Traffic calming schemes

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Opportunities and implementation strategies

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Summary

Commissioned by the Swedish National Road Authority, the current report aims to provide a concise overview of knowledge of and experiences with traffic calming schemes in urban areas, both on a technical level and on a policy level. Traffic calming refers to a combination of network planning and engineering measures to enhance road safety as well as other aspects of liveability for the citizens. More specifically, in the current report the starting point is that traffic calming schemes in residential areas aim to discourage motorized through-traffic to enter the area and to achieve an appropriate, safe speed of remaining motorized traffic. Traffic calming at main urban roads aims to achieve an appropriate, safe speed. Urbanwide, traffic calming aims to reduce the volume of motorized traffic by providing safe and attractive facilities for alternative transport modes such as cycling and walking.

The report discusses various characteristics of the urban network which are relevant for meeting the objectives of traffic calming, such as the functional classification of the network, the network structure of residential areas, and the need for a safe and attractive network for pedestrians and cyclists. In addition the report discusses the use of technical road engineering measures to achieve an appropriate safe car speed. In particular in residential and shopping areas, network characteristics have to be supported by road engineering measures, so that through-traffic is avoided and remaining motorized traffic drives at a low speed and is subordinate to the other users of the area. On urban main roads, the possibilities of traffic calming are much more limited. The efficient processing of motorized traffic is one of the major functions of this type of roads. This would require higher speeds at the road sections and, hence physically separated pedestrian and bicycle facilities. Speed reduction, however, would need to be realized at intersections and at midblock pedestrian and bicycle crossings, since at these locations, cars and vulnerable road users have to mix. At an urbanwide level, a traffic calming policy aims at a reduction of the number of car trips. Safe and comfortable facilities, for pedestrians and cyclists, reliable, dense and cheap public transport facilities and restricted parking facilities in the city centre will make alternative transport modes more attractive. It is concluded that much is known about the technical opportunities of urban traffic calming. It is also concluded that traffic calming is effective in reducing car speeds, car traffic volumes, and road traffic crashes.

However, getting traffic calming schemes actually implemented at a local level may appear to be difficult. In a general way, the support in society for the objectives and principles of traffic calming has been steadily growing, but at the level of concrete measures there are often controversies among the public and other stakeholders due to different interests and preferences. The report discusses the role of public participation, information, and education as means to facilitate the implementation phase. As the report states, an effective way to deal with contradictory interests and beliefs is public participation based on the principles of social marketing. Participation of citizens who are directly (e.g. residents) or indirectly (e.g. interest groups)

involved is a useful instrument to identify the existing and experienced problems and the preferences and dislikes with regard to specific measures. This way, resistance may be minimized and support may be maximized. Platforms at a neighbourhood level or at a citywide level provide a workable structure for the participation process. They allow for a systematic exchange of information between participants about the problems, the underlying causal factors, the aims, and in relation to that, the possible solutions. In addition, public information and education remain essential instruments to back up traffic calming policies. Public information as a stand-alone measure generally does not influence behaviour to a large extent, but by increasing understanding and knowledge about the problem, the aim and the measures, it does add value to other measures such as road engineering measures. Public information is a one-way process that hardly can take account of different groups and different opinions in society. Education, even though it has a more limited range, has the advantage that it is provided on a bilateral or small group basis and allows for direct interaction between the 'messenger' and the 'receiver(s)'. Education also has the advantage that the effects of measures and/or particular behaviour strategies can be experienced and trained in practice. It is concluded that public participation, information and eduction, emphasizing the positive effects of traffic calming schemes in the widest sense can contribute substantially to the level of support in society.

Sammanfattning

På uppdrag av Vägverket i Sverige redovisas en i denna rapport en sammanställning av kunskap om och erfarenheter av ”traffic calming”[1]-projekt i tätort. I rapporten redovisas såväl tekniska som implementeringsmässiga aspekter på traffic calming. Traffic calming omfattar en kombination av vägnätsplanering och fysiska vägåtgärder i syfte att öka storstadsbons livskvalitet. I rapportens inledning definieras syftet med traffic calming för olika tätortsområden. I tätortskärnan är syftet att minska genomfartstrafiken och att åstadkomma en säkrare hastighet bland kvarvarande fordon. På större tätortsgator är syftet att uppnå en säkrare fordonshastighet. I tätorten som helhet är syftet att uppnå en minskning av andelen motorfordon, detta genom att bl.a. bygga säkra och attraktiva cykel- och gångvägar.

I rapporten diskuteras olika karakteristika på tätortsvägnätet relevanta för de mål man vill uppnå med traffic calming, t.ex. funktionell klassificering av vägnätet, nätverksstruktur för bostadsområden och behov av säkra och attraktiva nätverk för gående och cyklister. Vidare redovisas olika fysiska vägåtgärder för säker fordonshastighet. Särskilt i bostads- och affärsområden behöver väg- och gatunätets sträckning stödjas med fysiska vägåtgärder för att åstadkomma en minskning av fordonens genomfartstrafik och säkra att kvarvarande fordonstrafik sker i en låg hastighet, underordnad övriga användare av området. På huvudgator är möjligheten till traffic calming mer begränsad. Huvudfunktionen för denna vägnätstyp är att skapa framkomlighet för motorfordon. Detta medför krav på ökade hastigheter på sträcka och därmed krävs fysiskt separerade gång- och cykelbanor. Hastigheten behöver dock sänkas i korsningar, rondeller, övergångsställen etc., eftersom där blandas åter motorfordon, cyklister och gående. I tätorten som helhet syftar traffic calming till att reducera antalet fordonsresor. Säkra och bekväma cykel- och gångtrafikleder, kollektivtrafik som är billig, tillförlitlig och har täta avgångar samt restrektioner då det gäller parkering för motorfordon kan öka de alternativa transportslagens attraktionskraft. En slutsats är att mycket är känt om de tekniska möjligheterna då det gäller traffic calming i tätort. En slutsats är också att traffic calming är ett effektivt sätt att reducera fordonshastighet, fordonens trafikvolym samt antalet trafikolyckor.

