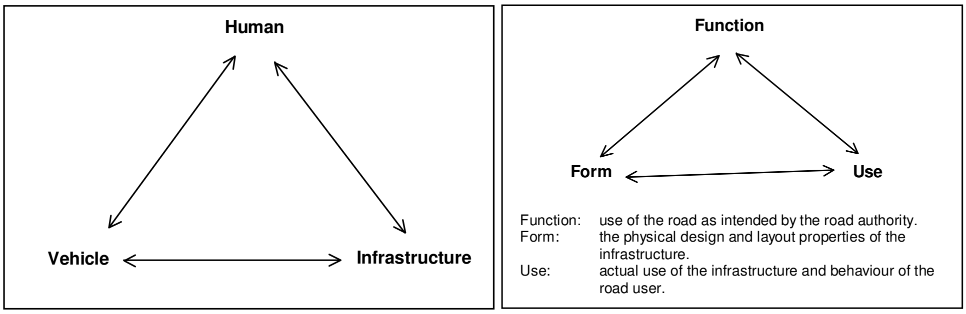
PRINCIPLES OF SUSTAINABLE SAFETY

In contrast to the spearhead policy, the sustainable safety strategy is characterised by a proactive and preventive approach. The spearpoint-policy was a reactive (and curative) approach aimed at addressing problems. Sustainable safety has “prevention is better than cure” as its motto.

Sustainable safety principles recognise that 90 per cent of the road accidents are attributable (to a greater or lesser extent) to human error. Consequently, a human being is the weakest link in the traffic and transport chain. Furthermore, people do not readily change or adapt, and many attempts at influencing road-user behaviour have either had merely short-term effects or failed. The limitations of a human being remain evident. Motivation, attention, emotion, observation, prediction, knowledge, and skills are the various aspects that influence human behaviour, and prevent people from being the ideal traffic participants.

In a sustainable safe traffic system, the humans take the central role. They are therefore incorporated in sustainable safety as a reference against which other system elements are gauged. Sustainable safety is based on a systems approach where all elements of traffic safety and the transport system are geared to one another. At the highest level, it is interaction among man, vehicle, infrastructure and legislation. At the next level, it is the relation between function, form, and usage.

Figure 4: The systems approach of sustainable safety



Function relates to the use of the infrastructure as intended by the road authority, form to the physical design and layout properties of the infrastructure, legislation to regulatory requirements for the use of the infrastructure, and usage relates to the use of the infrastructure to the behaviour of the road user.

A sustainable safe traffic system has the following elements:

- a road environment with an infrastructure adapted to the limitations of the road user;
- vehicles equipped with technology to simplify the driving task and provided with features that protect vulnerable and other road users; and
- road users that are well informed and adequately educated.

ROAD CATEGORIES AND SAFETY PRINCIPLES

Sustainable safety distinguishes the following three categories of roads:

- roads with a through function (for the rapid movement of through traffic);
- roads with a distributor function (for the distribution and collection of traffic to and from different districts and residential areas);
- roads with an access function (providing access to homes and shops while ensuring the safety of the street as a meeting place).

Each category of roads requires a design compatible with its function, while at the same time ensuring optimum safety. To meet the latter requirement, all road categories should comply with the following three safety principles:

- functionality (preventing unintended use of the infrastructure);
- homogeneity (preventing major variations in the speed, direction, and mass of vehicles at moderate and high driving speed);
- predictability (preventing uncertainty among road users).

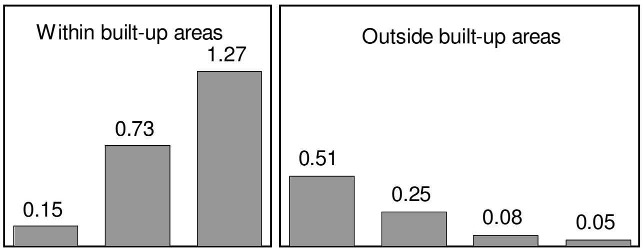
Preventing unintended use of the infrastructure

It is very important to make a clear distinction between roads with a through function and roads with an access function. Through traffic is absent on roads with an access function, and local traffic is not there on roads with a through function. For example, roads carrying long-distance traffic should not carry local traffic, which needs to stop frequently and access abutting landuse. This requirement has implications for the road designs. Roads with an access function should not offer time-saving alternative routes (rat runs) to through-traffic (that is, traffic travelling to or from a location outside the immediate area); and roads with a through function should not offer direct access to homes, schools, offices, factories, sports facilities, etc.

Preventing variations in speed, direction, and mass of vehicles at moderate and high speed

The severity of road accidents is usually determined by differences and variations in speed, direction, and/or the mass of vehicles. In the Netherlands, the safest roads are the freeways (Figure 5). Although driving speed there is the highest, it is relatively uniform. There is little variation in direction (e.g. no crossing traffic) and vehicle mass (no cyclists, mopeds, etc.). Also, relatively safe are the 30-km-per-hour zones and residential areas, despite considerable variation in the direction and mass of traffic participants. In these cases, the increased safety is attributable to low driving speed and small speed variations between different road users.

Figure 5: Road accident casualty rates on different road classes (SWOV, 1995)



Number of casualties per 10^6 km travelled type of road	Resd. access street	Collector	Arterial	Rural road	Rural arterial	Express-ways	Free-ways
Max. speed km/h	30	50	50/70	80	80	100	100/120
Mixed traffic	yes	yes	yes/ no	yes	no	no	no
Grade separation/ median	no	no	no/yes	no	no/yes	yes / no	yes

* ctct = Closed To Certain Traffic

The roads that fall between trunk roads (freeways and expressways) and access roads require special attention, since they are the most dangerous. These are roads with a distributor function. Here, vehicles travel at fairly high speed and there is a great deal of intersecting traffic. Safety on these roads requires a separation of motorised and non-motorised traffic (e.g. separate cycle lanes). This reduces variations in traffic speed and vehicle mass. At locations where motorised and non-motorised traffic intersects, low maximum speed has to be introduced, or traffic has to be separated in time (e.g. through traffic signals, roundabouts, etc.). At intersections, roundabouts are preferable. Traffic signals can cause large variations in driving speed (e.g. when drivers ignore red lights) although these are smaller than speed variations at uncontrolled intersections.

Preventing uncertainty among road users

To prevent uncertainty among road users, roads should be constructed and marked to make obvious what sort of traffic conduct is expected. In other words, the road must be 'self-explanatory.' To have a clear distinction between road categories, the number of road classes should be restricted, and their design and layout made as uniform as possible within each category. Road users will then have a better idea of what sort of driving behaviour is expected of them, and will be better able to anticipate the driving behaviour of other road users. With self-explanatory roads, road users will know at what speed to drive, whether to expect traffic from side roads, and whether cyclists are likely to be on the road.

General design criteria

Applying the sustainable safety principles described above, functional and operational requirements were formulated (CROW, 1997) for the three road categories.

The 12 functional requirements of a sustainable safe road network are given below:

- The traffic-restraint areas (areas of mixed use) must be continuous and as large as possible;
- The smallest proportion of the trip must occur on the relatively unsafe part of the road network, i.e. distributor roads;
- Minimise trip lengths;
- Combine the shortest and safest routes;
- Travellers must not have to search for destinations;

- Make the different road categories unique and recognisable to the road user;
- Limit the number of engineering solutions and keep them uniform;
- Avoid traffic conflicts with traffic moving in opposing directions;
- Avoid traffic conflicts with traffic crossing the road;
- Reduce speed on approaches to potential conflict points or locations;
- Avoid obstacles along the roadway.

Based on these functional requirements, operational requirements were developed (CROW, 1997) for each rural and urban road category (Tables 1 and 2). Important to note is the fact that in urban areas only two road categories have been provided, namely distributor and access roads (Table 2).

Table 1: Operational requirements for roads outside built-up areas (CROW

Operational criteria/design elements	Through (trunk) roads	Distributor roads	Acces
Maximum speed	120/100 km/h	80 km/h	60
Directional signs	Situation dependent on category		
Longitudinal road markings	Full	Partial	None
Number of lanes	2x1 or more	2x1 or more	1
Surfacing	Open graded asphalt or concrete	Asphalt or concrete	Sett-pave (pavingst
Connection with residential areas (property access)	No	Limited or none	Yes
Carriageway separation	Physical median	Difficult to traverse	None
Intersections	Grade separated Interchanges	Roundabouts/traffic control and priority control	Intersecti speed co measures
Parking	No	No	On carria
Provisions for breakdowns	Emergency lane	Hard shoulder or turnouts	None
Obstacle distance	Large	Medium	Small
Bicyclists	Separated	Separated	Situation- depender
Mopeds	Separated	Separated	On the ca
Slow-moving motorised traffic	Separated	Separated	On the ca
Speed-reducing measures	No	Suitable measures	Yes
Public lighting	Dependent on situation and category		

Table 2: Operational requirements for roads inside built-up areas (CROW 1997)

Operational criteria/design elements	Distributor roads	Access roads
Maximum speed	50 or 70 km/h	30 km/h
Directional signs	Dependent on situation and category	
Longitudinal road markings	Partial	None
Number of lanes	2x1 or more	1
Surfacing	Impervious (asphalt or concrete)	Pervious (pavingstone, brick)
Connection with residential areas	Limited	Yes
Carriageway separation	Difficult to traverse	None
Intersections	Roundabouts or speed control measures and priority control	Uncontrolled with speed control measures
Parking	Only in parking facilities	On carriageway
Provisions for breakdowns	Parking lane	None
Obstacle distance	Medium	Small
Bicyclists	Separated	On the carriageway
Mopeds	Separated on 70 km/h roads On carriageway on 50 km/h roads	On carriageway
Slow-moving motorised traffic	On carriageway	On carriageway
Speed measures	Yes	Yes
Public lighting	Dependent on situation and category	

FROM THEORY TO PRACTICE

In order to give extra impetus to road safety policy, a sustainable safety steering committee with representatives from all road authorities was set up in 1995. Its task was to introduce sustainable safety in the short term. Based on the available knowledge, it was concluded that it was not possible to introduce sustainable safety in an integrated manner. There was lack of knowledge with respect to applying the principles and functions of sustainable safety to the design and layout of the most dangerous roads, namely, the distributor roads. Another serious problem was that there were insufficient financial resources to realise the targets of the overall programme in the short term. Consequently, it was decided to introduce the programme in two phases.

The First Phase

The first phase pertained to the introduction of a number of measures known to have a positive effect on road safety. The introduction of this phase was drafted into a covenant named the Start-up Programme of Sustainable Safety (Ministry of Transport, 1997), which was agreed upon and signed at the end of 1997 by the umbrella bodies representing the four levels of road authority.

The measures included for implementation during the start-up programme were:

– expansion of 30- and 60-km-per-hour areas;

- introduction of mopeds on the roadways;
- regulating priority on arterial roads;
- adopting uniform priority regulations on roundabouts; and
- introduction of a general priority from the right rule (including slow traffic, such as cyclists and moped riders coming from the right).

Furthermore, the authorities had to produce new road network classification plans. The purpose of these plans was to reduce the number of road classes in the road network hierarchy to three outside the built-up area, and two within the urban area. These roads will eventually have to be given a layout that makes them unique and identifiable to road users (the concept of self-explanatory roads or SERs). The government granted about •91 million for the implementation of the first phase. In addition to this, the other road authorities jointly contributed an equal amount to the programme.

Till date, virtually all the road authorities have re-classified their road networks. Many 30- and 60-km-per-hour areas have been created (50 per cent of the length of the total urban network), the intersections on the arterial roads have been assigned priority, and the measures – 'mopeds on the carriageway' and "priority for all drivers from the right" – have been introduced.

The Second Phase

During the period from 1998 to the end of 2002, road authorities prepared the next phase as part of a working group. First, the areas for special attention were charted. To this end, comprehensive studies of literature were conducted, and all the major research institutes were consulted. On the basis of the information gathered, favourable courses of action to improve road safety were formulated. The costs and effects of the various measures were then determined. The measures pertained to the following themes: education and information; infrastructure; law enforcement; vehicles and vehicle technologies; land use planning; and the role of the private sector.

The working group came to the conclusion that the implementation of a policy targeted at predominantly infrastructure measures – as was the case in the first phase – was not the correct and most efficient approach for the second phase. The impact of the various measures to reduce road accidents would not be the same everywhere. Moreover, the implementation of certain measures will take more time and require substantial investment. Considering the target date set by the policy, there is little time. After all, by 2010 road accidents will surely be reduced substantially. An additional aspect is that if large-scale improvements in infrastructure are initiated without major maintenance work carried out, it will be counterproductive. It is preferred that these activities are coordinated and this cannot be effectively done at the national level. A regional approach is, therefore, deemed more desirable.

Another important finding of the working group was that road safety policy had hitherto been approached in a sectoral manner. It did not always match with policy adjuncts, such as mobility, accessibility, spatial planning, and the environment. Because road safety had its own consultation committee, it was difficult to successfully integrate road safety into these other policy domains. By integrating overlapping issues in the various policy domains, expensive mistakes can be avoided in future. A typical example is the design and layout of new residential areas. If road safety is included from the outset in the design of new residential areas, expensive investments for remedial treatments and re-engineering (e.g. traffic-calming devices) can be avoided in the future. Road safety must, therefore, be included as a facet in other policy domains.