Det är vid själva implementeringen av traffic-calming-projekt som svårigheterna uppstår.
På en generell nivå ökar stödet i samhället för de mål och principer som styr traffic calming. Det är på konkret åtgärdsnivå som motståndet uppstår och kontroverser uppkommer bland boende och företrädare för olika särintressen. I rapporten diskuteras vilken roll medborgarsamverkan, information och utbildning har som verktyg för att underlätta implementeringsfasen. I rapporten fastställs att ett effektivt sätt att hantera motsatta intressen och tyckanden är att involvera medborgarna i införandefasen. Genom att involvera de medborgare som är direkt

[1] Begreppet ”traffic calming” används i denna rapport. I Sverige användes begreppet ”lugna gatan”. ”Traffic calming” och ”lugna gatan” kan till stora delar ses som synonymer vad gäller såväl begrepp som strategiskt innehåll.

(innevånare boende i området) och indirekt (företrädare för specifik intressegrupp) berörda av traffic calming-projektet, kan man identifiera och diskutera existerande och förväntade problem och inställningen till specifika åtgärder. På så sätt kan motståndet minimeras och stödet maximeras. Ren storleksmässigt förespråkas en stadsdel eller ett grannområde då det gäller involveringsprocessen. Då möjliggörs ett mer systematiskt utbyte av synpunkter om problem, om underliggande negativa föreställningar, om existerande preferenser samt diskussioner om möjliga lösningar. Informations- och utbildningsinsatser å andra sidan är i all väsentlighet enbart instrument för att stödja acceptansen och synen på de övergripande målen och principerna som styr traffic calming-projekten. Enskilda informationsinsatser påverkar oftast inte trafikantens beteende. Information som ökar förståelse och kunskap om problemen, målen och åtgärderna kan dock öka effekten av andra åtgärder, t.ex. fysiska vägåtgärder. Informationsinsatser är en envägsprocess vari man svårligen kan ta hänsyn till och anpassa budskapet till alla olika grupper och olika åsikter i samhället. Utbildning, även om man når färre människor, har den fördelen att där tillåts en direkt dialog mellan “sändare” och “mottagare”. Utbildning har också den fördelen att effekten av åtgärder och/eller särskilda beteenden kan tränas och upplevas i verkligheten. Slutsatsen i rapporten är att, involvering av medborgarna samt informations- och utbildningsinsatser som i den vidaste mening understryker de positiva effekterna av traffic calming-projektet, bidrar substantiellt till att öka stödet i samhället.

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1. Introduction

Commissioned by the Swedish National Road Authority, a literature study was performed aiming to provide a concise overview of knowledge of and experiences with traffic calming schemes in urban areas both on a technical level and a policy level. Traffic calming is a rather broad concept and refers to a combination of urban planning and engineering measures to enhance road safety as well as the living conditions of the urban residents. Traffic calming schemes aim to promote non-motorized traffic modes or public transport, in particular though not exclusively in residential areas, and to achieve an appropriate, safe speed of motorized traffic.

In order to ensure that the study was maximally tuned to the needs and interests of Sweden, the Swedish National Road Authority and the Swedish Association of Local Authorities (the 'Svenska Kommunförbundet') were consulted. Based on their input it was agreed that the study would emphasise traffic calming schemes, i.e. combinations of measures in a wider area, rather than individual measures, such as road humps or road narrowing at a local level. It was also agreed that the study would not only cover traffic calming in residential areas but also on main urban roads, although for the latter category the possibilities for traffic calming are limited. Furthermore, it was agreed that the implementation strategies would receive specific attention: whereas it is one thing to develop plans based upon the most recent and best knowledge, having these plans realised and implemented is quite another.

Having taken the aforementioned issues into account, the report deals with the following issues. *Chapter 2* provides a brief general overview of the concept of traffic calming from an international point of view and from a Swedish point of view: the aims, the philosophy, the type of measures, and the current state of affairs.

In *Chapter 3* the network planning aspects of traffic calming are discussed. By network planning from a traffic calming point of view, it is aimed to divert motorized traffic from residential areas to roads with a traffic function; furthermore, it is aimed to make alternatives like walking and cycling attractive by specifically planning a network for these transport modes. The role of road categorization, the effects of network structures on traffic volumes and some characteristics of network planning for cycling and walking are reviewed.

Clearly, it is virtually unfeasible and probably also undesirable to abandon all motorized traffic from residential areas, let alone from the main urban roads. People have to be able to get close to their houses by car and to reach other destinations inside or outside their town. *Chapter 4* deals with the issue of how to make sure that remaining car traffic passes at an appropriate speed in order to enhance road safety and other aspects of the living conditions of the urban residents. The chapter focuses on combinations of engineering measures to support the general speed limit in residential areas and urban areas with a traffic function as well as the transition zones between those two types of areas. Potentially negative effects of traffic calming engineering measures for specific road user groups (e.g. public transport, emergency services, and disabled persons) as well as directions for solutions are discussed as well.

Chapters 5 and 6 deal with two elements of implementation, discussing the prerequisites and conditions for actually getting traffic calming schemes be realised: the role of participation and the role of information and education.

Chapter 7, finally, summarizes the main conclusions from the study with specific attention to the Swedish context.

2. The concept of traffic calming: an overview

Lars Eriksson, Theo Janssen, & Roelof Wittink

2.1. Definition and scope of traffic calming

There is not one single, overall accepted definition of traffic calming. As described in the Australian manual 'Towards Traffic Calming' (WSROC, 1992) some of the definitions are expressed in terms of the objective, whereas other are expressed in terms of measures. The objectives generally refer to elements such as improving traffic safety, increasing liveability, and protecting the environment. More generally it can be said that traffic calming aims to alleviate the adverse effects of motorized traffic. Measures generally refer to local speed control and other measures of traffic restraint, but may, more widely, also include network planning, parking policies and stimulating the use of alternative transport modes.

Furthermore, and in relation to this, traffic calming has a variety of connotations, in particular with regard to its scope. Originally, traffic-calming measures were limited to individual residential streets or residential areas or neighbourhoods, aiming to reduce the speed of motorized traffic. It soon became clear that from road safety point of view, traffic calming in residential areas had to be area-wide rather than appying it to an individual street only. The reason was that in residential areas accidents are seldomly concentrated at specific black spots, but are rather scattered over the area. Low intensities in residential areas make police enforcement inefficient, so physical speed reducing measures were introduced to support the speed limit and to increase safety in a whole area. Later on, traffic calming was also applied to regional roads and local distributor roads, since on these types of roads more accidents happen than in residential areas. As years passed by, the scope and considerations with respect to traffic calming broadened, emphasising urban-wide measures to reduce motorized traffic and to promote other transport modes. In this approach, environmental, liveability, and health considerations prevail, even though the safety consequence of an overall reduction in urban car travel is evident. Arguments that are used to promote this point of view include:

- Considerable savings in infrastructure costs can be made when investments in alternatives for the car make expansion of the car infrastructure unnecessary. An optimal investment system gives priority to walking and cycling for short trips, including trips to feed public transport, to restrict the need for car use as much as possible;
- Traffic management in built-up areas can be enhanced significantly by road categorisation and the promotion of car alternatives, e.g. public transport, cycling, and walking;
- Significant progress on road safety depends highly of segregation of traffic according to traffic function and the right conditions for a mix of traffic modes, to be created by road categorisation and traffic calming; the safety of cycling might be much more a consequence of creating conditions for mixed traffic than of segregated facilities (Wittink, in press);
- Crimes, such as robbery and molesting, have grown, also in public space. It is now considered as one of the most important problems of

society. Social security is related to opportunities for street activities and communication between road users; slow speeds and a large presence of pedestrians and cyclists help create the conditions;
- The emissions, the noise and the danger caused by motorized traffic cause health problems with an economic value comparable to their road safety toll;
- An increasing part of the population suffers overweight, partly due to too less physical activities. The mental development of children is even at stake due to a lack of possibilities for activities outdoors. Walking and cycling activities serve as a physical activity that helps prevent diseases (I-ce & the Habitat Foundation, 2000).

In the current report, traffic calming focuses on urban areas and refers to a combination of urban planning and engineering measures to enhance road safety as well as other aspects of liveability for the citizens. More specifically, in the current report the starting point is that traffic calming schemes in residential areas aim to discourage motorised through traffic to enter the area and to achieve an appropriate, safe speed of remaining motorised traffic. Traffic calming at roads with a traffic function aim to achieve an appropriate safe speed. Urban-wide, traffic calming aims to reduce the volume of motorized traffic by providing safe and attractive facilities for alternative transport modes.

2.2. A short historical overview

The term 'Traffic Calming' first emerged in the 1980s. However, the principles of traffic calming date from as early as the 1960s. The OECD report on vulnerable road users (OECD, 1998) presents a historical retrospective of the origin of the traffic calming principles. Starting point was the rapid expansion of car ownership in the 1960s and 1970s. It was found that the road network of towns and city centres could not take an indefinite increase of car traffic. Roads were built or widened to accommodate the growing car traffic, often with unfortunate effects to vulnerable road users and residents of built-up areas; pavements were narrowed to put in additional car lanes; parked vehicles increasingly took over the space previously devoted to pedestrians and cyclists; and large urban arterial roads secluded parts of urban areas or cut through historical neighbourhoods. It is clear that the explosion of car growth resulted in a conflict of interests. The search for a controlled development of private motorized traffic started.

The first reaction was to build new residential areas on the principle of complete segregation of pedestrians and motorized vehicles, first in Sweden (SCAFT, 1968), then in some British towns. But at the end of the 1970’s the virtues of segregation in residential areas started to be questioned. They were expensive; they did not allow easy planning of public transport; the position of cyclists and other non-motorized two-wheelers was unclear; they precluded any sort of mixed activities and complete segregation was only applicable to newly built areas. Complete segregation remained or was even expanded for very specific areas, resulting in traffic free city/town centres and pedestrian shopping zones.

A new concept of integration of mixed traffic appeared, termed 'woonerf' in Dutch, based on the idea that, in residential areas, drivers should drive at walking pace and give precedence to vulnerable road users in the street, particularly to children. Sidewalks for pedestrians were considered unnecessary and were not allowed. At junctions all traffic from the right, including pedestrians, had priority. For the first time is was acknowledged by decision makers that residential streets could have another function than just accommodation for motorized traffic. In two large scale pilot projects in the Dutch cities of Rijswijk and Eindhoven it was found that the 'woonerf' led indeed to a substantial reduction in the number of injury accidents, not only in the 'woonerf' areas, but also in the surrounding traffic areas. An overall effect of 25% fewer casualties was reported (Janssen, 1991). Interestingly, it appeared from this study that the more simple infrastructure measures performed at least as effectively as the more expensive and complex measures.

However, soon it became clear that there were also disadvantages associated with the 'woonerf' approach. These concerned the legal design requirements, the additional engineering measures, the space needed for realisation and, last but certainly not least, the high construction cost, especially when a 'woonerf' had to be realised by adapting an existing residential area. Consequently, the application of the 'woonerf' often remained restricted to relatively small areas.

It was generally acknowledged that the two essential features of the 'woonerf' were speed reduction of motorized traffic and reduction of through-traffic. From accident studies (Ashton & Mackay, 1979; Van Kampen, 1985;) it turned out that the probability of serious injury for vulnerable road users is minimal, if the collision speed does not exceed 30 km/h. From this finding it was deduced that in residential areas a general speed limit of at 30 km/h would be acceptable. Since just a 30 km/h sign would not help and police enforcement in residential areas would be inefficient, low cost speed-reducing engineering measures were applied to support, physically, the 30 km/h limit. So, in fact, the concept of the 30 km/h zones has been derived from the 'woonerf'-concept, enabling an application to much larger areas and at much lower cost, thus avoiding the major drawbacks of the 'woonerf' approach. Since the early 1980s, an increasing number of European countries apply 30 km/h speed limits for residential roads or residential areas, e.g. the Tempo-30 zones in Germany and the 'silent roads' in Denmark. In an evaluation of the effects of 30 km/h zones in the Netherlands, it was found that on average the number of injury accidents had dropped by 22%, but the variation in effectiveness was very large: c. 13%. It was also found that the volume of motorized (through-)traffic had decreased to a significant degree (Vis, Dijkstra & Slop 1992; Vis & Kaal, 1993; see also Chapter 4 of this report). The extension of the number of 30 km/h zones in urban areas is one of the major elements of the Dutch sustainable safety policy.

2.3. The Swedish context

By international standards, Sweden has made substantial progress in efforts to achieve a safe road traffic system. It belongs to the safest countries in the world. In 2000, in Sweden, 591 people died in road traffic accidents. This equals 6.67 deaths per 100,000 inhabitants which is the lowest ratio in the European Union and even in the world (Source: IRTAD).