A third aspect relates to the involvement of the private sector in achieving better road safety. Upto now, the freight transport sector has not truly taken up ownership of road safety. To a large extent, they are unaware of the positive role they could play. At present, transporters largely tend to use road traffic regulations and labour laws (e.g. driving hours) as the basis for their contribution. Generally, it is assumed that if these are complied with, no further actions are required. However, the opposite is true when one realises the motives that result in transgressions of these laws and regulations. Often, these play a role in road accidents, and operators need to impress upon their drivers the need to make road safety part of their everyday work. The development of safety culture within this sector offers excellent opportunities of tackling road safety at the source. Here again there is a win-win opportunity. Apart from the immaterial side to this issue, financial gains may be expected because drivers will less often be involved in accidents, thereby reducing the time required to recuperate (sick leave). Vehicles will incur less damage and there would be less delay resulting from incidental congestion caused by road traffic accidents.

The distinction between the first and second phases of sustainable safety can be characterised as follows: not sectoral but integral; not national but regional; the involvement of not only the authorities but also the private sector and individuals; and not measure-driven but dependent on the regional situation.

The second phase of the sustainable safety programme deals with the primary issue of translating national and safety targets into regional targets. Two years ago, the government started a process with the provincial, metropolitan and local authorities to translate the national targets into equitable regional targets. After weighing the various possibilities, it was proposed that the national target should be divided proportionately across the 19 regions (12 provinces and 7 metropolitan areas), with each area having an equal percentage reduction in the number of deaths and injured/hospitalised (at least 30 per cent fewer fatalities and 25 per cent fewer serious injury/accident victims). A correction was applied to those regions where the growth rates of certain demographic variables (population, car ownership, etc) were expected to materially differ from the national average. This correction ensured that targets remained realistic and took into account regional differences. A better distribution on the basis of road length, road type, and traffic volume will be introduced as soon as more data relating to the underlying road network become available. Currently, data, especially on traffic volumes on many roads on the underlying network, are lacking.

The institute for road safety research, SWOV, had calculated that the cost of implementing Phase II of Sustainable Safety will be about •5.3 billion (SWOV, 2000). Considering the present economic situation and the fact that there is a maximum amount of •700 million available, it is evident that less ambitious road safety targets will need to be set for 2010.

The provincial and metropolitan authorities coordinate the development of integrated packages of measures aimed at meeting regional targets. These packages will be determined on the basis of an analysis of road accidents in the region using risk-assessment methods, road-accident data, and monitoring instruments that have now been developed for identifying road hazards in certain regions. The best potential solutions can be specified using methods now available for determining the causes of accidents. The solutions will include not only infrastructure measures, but also measures to influence road user behaviour, such as intensified enforcement of traffic regulations, education, and/or public awareness.

To facilitate this, the first version of a catalogue of measures is being developed. The catalogue gives an insight particularly into the expected effects of infrastructure measures, and provides costs associated with these. Over the next few years, this catalogue will be further improved and amended on the basis of evaluations of road safety measures implemented.

ROAD SAFETY MEASURES

Precisely which measures are needed depends on regional conditions. What is important is that the regional authorities should put together an optimum mix of measures. The possible measures, among others, include:

- conversion to 30- or 60-km-per-hour areas (speed restriction, safe intersections on arterial roads, adaptation of traffic circulation so that through traffic is concentrated on arterial and trunk roads);
- redesigning arterial roads (separating different types of traffic according to direction, speed and/or mode of transport, converting intersections, for example, into roundabouts, introducing parking measures and providing uniform road markings);
- communication in combination with enforcement of traffic regulations (e.g. those related to use of alcohol, drugs and medications that influence driving behaviour, promotion of seat belts and helmets, speed checks, and bicycle lights);
- activities targeted at schools, scholars and parents;
- out-of-school education and training (e.g. moped course, refresher courses in road safety knowledge, training courses for parents);
- projects such as enhancing awareness, promoting safety culture and encouraging the use of safety devices in specific target groups (e.g. businesses, associations and different kinds of road users).

TASK OF THE GOVERNMENT

Freeways are an inseparable part of the regional networks. The working method is an integrated approach and therefore authorities at all levels have to take part. The government has its own responsibilities in applying measures (e.g. speed limits, driving hours, seat-belt use) that need to be introduced at the national level and which in turn are limiting conditions for the regional policy. Consequently, the government will also have to conduct many of these activities in cooperation with regional and local authorities, and, in certain cases, with the private sector and pressure groups. The activities planned at the national level are:

- development of a package of measures to improve the safety of vulnerable road users (pedestrians, cyclists, moped and motor-bicycle riders, motorcycle riders). This entails enforcing stricter vehicle standards, registration numbers, requirements of driving capability and driving ability, etc.
- giving quality incentives to the transport sector and commercial traffic, resulting in guarantees for efforts in the area of road safety;
- development of regulations to combat drugs that adversely influence driving behaviour, and monitoring these;
- measures targeted at newly qualified drivers (provisional driving licences, alcohol limit of 20 mg/100 ml);
- tightening of requirements for driving capability and driving ability at the European level;
- development of a mobility test for spatial planning processes;

– conducting research in association with the European Union on (vehicle) technologies aimed at promoting safer driving behaviour (intelligent speed governors, data recorders, etc.).

All these activities are included in the government's policy calendar of the National Transport Plan (*NVVP*, *Ministry of Transport*, *2002*). This policy calendar will be updated every two years on the basis of the results of monitoring and progress in carrying out the current government calendar (planned activities).

INSTRUMENTATION

The instrumentation needed to implement the measures described will, to a large extent, be developed in cooperation with other road authorities. An example of this is the current deliberations on the desired structure for joint knowledge development, and its dissemination and distribution in the area of road transport. An important element here is policy direction that is to be developed for the different knowledge platforms.

The Information and Technology Centre for Transport and Infrastructure has been commissioned by the government and other authorities to develop, amongst others, guidelines for the design of infrastructure and methods for analysing accident black-spots and dangerous areas. The Institute has been entrusted with the task of developing guidelines with the necessary support, and, if necessary, subjecting them to administrative tests. The Institute also functions as a centre of knowledge and many road authorities make use of its expertise.

Over the last three years, all the guidelines for roads outside the built-up area have been reviewed. This involved not only updating them, but also adapting them to the new sustainable safety road network classification. Draft guidelines have now been prepared for trunk roads, distributor roads, and access roads outside the built-up area. Discussions related to these guidelines are held at national workshops, and as far as possible, generally acceptable solutions are developed.

At present, a working group is developing minimum norms and layout requirements that will be set for infrastructure. These norms and requirements will have to be administratively adopted by the authorities. The supporting guidelines can be voluntarily applied as a sort of a design and implementation toolbox.

In addition to guidelines and other related resources, an information centre has been established to assist road authorities with their queries relating to the design and layout of infrastructure based on the principles and requirements set by the sustainable safety programme. The centre can be contacted via the telephonic helpdesk or the website, which has links to questions frequently asked, background information and supporting publications and resources.

EXAMPLES OF TRAFFIC CALMING IN THE NETHERLANDS

The choice and application of speed-reducing and attention-raising measures are to a large extent dictated by the road class. The type and layout of the measures must be in accordance with the expectations of the road user. In other words, the measures selected for a specific road class must solicit the desired behaviour from the road user.

The expectations of road users have been found to play an important role in causing road accidents (Malaterre, 1989). A study found that 59 per cent of the accidents investigated were the result of unexpected conditions leading to incorrect judgements of the traffic situation. Because expectations play such a significant role, it is important that road design and the view of the road take these expectations into account. The type of road that by the very nature of its design provokes safe road user behaviour is termed as a self-explaining road (SER) (Theeuwes & Godthelp, 1992).

To an extent, freeways and 30-km-per-hour roads in the Netherlands can be termed SERs. Compared to other road types, these roads are relatively safe because of their design and function. On freeways, road users know not to expect crossing or opposing traffic; they also know they are on a freeway with a maximum speed of 100 or 120 km per hour and there are no cyclists, pedestrians and other slow-moving traffic. In 30-km-per-hour zones, road users know they are in an urban environment and because of the proximity of, and accesses to, houses and buildings, and also because of road space being shared with other road users (cycles, pedestrians, etc.) they must drive slowly. Those roads where there is uncertainty regarding maximum speed, types of traffic modes, traffic situations, etc. are also the most dangerous roads. Table 3 gives the characteristics of different categories of roads.

In the Netherlands, urban access roads are almost always provided with a layout for 30-km-per-hour zones. These zones are designed in such a way that road users maintain a low speed limit (i.e. self-enforcing). In situations where this is not the case, the cause is often traceable to over-dimensioning, use and function of the road and type of surfacing. Surfacing plays an important role in emphasising road class. Asphalt surfacing is almost always associated with high-speed, higher-order road, whereas paved or cobbled surfacing is almost always associated with a low-speed, lower-order road.

Table 3: Characteristics of different road categories

Road type	Urban areas	Rural areas
Access roads	– recognisable gateway – speed 30 km/h – no longitudinal road markings – no directional separation – uncontrolled intersections – mixed traffic – speed calming measures between and at intersections	– recognisable gateway – speed 60 km/h – no longitudinal road markings – no directional separation – uncontrolled intersections – mixed traffic – speed calming measures between and at intersections
Distributor roads	– 50 km/h speed limit – longitudinal road markings – directional separation – controlled intersections – cyclists on cycle paths – no speed humps/bumps or plateaus	– 80 km/h speed limit – longitudinal road markings – directional separation – controlled intersections – cyclists on cycle paths – no slow motorised traffic – no speed humps/bumps or plateaus
Through roads		– speed 100 or 120 km/h – longitudinal road markings – directional separation with a barrier – intersection grate separated – no slow motorised traffic – no speed hump/bumps or other physical measurers

Shortcomings in the design of lower-order roads almost inevitably necessitate the implementation of speed-reducing traffic-calming measures. In the Netherlands, the most common are speed humps on road links and (raised) plateaus at intersections. Although these measures generally are effective when constructed according to Dutch guidelines, they have been known to cause increases in noise and vibration in certain situations. With specific types of soil, the measures cannot be implemented due to vibration and subsequent damage to buildings. Alternative solutions to vertical measures are those that restrict or prevent certain traffic movements within the network. Examples of such measures are full or partial closures, one-way systems, traffic chokers and chicanes. The last mentioned have been known to elicit reckless behaviour mainly among young motorists and motorcyclists. It becomes a challenge to see how fast the measure can be negotiated.

The entrance to a 30-km-per-hour zone is characterised by gateway treatments with speed-restriction signposting. In cases where the design of gateways is not optimal and therefore may not always be recognisable to road users, the treatment is supplemented by installing a raised plateau (a trapezoid-shaped speed-hump) on the roadway.

An optimal design and implementation of 30-km-per-hour zones can result in a reduction of 20-70 per cent in accidents (Table 4). If the zone is realised on the basis of minimum requirements, the reduction is estimated at 10-20 per cent.

Table 4: Road safety effects of measures on urban access roads

Measure	Estimated reduction in accidents (%)	Reference
30 km/h zones with optimal layout	20 - 70	SWOV 1993
30 km/h zones with a sober layout	10 - 20	Maatregel-Wijzer 2001
Plateaus at intersections	20	Maatregel-Wijzer 2001

DISTRIBUTOR ROADS

Traffic function is predominant on distributor roads, which in the Netherlands have a maximum speed limit of 50 or 70 km per hour. As a rule, non-motorised and motorised traffic are physically separated (i.e. separate roadway, cycle path and pedestrian walkway). Crossing is facilitated predominantly at T intersections; and where this is not possible, zebra crossings. Wherever necessary, other speed-reducing measures have been provided. Because mid-block pedestrian crossings are generally less safe, these are usually signal-controlled. In situations where space is limited and separate cycle paths cannot be provided, a cycle lane is provided on the roadway.

Road width is generally based on a driving speed of 50 km per hour. On distributor roads, the number of intersections and accesses need to be restricted to a minimum. The preferred form of intersection control at the intersections of two distributor roads is a roundabout with separate provisions for cyclists. Where this is not possible, traffic signals are installed as the next best alternative. Intersections with access roads are generally priority-controlled and, as a rule, provided with a threshold treatment. Threshold treatments are usually in the form of a long flat-topped (trapezoid) speed hump across the approach of the minor road. In cases where major intersections are frequent and regularly spaced, it is desirable to minimise crossing traffic at minor intersections. This can be achieved by providing deflection islands that prohibit certain movements (e.g. right in–right out islands).

Vertical speed-reducing measures are in principle not applied on distributor roads, a choice motivated by the discomfort and hindrance they cause to the emergency and public transport vehicles. The fact that the choice of speed-reducing measures on distributor roads is limited implies that in situations where roads are wide and cover long stretches, speeding will be a serious problem. Law enforcement is often the only means available to ensure that speed limits are obeyed.

During 1999, the Netherlands introduced legislation that made it mandatory for mopeds (with a maximum speed of 45 km per hour) to share the roadway with other forms of motorised traffic. Prior to that, mopeds used the cycle paths, but road accident studies revealed high proportions of moped/cyclist, moped/car and moped/pedestrian accidents. Based on the success of a number of pilot projects, it was decided to introduce the measure nationally. Since its introduction, the measure appears to be having a positive effect (Table 5).

Table 5: Effects of different measures on urban distributor roads

Measure	Estimated reduction in accidents (%)	Source
Roundabouts	70	Maatregel-Wijzer 2001
Separate provisions for cyclists	10 - 20	Maatregel-Wijzer 2001
Moped on the roadway	20	AVV 2001

RURAL ROADS

Access roads

The introduction of the start-up programme of sustainable safety also brought into being a totally new category of rural roads, namely, the 60-km-per-hour rural access roads, and with that a new concept of 60-km-per-hour zones in rural areas. Similar to the urban 30-km-per-hour zones, the entrances into the 60-km-per-hour zones are provided with gateway treatments.