Despite the very good position internationally, Sweden wants to improve the road safety and reduce the number of road traffic victims further. In October 1997, the Swedish Parliament adopted a ‘vision zero’ approach as a basis for Sweden’s long-term road safety objectives. As the name implies, the objectives involve the eventual reduction of fatalities and serious injuries resulting from road accidents to zero. The Government had set a first-phase maximum target for the year 2000 of 400 deaths and 3,700 serious casualties. By 2007, the number of people killed on the roads should have fallen to 270, or 50% of the total for 1996, when 537 people were killed. The latest road safety data show that the 2000 target was not met, and there is still a long way to go to meet the 2007 target. In fact, the last years there has been an increase in the number of road fatalities rather than a decline.

Already in 1998, the Swedish Government viewed the recent increases in the incidence of injuries on Sweden’s roads with growing concern. This development was considered to be unacceptable. Accordingly, in that same year, the Government commissioned the Swedish National Road Administration (SNRA) to draw up a special plan of road safety measures for the road network. The SNRA was also instructed to propose other measures designed to enable road safety objectives to be met efficiently and effectively. The SNRA completed this assignment, and arrived at the conclusion that the interim target set for 2000 could not be met. The authority proposes instead that efforts be concentrated on the target for 2007, i.e. a maximum of 270 fatalities.

In April 1999, the Government decided about a so called 11-point programme for improving road traffic safety. The Government expects that the initiatives to be taken in connection with this programme, combined with other road traffic safety work currently being undertaken, will serve to reduce the number of deaths and seriously injured on the roads substantially.

The programme identified eleven areas of great traffic safety concern:

1. Special safety measures for the most dangerous roads
2. Better road safety in urban areas
3. Emphasis on road-user responsibility
4. Safer conditions for cyclists
5. Quality assurance for transport services
6. Compulsory use of winter tyres
7. Better utilisation of Swedish technology
8. Greater responsibility placed on road traffic system designers
9. Handling of traffic offences
10. The role of voluntary organisations
11. Alternative forms of financing new roads

The Government declared that measures, to be able to implemented, must be based on co-operation - built on mutual trust and a sense of solidarity - between those responsible for the road traffic system and road users. The latter have a duty to comply with prevailing regulations and exercise consideration for other road users. Central to the ‘vision zero’ approach, however, is the concept that a driver should be able to make a mistake on the road without suffering serious injury as a result. To achieve high safety levels, it was clear that both the road network and the vehicles had to improve. Road users, for their part, must be better at observing existing regulations.

If this approach does not achieve the desired effect, a reduction in general speed limits may have to be considered. However, the Swedish Government argued that this would have a detrimental effect on accessibility, increase transportation costs for business, and reduce competitiveness.

In the 11-point road safety programme, safety in urban areas played an important role. Almost 40% of all accidents involving deaths or serious injury take place on roads which are owned and maintained by municipalities. Efforts to make roads and streets in built-up areas safer are currently being made by many local authorities. On 1st May 2000, the Government introduced new regulations, aimed at strengthening the right of way of pedestrians at unguarded pedestrian crossings. Local authorities introduced 30 km/h traffic zones. It was seen as important that all local authorities would review their road networks from a safety point of view and implement appropriate measures where necessary. The Government was of the opinion that demonstration projects were of strategic significance for safety on municipal roads and should get under way as soon as possible. The SNRA distributes funds for projects of this kind.

Since then, in many Swedish municipalities, discussions haven been going on about how to make streets safer and at the same time eco-friendly, negotiable, pleasant, and aesthetically appealing. Traffic calming is one of the promising approaches that (again) receives much attention, both at the local level and the national level. In June 1997 the Government decided that between 1998 and 2002 the SNRA should allocate a SEK 1 billion (i.e. just over € 1 million) state subsidy to local authorities in order to facilitate traffic safety measures and environmental improvements to the municipal street network. It is in this framework that the Swedish Association of Local Authorities published the handbook 'Calm streets' (Svenska Kommunförbundet, 1999). The handbook focuses primarily on the planning process for remodelling streets with mixed environments. With this handbook it is aimed to assist local authorities in the planning process to realise traffic safety measures and environmental improvements in the urban road network and as such it can be considered as a new impulse to the application of traffic calming measures in Sweden.

2.4. Conclusions

Traffic calming is a relatively new term for a concept with a long history. Starting point was the enormous expansion of car traffic in the 1960s and 1970s, often with disastrous effects on the safety and well-being of vulnerable road users and residents of built-up areas. The search for a controlled development of private motorized traffic started. Whereas there is not one single definition of traffic calming it can be said that traffic calming aims to alleviate the adverse effects of motorized traffic.

Over the years, the scope and aims of what is now called traffic calming changed. Originally, traffic-calming measures were limited to individual residential streets or residential areas or neighbourhoods, aiming to reduce the speed of motorized traffic. Later on, traffic calming was also applied to regional roads and local distributor roads, since from a safety point of view, these types of roads were more relevant than residential areas. As years passed by, the scope and considerations with respect to traffic calming broadened, emphasising urban-wide measures to reduce motorized traffic and to promote other transport modes. In this latter approach, not only safety plays a role, but also environmental, liveability, and health considerations.

Recently, in Sweden, the traffic calming philosophy got a new impulse with development of the vision zero and the resulting 11-point road safety programme which included urban safety as well as cyclist safety as two of the 11 key areas for action. The handbook 'Calm Streets' of the Swedish Association of Local Authorities which describes in detail the planning processes it can be concluded that also here the scope of traffic calming and urban planning is broader than just road safety and includes the integration of environmental, aesthetical, and social considerations.

3. Traffic calming: the role of network planning

Theo Janssen & Peter Wouters

Network planning is an essential first step when setting up area-wide traffic calming schemes. The main goal is to avert motorized traffic from areas with a residential function. A number of conditions have to be met to realize this. First of all, the network must be so that through-traffic avoids routes through residential areas. Secondly, destination traffic must reach its destination at the shortest possible distance from the entrance of the residential area. These two, sometimes contradictory conditions are discussed in *Section 3.2*. However, this presumes that it is known which areas are classified as residential areas. *Section 3.1* presents some considerations for a functional, safety-oriented road categorization. Thirdly, and the subject of *Section 3.3* there have to be sufficient and attractive facilities for alternative transport modes, including walking, cycling, and public transport to replace at least part of the urban car trips.

3.1. Functional road categorisation

3.1.1. *Residential function versus traffic function*

The starting point for a safe infrastructure network is functional road categorization. Each road is appointed one and only one specific function (monofunctionality) and, subsequently, it is designed in such a way that it meets the specific functional requirements as optimally as possible and that it is used according to the assigned function (see *Figure 3.1*); most of all that it guarantees optimal safety. For example, some roads enable access to properties, other roads open up districts and towns, link up regions, and so on. Roads or streets, which have a function to provide access to properties, should not be used to reach another urban district.

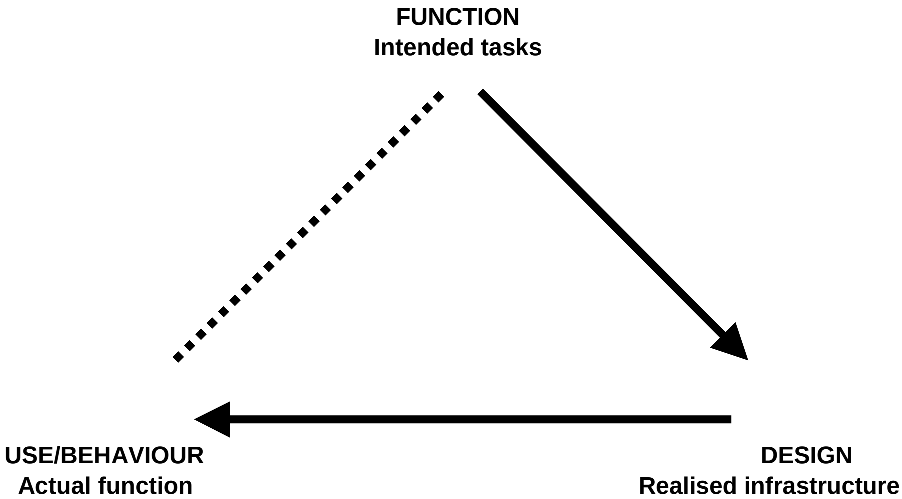


Figure 3.1. *The relationship between function, design and use for road infrastructure (Dijkstra & Twisk, 1991).*

For traffic calming in urban areas two functions can be distinguished: a residential function and a traffic function. Streets and roads with a residential function cater for activities such as shopping, walking, and playing; they have a very limited traffic function, i.e. providing access to properties alongside, which should be very much subsidiary to the residential function. This notion is underlying the 'woonerf' and the pedestrian shopping zone concepts: motorized traffic is not allowed at all or has to move at walking pace giving priority to playing, walking, and shopping residents. On urban roads with an important traffic function (distributor roads) the flow and circulation of (motorized) traffic remain the main purpose. At road sections, car speed is higher to allow efficient processing of through-traffic. As a consequence, for safety reasons, car traffic has to be segregated from vulnerable road users. At intersections, where roads with a residential function enter roads with a traffic function and different road user groups mix, the car speed has to be low.

3.1.2. *The size of residential areas*

It is clear that when planning for traffic calming schemes it has to be decided which road has which function, since the possibilities and limitations of traffic calming measures largely depend on the assigned function (see also *Section 4.2*). For safety reasons it is best to assign the residential function to a number of adjacent roads and treat them as a residential area. Large residential areas are considered to be safer than small residential areas. When having large residential areas, the length of the less safe traffic roads in the total network is reduced. Furthermore, large residential areas reduce the number of intersections with roads with a traffic function, the distributor roads, and the need for crossing these.

However, there is an upper limit for the size of residential areas. This upper limit has to be set by safety, liveability, and accessibility criteria (*Table 3.1*).

Road safety	Limit the travelled distance within the area Limit the traffic volumes within the area Prevent through-going motorized traffic through the area Limit speeds of motorized traffic
Liveability	Limit traffic volumes in the area (simplified crossing by pedestrians and cyclists, environmental improvements) Limit traffic volumes on surrounding distributor roads Limit speeds of motorized traffic (simplified crossing by pedestrians and cyclists, environmental improvements)
Accessibility	Accessibility for emergency response vehicles Accessibility of urban facilities by pedestrians and cyclists Accessibility for public transportation Accessibility for cars

Table 3.1. *Criteria to determine the maximum size of a residential area (Van Minnen, 1999).*

Van Minnen (1999) systematically calculated the effects of the size of a residential area on each of the above-mentioned criteria. He concluded that the size of residential areas should be as large as possible. However, if the size exceeds 100 hectare, traffic volumes on the surrounding distributor roads become too large. If the size exceeds 200 hectare, traffic volumes on residential streets become too large. The accessibility for emergency response vehicles and public transportation is a matter that should be monitored carefully. More specifically, Van Minnen concluded:

Total travelled distances (on residential streets and distributor roads): Total travelled distances are hardly influenced by the size of the residential area. No limiting values can be set.

Travelled distance on residential streets: An increasing size results in an increase of travelled distance on residential streets. No limiting values can be set.

Volumes on residential streets: If a residential area with only one connection to a distributor is larger than 20 - 30 hectares, volumes on residential streets exceed 3000 - 5000 vehicles per day. In a situation with a large number of connections, the size of the residential area can be up to 200 hectares, without exceeding an average daily traffic of 3000-5000 vehicles (*Appendix*).

Volumes on distributors: An increase in size results in an increase of volumes on distributor roads. In typical residential areas problems can arise if the size of the residential area is larger than 100 hectares.

Speed on residential streets: Up to a size of 200 hectares, the size of the residential area has no influence on the speed on residential streets.

Speed on distributor roads: The size of the residential area has no influence on the speed on distributor roads.

Accessibility for pedestrians and cyclists, inside residential area: Larger residential areas increase the accessibility for pedestrians and cyclists.

Accessibility for pedestrians and cyclists, external destinations: The size of the residential area has no influence on the external accessibility of pedestrians and cyclists.

Accessibility for cars: An increasing size of the residential area decreases the accessibility for cars slightly. No limiting values can be set.

Accessibility for emergency response vehicles: An increase in the size of the residential area can increase the emergency response time. For a fire truck, the additional response time with increasing size ranges from 11 seconds (growth to area size of 25 hectares) to 31 seconds (area size of 200 hectares).