Sixty-km-per-hour roads are characterised by the absence of a centre-line marking. Where the paved carriageway is wide, broken edge-line markings are introduced to create a narrowing visual effect. In these cases, the distance between the road edge and the edge-marking must exceed 40 cm. If required, a cycle lane with a width of 120 cm can be provided, and this may be at the expense of the lane reserved for motorised traffic. In such cases, when opposing vehicles meet, they temporarily move to the right and make use of the cycle path until they have passed each other. If there are cyclists, vehicles remain behind them until it is safe for them to pass.

Where the roadway has insufficient width to accommodate two passing vehicles, it is not widened. To prevent damage to the shoulders, these are hardened using a porous concrete paving block. Since these do not create the impression that the road is widened, grass and plants can grow through them, motorists do not permanently use them, and vehicle speed is not positively influenced.

A characteristic of 60 km-per-hour zones is that measures are limited to potentially dangerous locations only. The most common measures that are applied include 60-km-per-hour plateaus, road narrowing and mini-roundabouts.

Distributor roads

From road accident rates, it is evident that roads with a mixed use and high speed have the highest risk. In cases where non-motorised and motorised traffic are separated and the speed difference in motorised traffic is kept fairly small, the accident risk decreases markedly. On rural distributor roads, separate facilities for motorised and non-motorised traffic are provided for sustainable safety. Ideally, separate facilities in the form of parallel roads are also provided for slow-moving motorised traffic (e.g. agricultural tractors, combine harvesters). However, because of the extra cost and restricted space, parallel roads can seldom be provided. Ideally, a rural distributor road comprises separate parallel roads, cycle paths and a two-lane two-directional roadway with narrow hardened shoulders, a speed limit of 80 km per hour, an overtaking ban and a restriction for certain vehicle types.

The large proportion of head-on collisions resulting from overtaking is another concern on rural distributor roads. In an attempt to curtail this, road authorities in the Netherlands have been applying overtaking bans in the form of a solid, double-barrier line or a physical separation between the lanes. The measure has been reasonably successful. The application of the restriction has resulted in a decrease in the number of accidents resulting from overtaking. Travel speed has been reduced as a result of the narrowed road profile. Attitudinal studies among road users have shown that some 80 per cent of the respondents were generally in favour of the measure. A large proportion of them preferred the physical restriction above the double-barrier lane.

Single-vehicle accidents are another cause for concern on rural distributor roads. Soft shoulders and obstacles in the verge often play a major role in these accidents. Ensuring that shoulders are hardened or partially hardened and increasing the requirements for the roadside recovery distance (clear roadside area or zone) will positively contribute to road safety on these roads. These issues have been addressed in the new Handbook for Road Design (CROW, 2002), and the measures suggested are currently being implemented on a number of roads in the Netherlands. To conserve costs, these issues are generally integrated into reconstruction or major maintenance projects. It will therefore take a considerable time before all rural distributor roads have overtaking bans, (partially) hardened shoulders, and safer roadside recovery distances.

The recommended form of controlling intersections of two rural distributor roads is the roundabout. Both during the day and night, roundabouts reduce speed, ensuring a safe and efficient throughput. In contrast to this, traffic signals have a tendency to increase approach speed and red-light violations are frequent, especially late at night. Both these have a negative effect on road safety. To compensate for the increased speed, traffic signals are set to rest in red during the quiet night hours. Red-light violation cameras are placed to monitor offenders. Currently, experiments are being conducted to evaluate the effectiveness of 60-km-per-hour speed humps on the approaches to signalised intersections. Estimated effects of measures on rural distributor road on accidents are given in Table 6.

Table 6: Estimated effects of measures on rural distributor road on accidents

Measure	Estimated reduction in accidents (%)	Source
Roundabouts	70	Maatregel-Wijzer 2001
Treated shoulders/clear zones	20	Maatregel-Wijzer 2001
Overtaking ban	10	Maatregel-Wijzer 2001
Signals plus speedhumps	25	Verkeerskunde 1-2002

Trunk roads

The majority of trunk roads comprising the primary road network are freeways. All freeways have divided carriageways and grade-separated intersections, and are provided with paved emergency lanes. The speed limit on freeways is 100 or 120 km per hour, and vehicles that cannot or may not travel faster than 80 km per hour may not use freeways.

Relative to other road classes, freeways in the Netherlands have the lowest injury/casualty rate. The majority of the principles enshrined in sustainable safety have already been applied in the design and operation of freeways and hence it is unlikely that the sustainable safety programme will have a material affect on the current levels of safety on freeways. Some one-third of the accidents on freeways are single-vehicle accidents. This implies that improvements with respect to protection in the medians and verges are possible.

Besides freeways, the Netherlands also has single-carriageway motorways (expressways) as part of the trunk road network. To comply with the principles of sustainable safety, these roads should have grade-separated intersections and should be dual carriageways (or at least be provided with some form of median separation). However, due to high costs associated with these changes, it is not expected that this will be realised in the short term. As an interim measure, it has been recommended that an overtaking ban using a double-barrier line be introduced as a standard measure on single carriageway trunk roads. To distinguish this road class from the 80-km-per-hour rural distributor, it has been proposed to colour the area between the solid barrier lines green (virtual barrier).

Research is being conducted to assess the viability of adopting the three-lane single carriageway road, where the middle lane is alternately used as an overtaking lane. This alternative has been implemented with varying degrees of success in Germany, Sweden and Denmark. In the literature it is claimed that this type of road is 25 per cent safer than a traditional two-lane single carriageway road where overtaking is allowed.

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ROLE OF TRAFFIC CALMING AND SPEED REDUCTION IN ROAD SAFETY

Dinesh Mohan*

The number of people killed and injured in road accidents is on the increase throughout the world. In this, there are two trends: a stabilisation in the number of accidents in highly motorised countries (HMCs) and a continuing increase in accidents in less motorised countries (LMCs). HMCs are those where annual per capita income is $8,000 and more, and the principal mode of transport is personal car. In LMCs, per capita income is generally less than $8,000 per year, and people avail of non-motorised modes of transport, public transport and motorised two-wheelers.

Accidents in LMCs and HMCs differ considerably in pattern[1,2]. In LMCs, vulnerable road users (VRUs) are a vast majority of the victims, most of the colliding vehicles being trucks and buses. Car travellers comprise less than 10 per cent of the victims in most of these countries. On the other hand, in HMCs, car travellers are more than 40 per cent of the victims, and cars are involved in a majority of the accidents.

It is interesting that though road safety has for decades engaged the attention of the lay public, policymakers and the media, progress in this area has been slow or non-existent in many countries. This is partly because the science of road safety is still very young and very few professionals are aware of the scientific evidence base accumulated over the years in this regard. Figure 1 shows the number of people killed in road accidents in different cities per million people. The data are plotted according to the per capita income of the country in which the city is located. Data show that there are wide variations in per capita death rates within similar income groups and within the same country. Even more interesting is that per capita fatalities for cities seem to be similar across income levels, though modal shares by victim types could be different. This shows that even when policies, vehicle types and drivers' knowledge are similar in a country, fatality rates can differ across cities. There is indirect evidence to prove that fatality rates are determined by modal shares, road design and vehicle speed.

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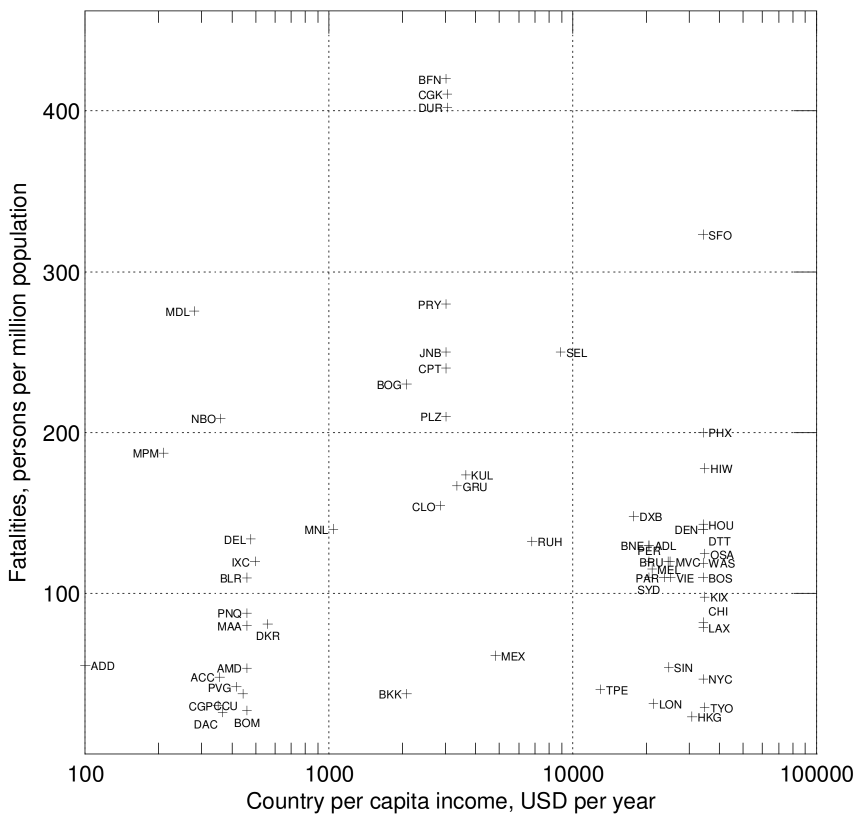
Figure 1: Road traffic fatalities in major cities



The above is further corroborated by a recent study of the comparisons of traffic fatality rates in Sweden, the United Kingdom, the Netherlands[3] which concludes as follows:

– Fatalities tend to change proportionally with changes in average speed in a double quadratic way. For example, an average speed reduction by a factor .95 gives an expected reduction of fatalities by a factor $(0.95^2)^2 = 0.815$, or a 5 per cent reduction in average speed gives an 18.5 per cent reduction in expected fatalities.

– The simplest explanation for the lowest car occupant fatality rate and the lowest total fatality rate of Britain is that Britain has a lower speed level than Sweden due to higher traffic density;

– Road improvements are in general likely to increase traffic and therefore casualties, particularly where the main impact is increase in vehicle speeds on the existing roads.

- It is clear from the comparison that an important factor in achieving a low fatality rate per vehicle kilometre in Britain is higher traffic level which leads to lower speed and distribution of risks among more road users.
- The European Union's target of a 50 per cent reduction in fatality rate has to be achieved through national road safety measures, in addition to vehicle safety measures in the EU.

Though the impact of "improvements" in road infrastructure on road safety is not clear, there is adequate evidence to show that design features can limit speed, prevent destructive impacts, and provide safe mobility to vulnerable road users. A guiding principle in this respect is that road environment and infrastructure must be adapted to the limitations of the road user[4]. Traffic-calming techniques, use of roundabouts, and provision of bicycle lanes in urban areas have provided significant safety benefits[5,6]. Traffic calming comprises a combination of road and infrastructure measures that reduce the negative effects of motor vehicle use, alter driver behaviour, and improve conditions for non-motorised street users.

EVIDENCE

There is enough evidence to show that lowering speed limits on expressways and urban roads results in fewer fatalities and injuries[7]. The data show that increase in the speed limit from 55 mph to 65 mph on interstate highways in the US resulted in a 2-4 mph increase in the mean speed and a 19-34 per cent increase in fatalities. Reduction in the speed limit by 10-20 km/h on motorways and rural roads in Switzerland and Sweden resulted in a lessening of fatalities by 6-21 per cent. In 1987, the state of Illinois in the US raised the speed limit from 55 to 65 mph on rural highways. A study shows that this resulted in 300 extra accidents per month in rural Illinois[8]. Some have argued that changes in speed limits on certain roads lead to changes in exposure rates on those roads, and these changes should be taken into account before calculating benefits or losses. This argument is important for understanding the theoretical issues involved, but is not of much consequence for assessing the detrimental public health effects of high speed.

Effects of speed limits in urban areas have also been studied by several researchers. Fieldwick and Brown studied the effects of speed limit on casualties in 21 countries and concluded that reducing the speed limit from 60 km/h to 50 km/h would result in a 25 per cent reduction in fatalities and casualties[9]. A reduction in the speed limit from 60 km/h to 50 km/h in Zurich is reported to have caused 24 per cent fewer pedestrian fatalities.

Small reductions in speed result in large reductions in injuries and fatalities both in the urban and rural areas. This is due to the following reasons:

- The chances of accident are high at high speed;
- The stopping distance of a vehicle applying the brake is proportional to the square of the original velocity; and
- The damage to human beings is related to the square of the impact velocity.

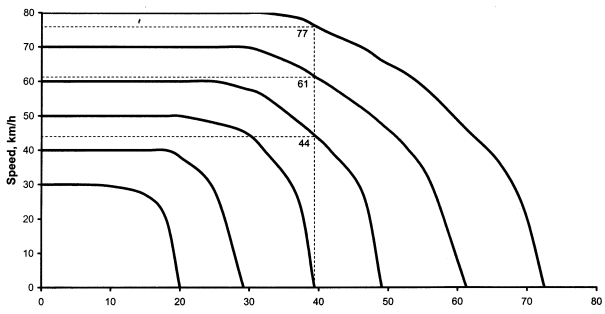
REACTION TIME

Low initial speed means that the driver has better control of the vehicle and the vehicle can stop much earlier and reduce the chances of crash. A recent study shows that the time for initial steering (defined as the point at which the driver first begins to use the steering to avoid the crash) can be about 1.7 seconds and the period between the point at which the driver begins to release the accelerator pedal and the maximum brake application point can be 2.2-2.3 seconds. This means that a driver driving at 80 km/h will have travelled 14 metres extra before making a corrective steering manoeuvre, than the person driving at 50 km/h. Similarly, at 80 km/h a driver will cover an extra 19 metres before applying the brakes compared to the driver going at 50 km/h.

BRAKING DISTANCE

The stopping distance of a vehicle applying the brake depends on the square of the original velocity. When this is combined with extra reaction time, we see that the distance covered at higher speed is much higher than that covered at lower speed. These relationships are shown in Figure 2[10].

Figure 2: Relationship of speed with braking distance for a typical car on a dry road surface



COMBINED EFFECT OF SPEED AND REACTION TIME

Figure 2 shows that vehicles travelling at high speed need longer braking distance. The hatched lines show that if an object is detected at, say, 39 metres by a driver travelling at 50 km/h, the driver will be able to bring the vehicle to a halt a few cm before the object, thus avoiding a crash. However, vehicles travelling at speeds of 60, 70 and 80 km/h will hit the object at velocities of 44, 61, 77 km/h, respectively. Thus, in this case, an increase of 10, 20 and 30 km/h in speed over 50 km/h can have the effect of increase in impact speeds of 44, 61, 77 km/h, respectively. This shows how increases in speed affect the outcome in proportions that are disproportionately higher. The effect of this on severity of injuries is even more disastrous. This is shown in the next section.

RELATIONSHIP OF SPEED WITH INJURY

In the event of a crash, injuries are less severe at lower impact velocities. This is because the severity of injuries depends to a large extent on the energy transferred to the human body during an impact. The relationship between speed and energy is: E = ½ x M x $V^{2,}$ where E is energy, M mass of the object, and V velocity of the object.

In such a situation, small increases in velocity bring about much larger increases in energy:

Velocity increase	Energy increase (related to severity of injury)
10%	21%
20%	
50%	
2 times	
3 times	

This theoretical understanding is c car occupants, in crashes at 80 km/h, the at 32 km/h[11]. The probability of getting hurt or killed in the case of belted car passengers is shown in Figure 3. Figure 4 gives the probability of death for pedestrians impacted at different speeds. This shows that the probability of death for a pedestrian hit at 50 km/h is about 10 times more than the one hit at 30 km/h. The relative risks as shown in these figures are tabulated below (Table 1) for different impact velocities. The rates for bicyclists and motorcyclists would be similar to those for pedestrians.

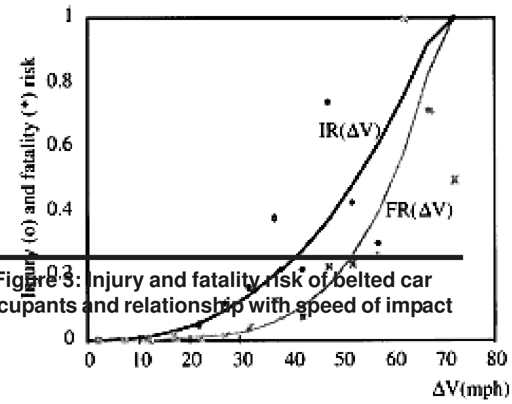


Figure 3: Injury and fatality risk of belted car occupants and relationship with speed of impact

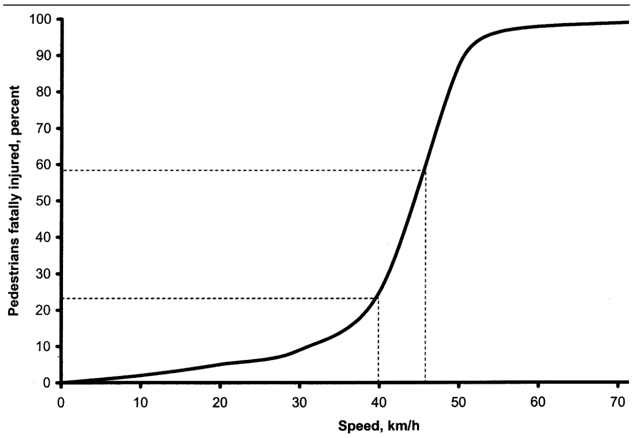
Figure 3. Injury and fatality risk of belted car occupants and relationship with speed of impact. Adapted from

Table 1: Approximate risk of death and injury for car drivers and pedestrians at different impact speeds

Impact velocity, km/h	Estimated risk for different road users		
	Injury, belted car drivers	Fatality, belted car drivers	Fatality, pedestrians, car impact
30	0.04	0.01	0.08
50	0.10	0.03	0.87
80	0.42	0.21	1.00
100	0.80	0.61	1.00
120	1.00	1.00	1.00

The above data show that speed control can bring about enormous reduction in deaths and injuries on rural and urban roads. It is clear that for preventing fatalities an impact speed above 30 km/h for pedestrians and above 60 km/h for belted-drivers would be unacceptable in frontal collisions. To avoid injuries that require hospital treatment, crash speeds greater than 50 km/h for belted drivers and over 10-15km/h for pedestrians would be unacceptable.

Figure 4: Probability of death for pedestrians impacted at different speeds



The above data seem to suggest that human beings reach their tolerance limits of sustaining severe injury due to blunt impacts with hard surfaces at velocities of about 10-15 km/h and fatalities at speeds as low as 30 km/h. The limits for elder individuals would be still lower. Belted car drivers are able to withstand impact speeds of 50 km/h as the belt and car interior design prevent impact with hard surfaces.

SPEED LIMITS

The European Transport Safety Council has recommended a maximum limit of 50 km/h in urban areas with a limit of 30 km/h on residential roads. On motorways, a speed limit of 120 km/h has been recommended. However, according to Noguchi, the speed at which a driver travels depends on many factors, such as the vehicle's engine power and stability, road and traffic conditions, perception of safety, speed limits and level of enforcement, travel motivations, personal characteristics, and behaviour of other drivers[12]. Out of these factors, we can have significant influence through policy only over setting of speed limits and their enforcement, road design, and vehicle design. It is also true that LMCs may not be able to adopt all the road design policies and enforcement levels as those applicable to HMCs because of resource constraints. This makes the issue much more complex in the case of LMCs and the solution may lie more in innovative approaches to road and vehicle designs than enforcement. The data on speed and risk suggest the following:

- Wherever there is a significant presence of pedestrians and bicyclists, motor vehicles must not exceed the speed of 30 km/h;
- In locations where bicyclists and pedestrians may be present frequently, the speed may be limited to 50 km/h;
- A speed greater than 50 km/h may be allowed where interactions between pedestrians and motor vehicles are unlikely and where there are very few intersections;
- A speed greater than 80 km/h be allowed only on limited access motorways.

There is a general consensus among most researchers that the following speed limits for different types of roads may be adopted for increasing the safety of road users:

Area/target group	General limit (km/h)
Urban major roads	50
Residential and shopping areas	30 or less, walking pace
Rural highways	80
Trunk roads, Motorways (car)	100-120
Trunk roads/motorways (bus, lorry)	80-90

Speed limits are difficult to enforce if the design speed of a road is much higher than the speed limit and the road has low density of traffic. This is particularly true for rural roads. Red light cameras have been found to be very useful in controlling speed[13, 14] especially in urban areas, but it may not always be possible to use them. It is essential that the city police departments give great importance to apprehending high-speed vehicles so that drivers are made aware of the existence of speed limits. However, such enforcement, especially on rural roads, is very difficult. The police departments can have regular drives on urban roads and periodic drives on rural roads to apprehend speed-limit violators, but this has only a limited effect. Fleet-owners can also be forced to have their trip times so regulated that the drivers do not have to exceed speed limits on business trips. However, the only effective measure of regulating speeds is through road design.

CONCLUSIONS

A recent study of the effectiveness of road structure on road accidents has come to the following conclusions[15]:

- Results strongly refute the hypothesis that infrastructure improvements have been effective in reducing fatalities and injuries;
- In general, infrastructure improvements have led to an increase in total traffic-related fatalities;
- Arterial road lane width of 3 metres is associated with decrease in fatality rates and a lane width of 3.7 metres with increase in injury rates;
- Collector road lane width of 3 metres or less is associated with decrease in injury and fatality rates and wide lane widths with increase in fatality rates.

In India, less than 10 per cent of the fatalities comprise vehicle occupants. Therefore, seat belt use, while very effective and desirable for car occupants, will not result in major overall fatality reductions. Since a vast majority of fatalities in Indian urban areas and rural highways include pedestrians, bicyclists and motorised two-wheeler riders, we have to focus on safer road design and speed control.

Use of roundabouts at intersections and visual cues, which do not give the driver a feeling of great expanses, helps in controlling speeds. These include advisory speed-limit signs, reflecting surfaces on the side of the road (painted trees, reflectors mounted on posts, etc.). When rural roads pass through built-up areas, physical measures are necessary to slow down the vehicles. These include constructing very conspicuous "gates" at the entrance of the village/town, the use of the speed-breaker and even putting barriers to make the road less negotiable at high speeds.

In urban areas, speed is controlled by intersections and high density of traffic. Roundabouts are very effective in controlling speed on arterial roads in urban areas and some modern designs are also greatly helpful in channelising traffic. One great advantage of roundabouts over traffic lights is that they are effective even in the absence of policemen and at night.

In residential and shopping areas, the maximum speed of vehicles has to be kept below 30 km/h, and this can only be done through traffic-calming methods. With well-designed traffic-calming measures, road fatalities can be significantly reduced in residential areas.

Speed control and traffic calming measures appear to be the most effective ways of reducing injuries and deaths. For HMCs, this holds great promise because improvements in vehicle design have perhaps reached a point of diminishing returns. In the case of LMCs, the effects of low speed on vulnerable road users would be more significant than safer vehicle designs. Speed-control methods, which depend mainly on policing, are very inefficient and expensive. Any money spent on research to develop vehicle and road designs that control speed automatically, is money well spent, both for LMCs and HMCs.

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DRIVER'S PERCEPTION OF TRAFFIC SIGNS

A Case Study in Poland

Lidia Zakowska*

INTRODUCTION

Driver communications systems are an important aspect of highway safety. And traffic control devices (TCDs), are an important part of the driver communications systems. The most prevalent of all TCDs are highway signs, and for effective traffic control it is essential that all drivers comprehend their meanings. As our world shrinks into a global village, and as more and more of us cris-cross this village, variations in signs among countries, poor sign design, and different levels of familiarity with signs used in different countries may all impair communication with drivers. The purpose of this study is to evaluate the scope of the problem by comparing sign comprehensions of different driver groups in Poland, using signs from four countries one each from four continents. The sign comprehension test consisted of a set of 31 colour pictures of highway signs. The results of this study demonstrate the urgent need for greater uniformity in highway sign design among countries, and greater emphasis on ergonomic principles in the design of new signs and redesign of existing signs.

Previous studies have indicated individual differences in sign comprehension – especially driver's age and culture – showing that older drivers had generally lower levels of comprehension than younger drivers.

The findings of the previous decade suggest that communication through symbolic signing may be a problem. This problem of course gets exacerbated in a world where people are licensed in one country in which they are required to learn one 'standard' set of signs, and then are expected to obey signs in other countries whose 'standard' signs are different.

THE RESEARCH PROJECT

Subjects

As many as 250 unpaid volunteers participated in the study. The sample consisted of 50 drivers (25 males and 25 females) from each one of the following five groups.

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G1. *Novice drivers*: Licence applicants who have just passed the 'theoretical test', which evaluates knowledge of rules of the road and sign comprehension; or the group comprising inexperienced drivers who have just received their licences.

G2. *Tourists*: Drivers who are licensed in another country.

G3. *Older drivers*: Licensed drivers who are at least 62 years old, and who have not taken a driving test in the last ten years.

G4. *Problem drivers*: Drivers with repeated violations, with essentially enough points to warrant a 'remedial training course'.

G5. *Regular experienced drivers*: Selected from university students.

Materials

A short questionnaire was prepared for each group, apart from a sign comprehension test. The questions were on the driver's age, sex, and driving experience. The sign comprehension test consisted of a set of 31 colour pictures of highway signs, each printed on a separate cardboard card. Diamond- and square-shaped signs were 7-10 cm across, triangular signs were approximately 10 cm high, and circular signs were approximately 10 cm in diameter.

Annexure 1 contains the 31 signs, along with the names of the specific countries that use them, and lists the meanings of the signs. In general, there were 15 signs common to four continents – Europe, North America, Asia, and Australia (Nos. 8, 9, 10, 11, 13, 14, 16, 17, 18, 19, 25, 27, 28, 29 and 30). The remaining 16 signs were unique to specific countries: three signs unique to Canada (Nos. 20, 21, and 31), three to Finland (Nos. 15, 23, 24), two to Poland (Nos. 3 and 4), two to Israel (Nos. 5 and 22), and three to Australia (Nos. 1, 2, and 6). One sign was common to Finland and Poland (26), one to Finland, Poland, and Israel (7), and one to Canada and Australia (12).

Procedure

All participants first answered the questions, and were then presented with the sign cards, one at a time. They were shown all the 31 signs: both those in use in their countries and those that are not. Prior to each presentation, the cards were shuffled, so that each participant could see the signs in a different random order. The instructions pertaining to the sign comprehension were: *"You are driving down a road when you see this sign ahead of you on the side of the highway. Tell me in as much detail as you can what you think is the meaning of this sign."* The experimenter then wrote down the participant's response verbatim. If the answer was incomplete, the participant was asked to elaborate.