Accessibility for public transportation: The extra travel time for areas larger than 60 - 70 hectares, exceeds one minute.

3.2. The effect of the network structure on traffic volumes and safety

3.2.1. *Basic network structures*

As indicated in the previous Section, network planning for traffic calming commences with a distinction between roads with a traffic function and roads with a residential function. Residential streets are best brought together in a residential area that is not intersected by a distributor road. The road network structure within the residential area and the number of connections with the higher order distributor roads determine the volume of motorized traffic within the residential area. From a traffic calming point of view the traffic volumes would need to be as low as possible, i.e. unattractive for through-traffic and on the other hand providing good accessibility for destination traffic without large detours. Furthermore, the network structure should provide high safety standards.

There are three basic network structures for residential areas: the grid network, the limited access network and the organic network (*Figure 3.2*).

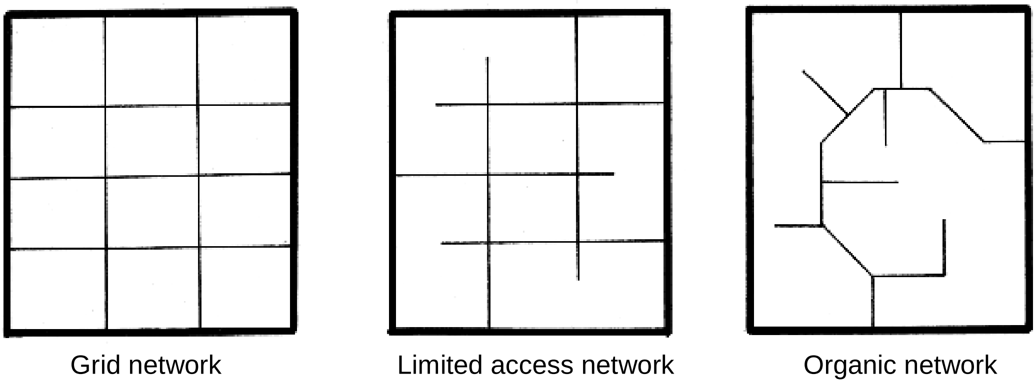


Figure 3.2. *The three basic residential area network structures (Dijkstra, 1997).*

A grid network provides direct access to destinations resulting in the shortest travel distances through the residential areas for destination traffic. The mean trip length in the grid network is approximately 15.5% shorter than the trip length in limited access and organic network and it was found that during the morning rush hour, the grid network generates approximately 10.5% less kilometres of travel (origin-destination traffic only) than the limited access and organic network (McNally & Ryan, 1993). However, at the same time, a grid network attracts more through-traffic than the other two network types. In a grid network, the traffic volumes are equally spread over the streets in the network. Without additional speed reducing measures, the long straight road sections will result in high driving speeds. Furthermore, a grid network has many relatively unsafe connections with distributor roads.

With a limited access network the number of connections with distributor roads is limited. The travel distances are longer than in a grid network, but shorter than in an organic network. Because of the dead-end streets, there is hardly any through-traffic, but destination traffic has to cover larger distances. Overall, traffic volumes are limited, but there is no even distribution of these volumes over the network streets. Because the straight road sections are shorter, speeds are lower than in a grid network.

Organic networks result in the longest travel distances; journey times can be up to 30% longer than on a grid network (Van Minnen, 1993). Again, there is hardly any through-traffic on residential streets. The traffic volumes are limited, but it is not evenly distributed over the streets in the area. Because of the short straight road sections, organic networks have lower driving speeds than both grid and limited access networks. Organic networks also have a large share of T-intersections, which are safer than X-intersections. The number of connections with distributor roads is very limited.

Table 3.2 summarizes the most relevant characteristics of the three network structures for residential areas. It can be concluded that the organic network structure approaches the traffic calming requirements most: it is best in discouraging through-traffic and has the highest safety standard by nature. A point of concern is the central street of the network which has to carry a relative large amount of (destination) traffic and as such may easily turn into an internal barrier for its residents. Part of the solution can be found in increasing the number of non-motorized urban trips at the cost of the number of motorized urban trips (see also *Section 3.3*).

	Grid network	Limited access network	Organic network
Avoidance of through-traffic	-	+	++
Short distances for destination traffic	++	+	-
Self-induced speed reduction	-	+	++
Limited number of connections with distributor roads	-	+	++

Table 3.2. *Relative score of three types of residential area network structures for the four most relevant indicators*.

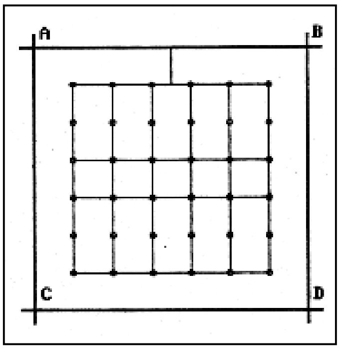
3.2.2. *The number of connections and distance travelled*

As indicated, a relevant aspect both for safety and for traffic volumes is the number of connections between the residential area and the surrounding distributor roads. Van Minnen (1993) also calculated the effect of the number of connections on the distance travelled inside the residential area and the distance travelled on the distributor roads (*Figure 3.3*).

It was found that, in general, the less connections, the larger the distance travelled both on residential streets and on the surrounding distributor traffic roads. There is one exception and that is a network with six connections: here, the travel distance on the traffic roads is larger than in the four-connection variant and comparable to the two-connection variant. This may be explained by the fact that if the number of connections exceeds a particular number, the car becomes more attractive as a transport mode, at least in comparison to alternative modes like cycling and walking.

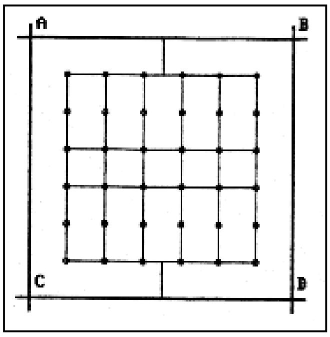
The calculations also show that, in general, the higher the number of connections, the smaller the relative share of distance travelled on residential streets. Again, there is one exception; this time with the one-connection variant. Compared to the two- and four-connection variant the one-connection variant has a smaller share of distance travelled on residential roads. This may be explained by the fact that residents living furthest away from the connection are more often inclined to use other transport modes than the car.

One connection



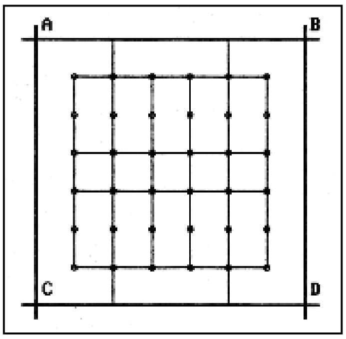
Distance on residential streets 180 (41.7%)
Distance on traffic roads 252 (58.3%)
Total distance: 432 (100%)

Two connections



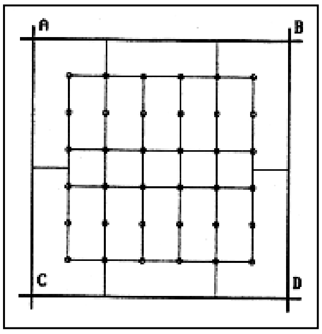
Distance on residential streets 150 (47.1%)
Distance on traffic roads 168 (52.9%)
Total distance 318 (100%)

Four connections



Distance on residential streets 126 (45,6%)
Distance on traffic roads 150 (54,4%)
Total distance 276 (100%)

Six connections



Distance on residential streets 102 (37.6%)
Distance on traffic roads 169 (62.4%)
Total distance 271 (100%)

Figure 3.3. *Effects of the number of connections on distance travelled (From: Van Minnen, 1993).*

From these calculations it can be concluded that a large number of connections generate the smallest travelled distances, in particular within the residential area. It has to be noted, however, that the calculations presented above only include the traffic generated by the residents of the area. It was also found that an increase in the number of connections resulted in more through-traffic, and more so when the connections were situated in the centre of the residential areas instead of in the corners A, B, C or D (Van Minnen & Krabbenbos, 2002).

3.3. Promoting walking, cycling, and public transport use

Promoting walking, cycling, and the use of public transport as an alternative to trips by car is an important contribution to the traffic calming philosophy, and, if successful, may have an urban-wide effect.

Promoting the use of public transport has appeared to be very difficult. A first prerequisite is a dense and reliable public transport network in combination with relatively low fares and a strict parking policy, in particular for the inner cities. Large parking lots (transferia) outside the city centre and shuttle buses to and from the city centre can contribute to the reduction of car travel and parking problems inside city centres.

When considering the promotion of cycling and walking as an alternative to, in particular, short urban car trips, it is important to realise that cyclists and pedestrians are vulnerable road users, as traffic safety records show. Therefore, their safeguarding is a prerequisite for stimulating such a shift in modal choice. In that case it is certainly nót so that an increase in walking and cycling results in an increase in the number of casualties. On the contrary: from several sources it is known that an increase in cycle use goes together with a decrease in the absolute number of cyclist fatalities. For example, in the Netherlands the number of fatalities among cyclists was 54% lower in 1998 as compared to 1980 in spite of the increase in both car use and bicycle use (Ministry of Transport, the Netherlands, 1999). In Germany the total number of cyclist fatalities fell by 66% between 1975 and 1998 while the share of cycling in transport increased substantially from about 8% to 12% of all trips (Pucher, 1997; 2001). In the city of York in the UK 15 cyclists were killed or seriously injured from 1996 - 1998 compared to 38 in 1991 – 1993, while the cycling level rose from 15 to 18% (Harrison, 2001).

Two main elements determine the rate of success for a shift from the car to walking or cycling. One element is the land use characteristics of a town or city; another is the availability of a safe and attractive pedestrian/bicycle network.

The two most relevant aspects of land use affecting modal choice are the spatial allocation of urban functions and the density of land use (Frank & Pivo, 1994). A combination of employment and housing reduces car travel demands. Work travel lengths are reduced, and alternative modes are promoted, because of the shorter distance (Verroen, 1994; Hilbers, 1996). Analysis of simulations showed that the number of vehicle kilometres in combined/mixed situations can be approximately 1.5% lower than in situations where employment and houses are separated. The number of casualties was found to be approximately 0.5% lower (Hilbers, 1996). Facilities that attract vulnerable road users, should be located in such a way that routes to and from the facility are short and direct and do not cross major barriers (e.g. hazardous or high-volume roads) (see *Figure 3.4*).

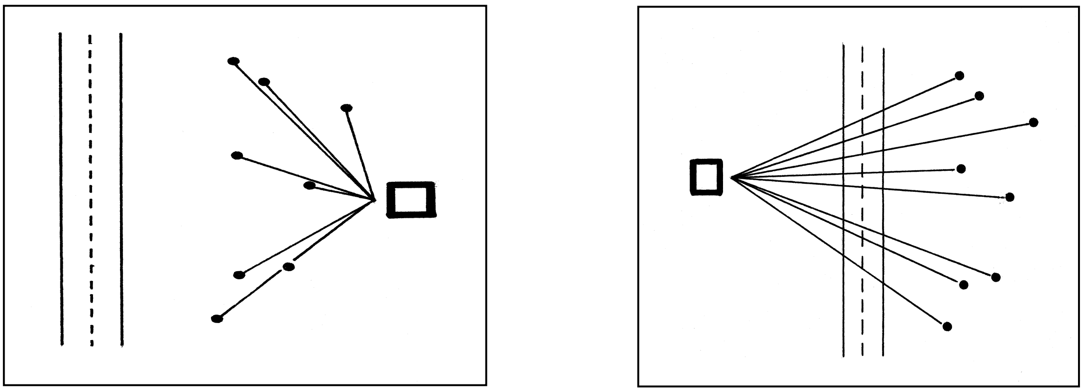


Figure 3.4. *A major barrier between origins and important destination of vulnerable road users should be avoided (From: Hummel, 2001).*

In a compact urban design with high-density land use, distances between origins and destinations are small. High densities cause compact traffic patterns, resulting in more walking and cycling trips. They also improve the basis for public transportation, because more urban functions are located in the vicinity/ influence of stops. A German study on the relation between safety and building structures in existing German and Dutch cities found a strong relation between density (number of square metres per inhabitant) and the number of accidents (Apel, Kolleck & Lehmbrock, 1988). A more recent German study (Becker et al., 1992) also found that an increased density causes a decrease in the number of injuries. Steiner (1994) concluded that residents of high-density areas use public transport or walk more frequently than residents of lower-density areas, and travel shorter distances overall. Steiner also found that the rate of automobile ownership was higher in low-density areas. It has to be noted that the results were not corrected for possible differences in income.