The participants' responses to each sign were coded into one of the following four categories:

- correct and complete (coded as +2),
- partially correct (e.g. the response 'no turn, instead of no left turn', coded as 1),
- incorrect (0),
- opposite of the correct meaning (e.g. priority to traffic in my direction, instead of priority to oncoming traffic – coded as –2).
- In rare cases where the appropriate code was not immediately obvious, the experimenters made a group decision, and that decision served as a guideline for the coding in all other participating countries. In general, the coding was quite straightforward.

ANALYSIS OF RESULTS

The first stage of analysis was conducted in order to identify the most significant variables that were responsible for the comprehension of signs. Descriptive analysis and analyses of variance of all tested signs (without groups) were useful in the classification of signs under their picture perceptual correctness. Based on this analysis, all signs were grouped into five categories: *very good sign, good sign, satisfactory sign, poor sign* and *unsatisfactory sign,* as shown in Table 1. The second type of analyses sought to identify the level of comprehension and variations among drivers of different groups.

It is obvious from Table 1 that apart from the expected and large overall differences in performance on local vs. non-local signs, a simple pattern is not the rule. To understand these results, performance on the individual signs was assessed, and is discussed below.

Comprehension of 'very good' signs

Six signs (Nos. 9, 10, 14, 16, 19 and 28) had been classified as very good, and recognised by nearly all drivers. All these signs belong to the group of widely used standard signs in all the four countries from four continents. Five of them are warning signs, and one is a prohibition sign. An example of sign from this group which is perceptually correct, is the warning sign (No. 9) 'road works'. Nearly all the 250 subjects precisely understood the meaning of the sign, and none gave the opposite meaning, as shown in Figure 1.

Table 1: Classification of Signs

Sign No.	Numerator	Sum	Mean	Variance	Introductory classification
Sign 1	250	273	1,092	0,421221	*poor sign*
Sign 2	250	134	0,536	0,868177	*unsatisfactory sign*
Sign 3	250	369	1,476	0,555647	*satisfactory sign*
Sign 4	250	262	1,048	1,073992	*poor sign*
Sign 5	250	415	1,66	0,924096	*good sign*
Sign 6	250	222	0,888	0,927165	*unsatisfactory sign*
Sign 7	250	392	1,568	0,672064	*good sign*
Sign 8	250	442	1,768	0,403791	*good sign*
Sign 9	250	488	1,952	0,078008	*very good sign*
Sign 10	250	478	1,912	0,136803	*very good sign*
Sign 11	250	446	1,784	0,234281	*good sign*
Sign 12	250	19	0,076	0,383759	*unsatisfactory sign*
Sign 13	250	396	1,584	0,348337	*good sign*
Sign 14	250	480	1,92	0,138153	*very good sign*
Sign 15	250	250	1	1,228916	*poor sign*
Sign 16	250	463	1,852	0,158731	*very good sign*
Sign 17	250	479	1,916	0,197735	*very good sign*
Sign 18	250	442	1,768	0,291341	*good sign*
Sign 19	250	480	1,92	0,114056	*very good sign*
Sign 20	250	214	0,856	0,69404	*unsatisfactory sign*
Sign 21	250	191	0,764	0,992273	*unsatisfactory sign*
Sign 22	250	292	1,168	1,401382	*poor sign*
Sign 23	250	357	1,428	1,097205	*satisfactory sign*
Sign 24	250	237	0,948	0,708129	*poor sign*
Sign 25	250	444	1,776	0,760867	*good sign*
Sign 26	250	436	1,744	0,504482	*good sign*
Sign 27	250	456	1,824	0,555245	*good sign*
Sign 28	250	489	1,956	0,066329	*very good sign*
Sign 29	250	420	1,68	0,901205	*good sign*
Sign 30	250	403	1,612	0,479373	*good sign*
Sign 31	250	268	1,072	0,814072	*poor sign*

Comprehension of 'good' signs

Eleven signs (Nos. 5, 7, 8, 11, 13, 18, 25, 26, 27, 29 and 30) got correct or partially correct assessments from at least 85 per cent of all 250 subjects, and no response was the opposite of the correct one. Eight of the signs from this group belong to the category of standard signs used in all countries, one sign is used in three countries (Poland, Finland, Israel), one in two (Poland, Finland), and only one sign in this group is not used in Poland. Signs recognised as 'good' have graphical symbols with physical representation, and also conceptual compatibility with the message of the sign. Histogram of evaluation of meaning of international (Canadian, Israeli, Polish, Finnish and Australian) sign No.9 'road works' by Polish respondents is given in Figure 1.

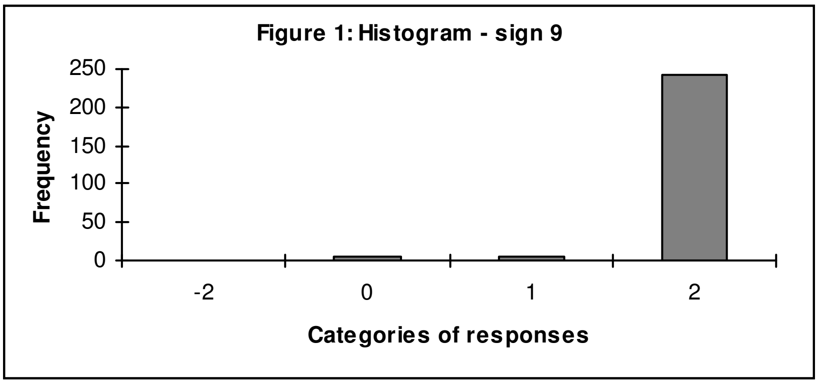

Figure 1: Histogram - sign 9

Unsatisfactory Signs

Five signs were not recognised by a majority of the 250 respondents, and also misunderstood by some of them. An example of such an unsatisfactory sign not understood by most drivers is the Australian and Canadian information sign (No. 12). Only 6 per cent of the 250 drivers understood the meaning of this sign, while 89 per cent answered: 'I do not know', or gave a wrong, opposite meaning. There are neither perceptual properties in the design of this sign, nor uniformity, spatial compatibility or familiarity, or sta
meaning of Canadian and Australian sig
respondents is given in Figure 2.

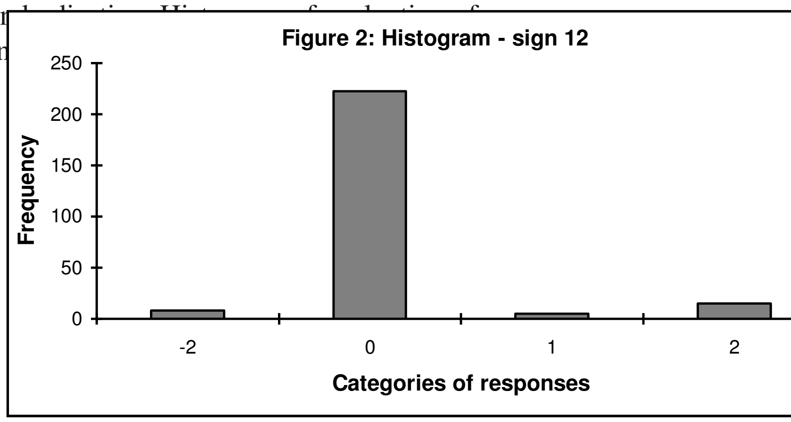

Figure 2: Histogram - sign 12

CONCLUSIONS

– The results demonstrate the urgent need for greater uniformity in highway sign design among countries, and greater emphasis on ergonomic principles in the design of new signs and redesign of existing signs.

– Signs with good spatial compatibility to the message they represent were all well understood.

– The study also demonstrates the effects of well understood – but often ignored – ergonomic principles of display design. To enhance comprehension, displays should embody as many of the following criteria as possible: spatial compatibility, conceptual compatibility, physical representation, familiarity, and standardisation. A factor that may account for some of the variations among the signs is relevancy. The desired recognition level should be high for highly relevant signs, and can be low for less relevant signs. Sign 'registration' studies (e.g. Johansson and Rumar 1996; Shinar and Drory 1983) have demonstrated that drivers attend more to signs that are in some sense more relevant to their needs and goals than to those less relevant. In this study, sign No.4 ('No entry to trucks carrying explosives') is not relevant to drivers of passenger vehicles, and therefore its comprehension level need not be as high as that of the signs that are.

– A good sign design should incorporate population stereotypes, such as the use of the red colour to indicate danger (as in 'Stop' signs); the use of different sign shapes to distinguish between prohibitive, warning, and guidance signs; and the use of a diagonal line to indicate prohibition (such as 'no smoking'). Stereotypes are cultural norms that derive from the ubiquitous use of some symbols, even in contexts other than highway signs and driving. For example, we often use diagonal lines over a symbol to indicate prohibition. Consequently, prohibition without such a line can create confusion. An example is the attribution of the opposite meaning to the 'No Entry to Motorcycles/Mopeds' sign (No.5), by a high percentage of the respondents (who believed that the sign indicated that motorcycle/moped entrance is allowed). This is despite the red border of the sign.

– Signs with high comprehension values typically contain several of the above criteria. Standardisation alone, for example, is not sufficient unless it is also accompanied by either a good spatial or conceptual representation, or by proper education (as in driver education and driver testing) when the representation is arbitrary. When the sign design is completely arbitrary, drivers who have not been exposed to it as part of their education cannot be expected to comprehend it. This was found to be the case in sign No.12 (Termination of Road).

– Signs that conform to good ergonomic design principles – incorporating high levels of spatial compatibility, conceptual compatibility, physical representation, familiarity, and standardisation – are more likely to be fully comprehended than signs that violate these requirements.

RECOMMENDATIONS

– Signage should be standardised across countries as much as possible;
– All signs should conform as much as possible to good ergonomic design principles that maximise spatial compatibility, conceptual compatibility, physical representation, and familiarity;
– An international committee should be established to evaluate the current signage in different countries and advance proposals for new signs.

ACKNOWLEDGEMENT

This report presents results of a study conducted in Poland, which is a part of an inter-continental research project of perception and recognition of traffic signs. The project covers representation of four continents: David Shinar (project co-ordinator, Israel, Asia); Bob Dewar (Canada, North America); Heikki Summala (Finland, Europe); Lidia Zakowska (Poland, Europe), and Australia. The Polish Committee for Scientific Research, KBN, and MOS in Israel supported part of this research.

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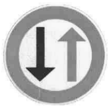
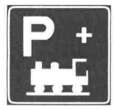
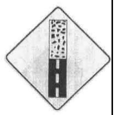
Annexure 1: Traffic signs tested during an experiment

Sign No.	Sign picture	Sign meaning	Countries which use this sign	Sign No.	Sign picture	Sign mea
1.		Railroad crossing with lights	Australia	**2.**		Truck cro
3.		Bus lane begins	Poland	**4.**		No entr vehicles c explosi
5.		No entry for Motorcycles/ Mopeds	Israel	**6.**		Reverse (left then
7.		Priority for oncoming traffic	Finland Israel Poland	**8.**		Bicycle
9.		Railroad works	Australia Canada Finland Israel Poland	**10.**		Bumps o
11.		Right curve	Australia Canada Finland Israel Poland	**12.**		Terminat roa
13.		Railroad crossing ahead	Australia Canada Finland Israel Poland	**14.**		Slippery
15.		Congestion	Finland	**16.**		Road na

Sign No.	Sign picture	Sign meaning	Countries which use this sign	Sign No.	Sign picture	Sign meaning	Countries which use this sign
21.		Truck entrance	Canada	**22.**		End speed limit (for trucks 30 kph, for cars 50 kph)	Israel
23.		End built up area	Finland	**24.**		Parking for public transport	Finland
25.		No U turn	Australia Canada Finland Israel Poland	**26.**		End priority road	Finland Poland
27.		No left turn	Australia Canada Finland Israel Poland	**28.**		No entry	Australia Canada Finland Israel Poland
29.		No entry for pedestrians	Australia Canada Finland Israel Poland	**30.**		No parking	Australia Canada Finland Israel Poland
31.		Pavement ends	Canada				

TRAFFIC CALMING MEASURES ON NATIONAL AND STATE HIGHWAYS PASSING THROUGH TOWNS AND VILLAGES

D. P. Gupta*

Local traffic dominates highways passing through villages and towns, resulting in wide variations in speed and safety hazards, particularly for pedestrians. To address the problem, the ministry of road transport and highways had proposed that a study be undertaken to evaluate the effects of traffic calming options on national highways (NH) and state highways (SH) passing through towns and villages, and develop guidelines for traffic calming measures. Subsequently, a research study was entrusted to the Asian Institute of Transport Development (AITD) and Transportation Research and Injury Prevention Programme (TRIPP), IIT, Delhi. The objectives of the study were:

- To prepare a state-of-the-art report on traffic calming measures for highways passing through towns and villages;
- To evaluate the performance of the existing traffic calming measures and select measures taken on an experimental basis;
- To prepare guidelines for traffic calming for highways passing through towns and villages, railway level-crossings, etc.

The typical corridors selected for the study are given in Table 1.

Table 1: NH/SH corridors for the study

Village/town size (population)	Land-use pattern around NH/SH section	Function of NH/SH section passing through town/village
Village	A few dwelling units, tea shops, etc.	Primarily carrying through traffic/almost no local cross traffic/pedestrian movement.
Small Town	Dwelling units, local manufacturing, auto repair shops, etc. Roadside parking, bus stop, etc.	Through traffic as well as local traffic on the shoulder, primarily non-motorised. NH/SH may be the only major road in the town.
Town – Population: 200,000 persons or more	Local commercial area, local manufacturing, parking by vehicles, bus stop, etc.	Local as well as through traffic. Some more arterials may be there to carry local traffic.
Residential areas and school zones of cities with population >1 million	Large areas along arterial or collector streets.	Local traffic along with high proportion of bicycles and pedestrians.

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The traffic situation in the select study corridors was assessed. Accident-data were compiled from the available police records. The evaluation was done keeping in view the effects of various measures on traffic speed, and users' perceptions of convenience and safety.

As part of the literature survey, a state-of-the-art report on various traffic calming measures has been prepared. The report includes traffic calming practices around the world. Traffic calming techniques have emerged primarily as society's response to concern for safety. In the western countries, these techniques have been implemented in residential areas, neighbourhoods and cities. In the last 25 years, residential areas and inner cities in these countries have become safer because of 30-km-per-hour zones in these areas, despite considerable variation in the directions and mass of vehicles using them. Traffic calming measures have played an important role in achieving safety by ensuring low driving speeds and smaller speed differences between various road users.

Vehicle speed is one of the critical factors associated with road accidents. Research studies carried out around the world demonstrate conclusively that the frequency and severity of accidents usually get reduced with reduction in average speed. It is estimated that a decrease in average speed by 1 km per hour will typically result in a 3 per cent decrease in fatal accident frequency. Variations in speed between different vehicles within a traffic stream are also a factor contributing to the occurrence of accidents.

Management of speed by designing the road in accordance with the desired speed is called 'speed management by design' or 'traffic calming'. Two main principles for reducing speed have been used: visual and physical. Speed-limit signs, painted strips across the road (visual brakes), road-surface patterns, plants, etc. are examples of visual measures. The general experience from different European countries indicates that visual measures *alone* are not sufficient to make drivers choose an appropriate speed. But when used in combination with other physical speed-reducing measures, significant results can be achieved.

Guidelines

Guidelines indicating various traffic calming measures were developed on the basis of an extensive literature review of traffic calming measures adopted in other countries and the pilot experiments conducted as part of this research study. The guidelines aim at providing design recommendations to highway engineers which should enable them to prepare: (i) road (spot) interventions that ensure local traffic safety and efficient movement of long-distance traffic; (ii) NH- and SH-corridor rehabilitation and construction plans and designs in which the requirements and interests of road users, including pedestrians, cyclists, bus passengers, truck drivers and car passengers are all taken into account.

The guidelines are covered under the following subheads: (i) know your zone; (ii) checklists; (iii) detailed designs; (iv) safe-speed zones and (v) visual-warning devices. A brief synopsis of the guidelines is given in the following paragraphs:

Know your zone

Demarcation of zones for settlements (towns/villages): The strategy should be to make the vehicle on the highway go through a process of gradual and informed deceleration to a safe speed and sustain the same for the distance where the potential of collision is high. To determine the conflict areas and facilitate a gradual reduction of speed, which is comfortable for the approaching vehicle, a system of concentric zoning has been worked out for a settlement (see Figure 1). The speeds recommended for different zones are indicated in Table 2.

Figure 1: Zoning concept – village/village market

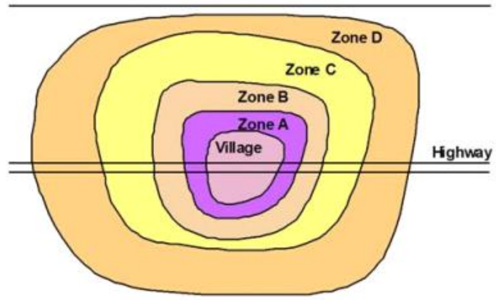


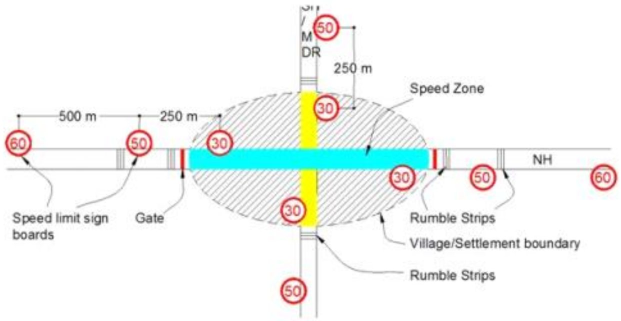
Table 2: Recommended speeds in zones

Zone	Length (m)	Recommended speed (kmph)	
		Heavy vehicles	All other vehicles
Village/town	Within boundary	20	25
A	150	25	30
B	180	35	40
C	220	45	50
D	260	55	60

Based on the demarcation of zones, an illustrative scheme of traffic calming measures on the highways passing through small settlements is given in Figure 2. It shows locations of warning signs and gate and rumble strips as a prewarner, which may be installed to ensure a gradual reduction in speeds

Demarcation of zones at road junctions: Usually there are two types of junctions: T-junction and four-arm intersection. The status of a minor road vis-à-vis a major road is an important parameter in determining zones of conflict. The

Figure 2: Speed zones on NH/SH passing through small settlements



hierarchy of the minor road calls for different traffic calming measures. Three cases are discussed below:

(i) *NH/SH meeting NH*: Most of the time, this would be a major intersection and an interchange point with either traffic police or signalisation equipment installed to control the traffic flow. The presence of a large volume of traffic itself gives rise to a number of commercial activities, which may act as a visual clue to the driver on the highway to slow down. Nevertheless, it is still advisable to treat the minor road with adequate traffic calming measures so that the approach speed is considerably reduced. The area of influence on the main road needs to be demarcated for appropriate treatment to reduce the speed to acceptable limits.

(ii) *MDR (Major District Road) meeting NH/SH*: Such roads usually connect important villages, village mandis (markets) and other important nodes in the region. Further, they are often unmanned and rarely signalised. As such, it is very important that traffic calming measures are installed on the minor road leading to a national highway or a state highway. The major road should also be treated visually to sensitise the vehicle about the approaching intersection.

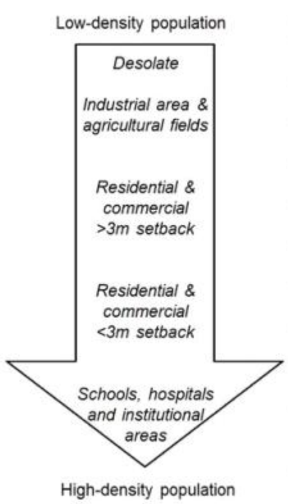
(iii) *ODR (Other District Road) meeting NH/SH*: This type of junction is more vulnerable to conflicts. Having a low traffic volume on the minor road results in less activity at the intersections. Thus, such junctions remain inconspicuous from a distance on the major road. Hence, vehicles approaching from the minor road need to slow down to "dead speed" before they can find gaps on the major road. The visibility of the major road should also be high so as to enable making appropriate decisions on the gaps. The measures to reduce chances of conflict could include visual warning on the major road and speed-breakers and pre-warners on the minor road. It is important to reduce the speed of the vehicles on the minor road and suggest a zonal speed of 45-50 kmph on the major road. This would be enough for the vehicles travelling on the minor road to manoeuvre and find gaps in the traffic stream.

Special area zoning: Areas within a settlement may require special traffic calming measures for additional safety. For example, in areas near schools and hospitals low speed is essential. School children are prone to commit mistakes while negotiating with highway traffic. In such areas, the desirable speed should be a maximum of 25 km per hour. In areas around hospitals, a speed up to 30 km per hour may be permitted.

Check lists

The guidelines cover checklists for traffic calming treatment on: (i) highway corridors with/without medians; (ii) highways without pedestrian footpaths or service lanes; (iii) intersection of roads; (iv) bridges; (v) urban roads; (vi) hill roads; and (vii) rail-road crossings. One example of a checklist for treatment on highway corridors is given below:

Checklist for Traffic Calming Treatment on Highway Corridors



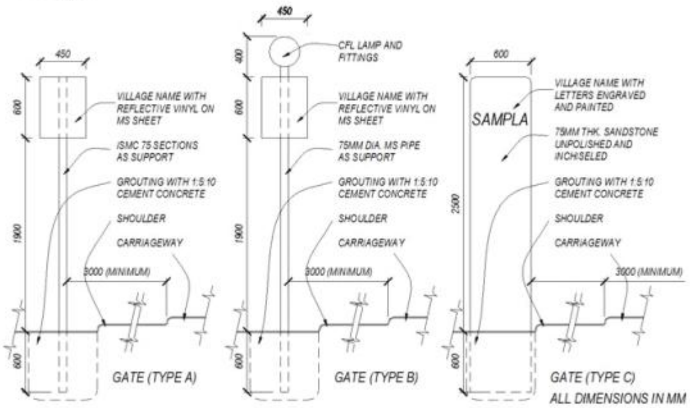
- No treatment
- Provide gates at both ends of the corridor passing through residential or commercial areas
- Provide signage showing name of the area and the length of the corridor
- Provide gates at both ends of the corridor passing through residential or commercial areas
- Provide signage showing name of the area and the length of the corridor
- Use-traffic calming devices to restrict corridor speed to 50 kmph
- Provide Speed limit signs, and warning signs for merging roads and traffic calming devices
- Provide gates at both ends of the corridor passing through residential or commercial areas
- Provide signage showing name of the area and the length of the corridor
- Use traffic calming devices to restrict corridor speed to 50 kmph
- Use traffic calming devices, with adequate signs, to reduce speeds to 30 kmph at intersections with minor roads or at locations with high pedestrian, animal or vehicular cross traffic
- Provide speed-limit signs, and warning signs for merging roads and traffic calming devices.

Designs of Traffic calming devices

(i) ***Gates***

Description: Posts with village name and speed limit signs, with or without light posts, 4m high erected on both sides of the road

Design:



(ii) ***Humps or speed breakers***

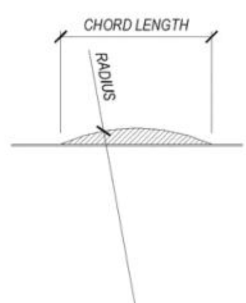
(a) *Circular hump*

Description: The profile of circular shaped hump is based on the shape of a circular arc with a radius varying from 11m to 113m and a chord length varying from 3.0m to 9.5m to achieve the desired speed of 20km/h to 50 km/h.

Design:

Hump geometry and desired vehicles speed

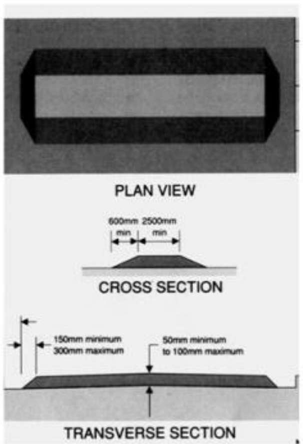
Desired speed	Radius (R)	Chord length (L)	Bus speed during passage
20 km/h	11 m	3.0 m	5 km/h
25km/h	15m	3.5m	10km/h
30km/h	20m	4.0m	15km/h
35km/h	31m	5.0m	20km/h
40km/h	53m	6.5m	25km/h
45km/h	80m	8.0m	30km/h
50km/h	113m	9.5m	35km/h



(b) *Trapezoidal hump*

Description: This is a hump, which constitutes a 50 to 100 mm raised flat section of a carriageway with ramps on both sides.

Design:



Left: Plans and sections showing details of trapezoidal hump.

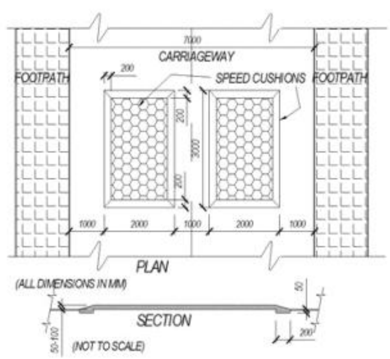
Bottom: Table showing relationship between trapezoidal hump geometry and the desired vehicular

Desired speed	Length of ramp	Gradient (percent)	Bus speed during passage
20 km/h	0.7 m	14.0%	-
25 km/h	0.8 m	12.5%	5 km/h
30 km/h	1.0 m	10.0%	10 km/h
35 km/h	1.3 m	7.5 %	15 km/h
40 km/h	1.7 m	6.0%	20 km/h
45 km/h	2.0 m	5.0%	25 km/h
50 km/h	2.5 m	4.0 %	30 km/h

(c) *Speed cushions*

Description: Speed cushions are a derivative of the road hump developed primarily to suit the passage of buses and ambulances whilst maintaining the speed reducing effect on cars. They consist of a raised hump similar in design to a trapezoidal hump but only 1.3m wide.

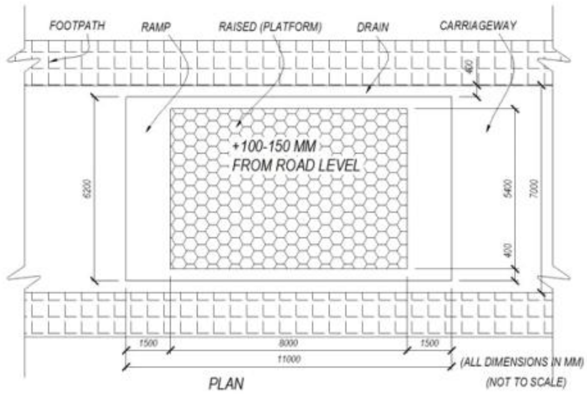
Design:



(iii) ***Platform***

Description: A raised device with approach ramps constructed kerb to kerb. Vehicles need to drive up and over the device (vertical displacement).

Design:

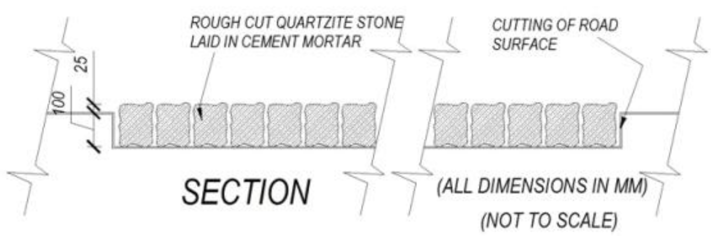


(iv) ***Rumble strips/bars***

(a) *Rumble strips*

Description: A variety of contrasting materials can be used, such as pavers, cobbles or bitumen slightly raised across travel path to create an auditory effect.

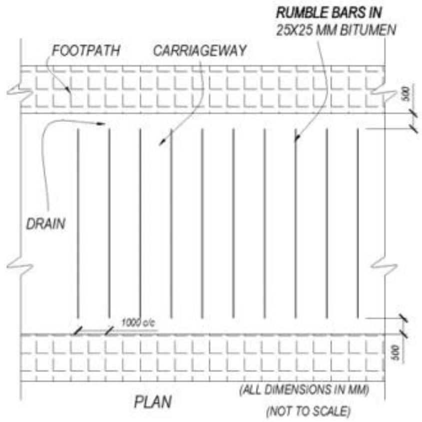
Design:



(b) *Rumble bars*

Description: Raised concrete blocks 300x100 mm to delineate travel path.

Design:

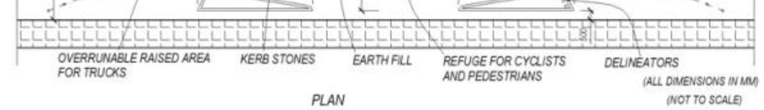


(v) ***Narrowings***

(a) *Centre blister onion ring*

Description: Elliptical shaped blister on centre line of road with kerb blisters creates a single travel path in each direction. Slows vehicles by deflecting them from the straight travel path (horizontal displacement).

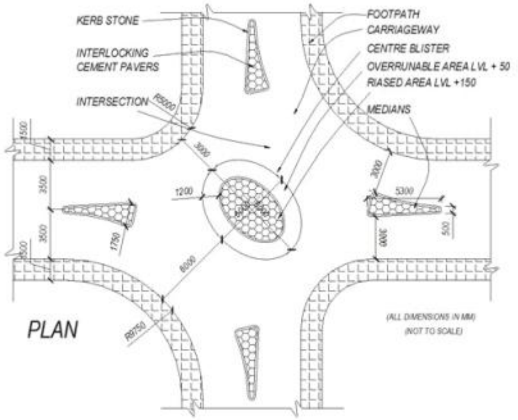
Design:



(b) *Impellor*

Description: Elliptical centre islands at intersection with a right-turn bay. This is made possible by aligning an elliptical island in a manner that two diagonally opposite right of ways are two lanes (to allow right and left turn) and two diagonally right of ways are single lanes.

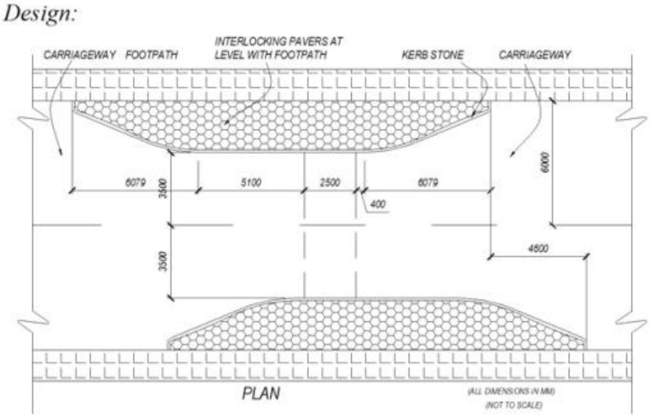
Design:



(c) *Narrowing from side road*

Description: Narrowing of a two-lane road to a single lane on two-way undivided road, using kerb blisters either from both or single side of the carriageway and not exceeding 30 metres in length. Angular deflection of lane alignment in order to produce a narrowing must not exceed 1:3.

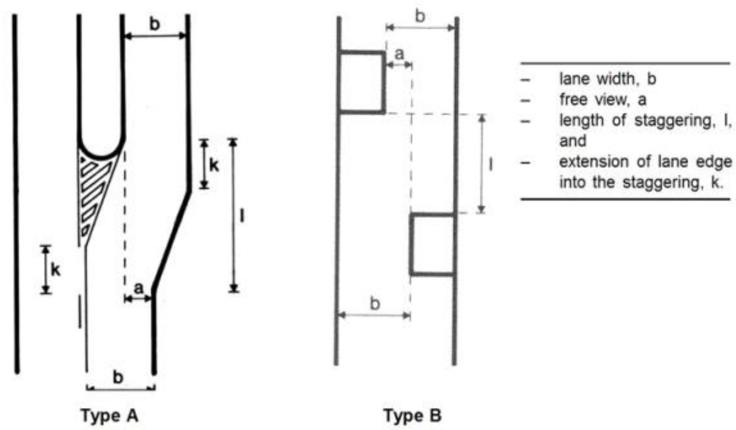
Design:



(vi) ***Staggering***

Description: Two large triangular-shaped kerb blisters cause a deflected travel path.

Design:



Desired Speed	30 km/h		40 km/h		50 km/h	
Smallest lane width b	2.75 m		3.00 m		3.00 m	
Free view a	l (m)	k (m)	l (m)	k (m)	l (m)	k (m)
-1.0 m	26	5	25	3	35	3
-0.5 m	25	5	24	3	32	3
0.0 m	22	5	23	3	28	2
0.5 m	20	4	19	3	25	2
1.0 m	18	4	18	3	23	2

(vii) ***Roundabouts/rotaries***

Description: Dome-shaped central island, 6 metre in diameter and 150-mm-high at the centre.

Design:

– Must not be sunk in a hollow. Therefore, the circulating carriageway should be sloping outward, keeping the rotary on the crown.
– Island diameter normally 2-4 metres for 3-arm junction, up to 6 metres for 4-arm junctions, but in any event large enough to ensure adequate deflection for crossing and right turning traffic.
– Normally dome-island 20-25 mm per 1 metre diameter.
– Drain gullies should not be provided next to the central island.

- Central island should be well raised (raise of the roundabout effectively increases when the circulating cariageway slopes outward) but not to obstruct entering driver's view of right/left turn indicators on circulating traffic. Maintain an outward radial fall of about 2.5 per cent.
- Provide safe overrun area on the edge (of the roundabout) up to 1 metre (this width could be designed as a rumble area) – do not use high kerbs on the inside.

Approach:

- Never use priority arrows (these are used on priority junctions and give drivers positively misleading information).
- Avoid any arrows except to encourage double lane use (where more than one entry lane may be used towards the same exit).
- Work central line progressively offset to off-side on approach to cause visual break with opposite centre line
- The approach to be split into two 3-metre lanes where possible (start at 2 metre lane widths).
  (The visual effect of this is very important; such narrow lanes are safer for cyclists too).
- Give way line just behind outer swept path not usually on inscribed circle circumference.
- Give way triangle if particular problems are expected but avoid double give way line.
- Avoid single wide lane with central hatching reminiscent of (former) T-junction layout. If there is no option but a single lane approach, use solid hatching (tapered parallelograms).
- Avoid kerbline bulges (profiling the nearside kerbline carefully will usually be satisfactory, but the short abrupt kerb 'blisters' that are seen so often are ineffective and sometimes dangerous. Evidence is mounting that they cause accidents rather than prevent them (on its own kerb, a blister is not a speed reducing feature).

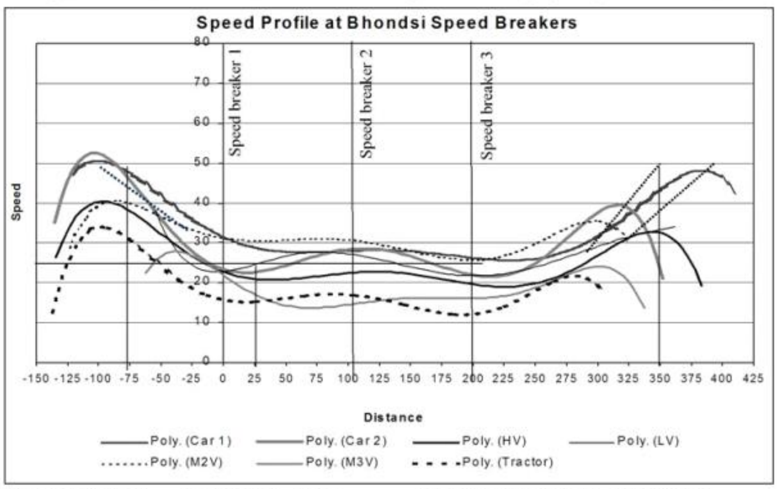
The design of the roundabout must be worked out using the guidelines mentioned above and keeping in view the existing site conditions.

Safe-speed zones

The study of speed-breakers and other traffic calming measures at different sites on NH8, NH10, NH58 and SH13 brings out the relationship between the physical design of the 'traffic calming device' and the speed reduction achieved. Also, the introduction of a traffic calming device on the carriageway forces vehicles into a cycle of deceleration and acceleration. The study conducted on speed-breakers at Kheri Village and Bahadurgarh on NH10, and Bhondsi village on

SH13 was analysed to understand the behaviour of different vehicle categories as they go through this cycle. Figure 5 gives the speed profile for different vehicle categories at Bhondsi.

Figure 5: Trend lines of different vehicle categories showing speed profile at Bhondsi



CAR 1: Sedan Cars CAR 2: Vans, Jeeps LV: Tempos, Light Commercial Vehicles
HV : Trucks, Buses M2V: Scooters, Motorcycles M3V: Three-Wheelers, Autos, Tractors

The speed profile of different categories of vehicles, namely passenger cars (Car 1), jeeps and other SUVs (Car 2), heavy goods transport vehicles (HV), light goods transport vehicles (LV), tractor trailers (tractor), motorised two- and three-wheelers (M2W and M3W), is shown in Figure 5. The study of the speed profile (trend line) suggested the following:

(i) Steeper trend lines of Car 1 and Car 2 vehicle groups are representative of quicker accelerations and decelerations. This underlines the need to design traffic calming devices addressing this group while keeping in mind the comfort and safety requirements of other vehicular groups.

(ii) The mean speed of different vehicles on the speed breakers in km/hr.

(iii) The effectiveness of the speed breaker in maintaining speeds lower than a set limit, over a particular distance in metres.

An understanding of the vehicular speed at the speed breaker and its effect on vehicle behaviour over a distance on the carriageway is a prerequisite for enforcing by design a speed zone over a corridor.

The results of the study establish an inverse relationship between the vehicular speeds at the speed breakers and at the hump gradient. A higher hump gradient results in a lower speed over the speed breaker. Speed humps with gradients greater than 1:9 have been found to be unsafe for motorised two-wheelers and hence should not be used. Similar experiments the world over show that the specific geometry of a particular traffic calming device can be used to achieve the desired vehicular speed at the device.

The effect of a traffic calming device over a distance on the carriageway, also referred to as the range of the device, is a factor of deceleration and acceleration of vehicles approaching and receding the device. The study of Kheri and Bhondsi village speed breakers shows that these deceleration and acceleration values (represented by the steepness of trend lines) show no relationship to the speed breaker geometry. Instead, the traffic volume and other site features affect the range of the speed breakers at these sites. For example, at Kheri village, the vehicular traffic volume at peak hours is 195 vehicles per hour. Here the mean deceleration and acceleration distances for Car 1 and Car 2 groups from 50 to 25 (at the speed breaker) to 50 km/hr is 56 metre and 113 metre, respectively. At Bhondsi village, where the traffic volume is much higher, i.e. 645 vehicles per hour, the deceleration and acceleration distances for Car1 and Car2 groups from 50 to 25 to 50 km/hr is 102 metre and 168 metre, respectively. The sum total of the distance travelled by the vehicles below 50 km/hr before and after the traffic calming device is its range in a 50 km/hr speed zone. For example, here, the range of the Kheri Village speed breaker is 169 metre and for the Bhondsi village speed breaker 270 metre.

Table 3 provides the range for traffic calming devices with different speed reducing effects, for very low and very high-traffic volume areas.

Table 3: Effective range for different traffic calming speeds

Speed zone in km/hr	Traffic volume of corridor in vehicle/hr	Effective range in metre for traffic calming device speeds in km/hr (before + after)						
		20	25	30	35	40	45	50
50	195	58+119	65+93	68+68	54+54	42+29	27+13	0
	345	74+149	83+116	85+85	68+68	54+38	34+17	0
	495	89+180	100+140	103+103	82+82	66+47	43+20	0
	645	104+211	117+164	120+120	95+95	78+56	48+24	0
30	195	38+78	44+62	0	-	-	-	-
	345	52+107	61+85	0	-	-	-	-
	495	63+129	73+103	0	-	-	-	-
	645	74+151	85+121	0	-	-	-	-

Visual-warning devices

The road signs and pavement markings, delineators, etc. are used in combination with traffic calming devices discussed above. These are to conform to standards already laid down by the Indian Roads Congress.

Traffic calming measures for select situations

Detailed guidelines for traffic calming measures for select situations such as intersections, railway-level crossings and highways passing through villages/small settlements have been formulated.

Conclusion

The general experience from different countries indicates that speed limit signs and other visual measures alone are not always sufficient to make the drivers choose an appropriate speed. But when used in combination with other physical speed reducing measures significant effects are observed. Appropriate designs can be developed with the help of guidelines to reinforce the road hierarchy, reduce number and severity of accidents. With widespread application of traffic calming measures overall efficiency of traffic flow and road capacity can be improved.

References

AITD & TRIPP, *Traffic Calming on National Highways and State Highways*, Final Report to Ministry of Road Transport and Highways, Government of India, September 2002.

EXPERIENCES OF EAST AFRICAN CITIES IN TRAFFIC CALMING

Tom Opiyo*

The World Bank's Sub-Saharan African Transport Policy Programme (SSATP) pilot projects on Urban Mobility and Non-Motorised Transport were undertaken in Kenya and Tanzania between 1995 and 1999. The pilot cities were Nairobi and Eldoret in Kenya, and Dar-es-Salaam and Morogoro in Tanzania.

The projects were a follow-up to a series of studies undertaken in 1993-94, in which the non-motorised transport (NMT) was found to be a major contributor to urban mobility in many African cities. It was also found that NMT users were confronted with a number of problems such as lack of transport infrastructure, high accident rates, and poverty.

One of the four main objectives of the pilot projects was to explore instruments that enhance efficient walking and cycling in African cities through possible physical engineering interventions, and monitor the findings.

Among the interventions tested, traffic-calming measures formed a substantial component, as the high speed of motorised traffic was found to be the main obstacle to the NMT modes.

This paper gives a brief summary of some of the interventions and their results.

Traffic-calming Menu

Traffic calming is a general attempt to establish safe and smooth traffic circulation conditions. For an existing road, it is an attempt to restore the balance between the functions of the road by influencing its use through changes in shape. For a new road, traffic-calming measures can be incorporated during the planning and design phase so that the balance between function, shape and use of a road is ensured during its operation.

On existing roads, a number of such measures can be implemented:

– Raised zebra crossings
– Speed humps

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- Intersection corner and shape reconstruction
- Hard separation of shoulders from encroachment by motorised traffic
- Reduction of road carriageway cross-section
- Median in a 2x1 wide carriageway.

In the planning and design of new roads, the most important consideration is to design the roads based on hierarchy in the road network. All roads in the network should be classified according to their intended functions. Roads to provide fast movement should be designed to serve a flow function, while those for access should be designed for low speeds. The application of traffic-calming measures should, therefore, be based on road class/hierarchy in the network.

In general, and in Africa, in particular, traffic-calming measures should be self-enforcing. That means that they should not require the intervention of the traffic police.

In cases of improvements of roads or new road designs, traffic-calming measures must be applied on an area-wide basis. If that is not done, the traffic will easily divert to other roads in the network, sometimes with undesirable results.

Experiences

A variety of traffic-calming interventions were tested, the most effective and inexpensive option being the speed hump of sinusoidal shape. This was used at many locations before it was discovered that combining it with NMT crossing was much more beneficial.

Raised Zebra Crossings

Pilot works were undertaken with this kind of zebra crossings because the normal zebra crossing was completely ignored by motorists using the roads. In fact, they could be considered as providing false safety to pedestrian, and hence being more dangerous. However, no data was collected to support this view.

The interventions consisted of raised platforms with pre-cast concrete blocks laid on each side as ramps. The approach slopes were between 1:8 and 1:10, depending on the desired vehicle speeds at each location. The flat top of the zebra crossing was made of pre-cast paving blocks laid on a sand bed, on a well-compacted road base. This type of construction had not been used in Kenya and Tanzania and was a very welcome idea, as it was more comfortable to go over than the usual round-topped hump.

Before the construction of the humps, motorised traffic speed was quite high, sometimes as high as 80 km/h on access roads. Crossing pedestrian volumes were also high. The result was a high number of accidents along the road sections.

The effect of the raised zebra crossings was, of course, a reduction in vehicle speed and almost total elimination of traffic accidents. Further, cyclists could easily share the road space without any problems. For the motorised traffic, there was more uniform flow, less waiting time at intersections, and savings on vehicle damages due to elimination of accidents.

Pedestrian Crossing Island

Pedestrian crossing islands (refuge islands) were constructed between two lanes for the traffic moving in opposite directions. The interventions were meant to allow pedestrians to cross the road in two phases. Also, the islands did not have any discomfort effects on motorists, except speed reduction which was to a less degree, compared to the hump.

The waiting time of pedestrians at the shoulder to cross the road was reduced, but the overall crossing time remained almost the same. The motorised traffic flow became more uniform and predictable, as the islands created channelistion, which was absent before the interventions were implemented.

Median between Two Traffic Lanes

Two medians were constructed on a two-lane two-way rural road approaching a town. The road cross-section was 10 metres wide and was used as two lanes. The width of the road and the steep gradients from both approaches encouraged drivers to speed within the section. However, there was a narrow river bridge at the bottom of the vertical curve, which also accommodated a horizontal curve. The combination of the road alignments, the narrow bridge, high motorised vehicle speeds, and the presence of cyclists and pedestrians contributed to many accidents occurring.

The effects of the intervention were: (i) increased road safety due to reduced vehicle speeds and channelisation; and (ii) increase in the number of cyclists by 13 per cent over a period of three months, mainly due to being attracted from other longer and more difficult routes.

Other Experiences

Some general experiences gained are:

– Traffic calming enhances cycling in urban areas more than the construction of isolated cycle tracks, which may not connect the main origin and destination of cyclists.

- Traffic calming allows motorised and non-motorised traffic to co-exist and share the same road space. Pedestrian crossings are more dispersed, as the decision to cross is made at many locations along the road.
- Road markings can be used as instruments of traffic calming if enforcement can be guaranteed. Without enforcement, their effect is minimal as motorists largely ignore them.
- Traffic-calming instruments must be made very visible. Otherwise, they can be very dangerous, especially at night. Proper signage and markings are required.
- Particular attention needs to be paid to the design of these instruments for the desired results to be achieved.

Reference

De Langen, M., R. Tembele: *Productive and Liveable Cities: Guidelines for Pedestrian and Bicycle Traffic in African Cities*, Version 1.3, A.A Balkema Publishers, 2001.

GUIDELINES FOR PEDESTRIANS AND CYCLISTS IN AFRICAN CITIES*

Marius de Langen and Rustica Tembele

RAISED ZEBRA CROSSING

Intervention

The intervention consists of a number of raised zebra crossings of the design shown below. In most cases, the slopes were constructed with precast concrete blocks on the pavement on top with bricks. At the sides, zebra-painted steel bollards were used to assure visibility (preference:> 80 cm high) and a row of T-blocks was placed to eliminate motorised transport (MT) Access to the walkway near the crossing point.

Background

Ten raised zebra crossings were constructed in the pilot project in Dar-es-Salaam (Temeke ward) and one in Morogoro. Different heights and slopes were used to find out the reduction in vehicle speed that different slopes and height combinations bring about. The tests showed that in Tanzania, the variety in vehicle types and, more importantly, their quality is much more pronounced than in Europe or the US. The clearance below a significant number of vehicles is less than it should be according to the vehicle specifications either because of failing suspension or overloading. This means that flat-top humps (a raised zebra crossing is a flat-top hump) create much less damage to vehicles than humps. As a result, raised zebra crossings – previously unknown in Tanzania – were welcomed as a better alternative to humps and applied in other projects.

Location

Temeke Road, Dar-es-Salaam, Tanzania

Conditions

A large number of pedestrians cross this road. As an example, the estimated pedestrian average daily traffic (ADT) on Mahunda Street near the intersection

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* *Guidelines prepared as part of the urban component of the World Bank Sub-Saharan Africa Transport Programme (January 2001).*

with Temeke Road is 10,000 persons. The average pedestrian ADT crossing Temeke Road at the locations where a raised zebra is constructed is approximately 2,200. The concentration of pedestrians is highest at junctions with side streets, but the activities along this road section are so dispersed that pedestrians cross everywhere.

During the day, motor vehicle traffic ranges between 500 and 1,000 vehicles per hour (two-way). Most vehicles are mini-buses (‘dala dala’), resulting in a peak hourly passenger flow on this road of about 15,000 passengers/hour in the peak direction. Dala Dalas stop randomly on the road shoulder to (un-) load passengers. The estimated ADT of cyclists on Temeke Road is 1,000-1,400, depending on the section. The bicycle ADT on Mahunda Street is around 2,300.

Problems

- Crossing the road is dangerous for pedestrians because of the high speed of motor vehicles, combined with the unwillingness of most drivers to slow down to let pedestrians cross.
- The high speed of vehicles increases the risk of vehicle-vehicle collisions, which create a lot of damage and slow down traffic.
- Due to high speed, cycling in mixed traffic conditions is dangerous.

Objectives

- Calming down traffic along the entire section of Temeke Road.
- Allowing safe crossing for pedestrians at most points.
- Create crossing points with low vehicle speed, where vulnerable pedestrians (elderly, children, etc) can be sure that they can always cross without danger (create ‘green spots’)

Effects

- Positive for pedestrians and cyclists: traffic accidents on the road section where raised zebras were constructed systematically were almost eliminated. Safe crossing became possible and bicycle safety improved significantly.
- An unexpected positive effect was created by the concentration of Dala Dala stopping, where bus bays were constructed adjacent to the raised zebras.
- Positive for motor vehicle traffic: reduced cost of accident damage; and no significant increase in average speed on this road section.
- The unchanged average speed is the combined effect of lower maximum

speeds (-), reduced intersection waiting times (+), and less delay caused by random stops of mini-buses (+).

– Negative for operators of large carts. The raised zebras are difficult obstacles for them (although easier than road humps of similar height). A systematic introduction of raised zebra crossings on all local collector roads and collector roads in the city will probably make the operation of large pushcarts so unattractive that the operators will be forced to change to other smaller types of carts that can be operated on pedestrian walkways. From a traffic-circulation point of view, this should probably be regarded as a positive effect of the large-scale introduction of raised zebras.
– Pedestrian wait at raised zebra crossings has not been reduced but, on the contrary, increased. This is due to two factors: (i) Slowing down the vehicles does not influence the size and distribution of the inter-vehicle gaps, nor increases the willingness of the drivers to yield to pedestrians that cross; (ii) The calming of an entire road section leads to more dispersed pedestrian crossing. This reduces the overall pedestrian/motor vehicle interference and the corresponding delays. However, at the raised zebra sites, one now finds a better percentage of the more vulnerable pedestrians that wait for longer gaps before crossing.

Safe Waiting Areas

Safe pedestrian waiting areas must be provided. They should not be accessed by motor vehicles (either for bypassing the raised zebra or for parking). This is how crossing points become more useful for pedestrians, and they can be identified more easily.

Perception of Safety

Interviews with road users confirm that most people feel more safe and at ease after the traffic-calming interventions. It is interesting to note that pedestrians say that drivers are now more polite towards them, and more often let them pass. On raised zebra crossings, vehicles push through as much as possible, and pedestrian waiting time does not go down.

Proper integration of pedestrian-crossing facilities in a network of improved main walking routes enhances the use of the crossing points. Such a pedestrian route network can be partly over separate access road reserves rather than along the main motorised traffic roads.

The driver behaviour at a hump seems to be more uniform in Tanzania than it is in Europe, probably due to the higher importance attached to the risk of vehicle damage. This seems to apply equally to drivers of new and public transport vehicles. While the latter seem to drive rather reckless by at some points, one will not see them drive fast over a raised zebra or speed hump.

Visibility

The visibility of the raised zebra is very important. Painted white strips bring about little improvement due to sand and dust accumulating on the road surface and also because of quick wear and tear. The legally required traffic signs also do not help much to improve the visibility of a raised zebra. The most effective elements are: (i) high vertical iron pipe bollards (>80 cm), painted with black and white stripes, and (ii) white T-blocks that protect the pedestrian waiting area from vehicles that might attempt to bypass the raised crossing over the road shoulder. Precast concrete sloping blocks can also be painted with black and yellow triangles.

Uniformity of Design

Uniformity of design throughout the entire city is also important to achieve easier recognition by vehicle drivers.

Strength

The strength of the hump foundation and pavement is very important. If it is not sufficient, pavement damage will quickly develop directly in front of and behind the slopes. Tests were conducted to minimise this:

– by the application of brick pavement in front of and behind the raised zebra (the tests have already shown that on top of the raised zebra, brick pavement is much stronger than bitumen); and
– by the application of an extra cast concrete foundation. The initial findings are positive. A revised version of the guidelines will report on longer-time effects on pavement damage prevention.

Costs and Benefits

Typical costs of a raised zebra crossing constructed on an existing road are around US$4,500, including accompanying measures. The corresponding annual costs are US$1,000, including maintenance.

Benefits: Five raised zebra crossings were built at the first test section along a part (40 per cent) of Temeke Road in Dar-es-Salaam. In the six months before the intervention, 12 accidents had occurred there (with three hospitalised victims). During those six months, no fatal accidents occurred, but in the previous year, there were five (on Temeke Road). In the six months after the intervention, the accident number went down to 2 (with 1 hospitalised victim). A benefit/cost estimate based on these accident numbers gives:

		US$
–	annual costs of the intervention (5 raised zebras)	5,000
–	avoided costs 1 fatal accident	3,000
–	avoided costs 4 serious injury accidents/year	1,000
–	avoided costs of 16 vehicle damage accidents	4,800

The corresponding cost-benefit ratio is 1.75. It is interesting to see that the avoided costs of damage to vehicles (i.e. benefits to motorised traffic) are equal to the costs of the interventions.