In addition to the land use characteristics, network planning aspects are of importance when aiming to promote walking and cycling. Designing a network for pedestrians and cyclists is much alike the process of developing a sound infrastructure for the circulation of motorised traffic. It regards, for instance, the analysis of data on the traffic volumes involved, studying the area layout, considering opportunities for in integrating the network in the overall traffic and transport system, in stating routes for connecting the places of origin and destination, and so on.

In the Netherlands, five criteria are in use as the main requirements for the network and design of bicycle facilities (CROW, 1996). They can be used for pedestrian networks as well.

1. Coherence (the infrastructure forms a coherent unit and links with all departure points and destinations);
2. Directness (the infrastructure continually offers routes direct as possible (so detours are kept to a minimum).
3. Attractiveness (the infrastructure is designed and fitted in the surroundings in such a way that cycling or walking is attractive);
4. Safety (the infrastructure guarantees safety, that includes road safety and social safety);
5. Comfort (the infrastructure enables a quick and comfortable flow).

These criteria can be implemented in relation to the local situation. A perfect situation does not exist and the process of facilitating cycling and walking will be long term. But the five criteria perform the best guidelines for planning and design, at strategic, tactical, and operational levels of measures.

With respect to the directness criterion, as indicated in *Section 3.2*, a grid network provides the shortest and most direct routes and is, as such, the most appropriate network structure for pedestrians and cyclists. However, as pointed out above, it has major disadvantages when aiming to discourage car travel. The seemingly conflicting conclusion can be overcome by closing some of the streets off for cars, but providing a passage for cyclists and pedestrians only (*Figure 3.5*). Similarly, limited access or organic network structures can be made more attractive for cyclists and pedestrians by creating shortcuts for their exclusive use. It should be noted, however, that from a safety point of view such a direct network has major disadvantages as well, because the number of intersections between the bicycle network and the distributor roads increases. These intersections have to be treated with the utmost care.

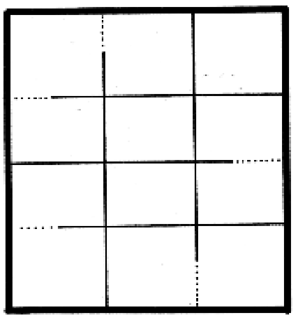


Figure 3.5. *A grid network structure for cyclists and pedestrians (From: Hummel, 2001).*

With respect to the safety criterion, decisions about segregation or integration of motorized and non-motorized road users are of major importance. Generally speaking, in residential areas integration is most appropriate, but only if traffic calming engineering measures are applied to achieve safe car speeds. In traffic areas, segregation is generally more appropriate. At places where the pedestrian, the bicycle, and the car network meet, and road users have to mix, i.e. at intersections, either a 'conflict-free' type of solution (e.g. underpasses or overpasses) has to be found or a drastic reduction in car speed has to be realised. When segregating pedestrians and cyclists from motorized traffic, (subjective feelings of) social security have to be taken seriously into account as well (Van Wegen & Van der Voordt, 1991).

Obviously, although not really an element of network planning, uncomfortable and unattractive conditions during a trip are not stimulating for cycle use. Rough paving, insufficient road maintenance, snow and ice residues, many traffic lights and long waiting periods, narrow cycle paths or pavements, parked vehicles, etc. are a nuisance for the cyclist and the pedestrian and have to be avoided. Bicycle theft, vandalism, and lack of parking facilities are other problem types to be solved.

An example of the successful application of pedestrian and bicycle network can be found in the Dutch town Houten. Houten has grown from a small village with around 4,000 inhabitants to an important commuter town with 28,000 inhabitants in the early 1990s. Houten is in fact one large residential area of approximately 300 hectare, divided into 16 neighbourhoods connected by a ring road. For cars there are no through-traffic opportunities from one neighbourhood to another, they have to use the ring road. Houten has a dense network of direct cycling routes. These days, the inhabitants spend two-third of all purchases in their town (100% in the food sector). Nearly all children go to school by bicycle or on foot. The use of cars in the town is 25% lower and the number of traffic-injured people per 1000 inhabitants is more than 3 times lower than in comparable towns (De Jong & Bosch, 1992).

3.4. Conclusions

Streets in residential areas have a function to provide access to properties and should not be used by through-traffic to reach another urban district, other towns or regions. Roads around the residential areas are intended for flow and circulation of motorized traffic with higher speeds and volumes. The size of the residential area should be as large as possible. But, if areas are more than 100 hectare, traffic volumes on the surrounding roads could be too high and if the size exceeds 200 hectare, high volumes on the residential streets are the negative result.

The best structure of the street network in a residential area is an organic one. Traffic volumes are limited because of avoidance through-traffic, driving speeds are low, and there is a limited number of connections to distributor roads.

The number of connections between the residential area and the through-traffic roads are related to the distance travelled by the residents both on streets and on roads. In general the more connections, the less the distances. It has to be noted that the number of connections are also related to the share of through-traffic on the residential streets: more connections give a higher share.

Promoting other transport modes than traffic by car, land use characteristics and network planning aspects on an urban-wide level are important. No traffic barriers between origins and destinations for vulnerable road users like pedestrians and bicyclists. Their routes must be short and direct, coherent, attractive, safe, and comfortable. Quality of public transport needs a dense and reliable network and a discouraging policy for car traffic, for instance limited parking in the city centre.

4. Traffic calming: engineering measures

Sjoerd Houwing

Whereas network planning is an essential element for traffic calming purposes, engineering measures are necessary to support the objectives. This chapter discusses in a general way traffic calming engineering measures that can be used to achieve a safer speed in built-up areas and to make residential areas less attractive for through traffic. In the first Section the different kinds of measure types as found in literature will be discussed. After this, general design and location recommendations will be examined. In other words, what should measures have to look like and where should they be placed in order to reach the best effects. After this, effects of single measures, groups of measures, and measures in a whole area will be discussed. Finally some secondary effects of traffic calming measures will be mentioned.

4.1. Types of engineering measures

Traffic calming engineering measures are often classified according to their physical appearance. A distinction between vertical and horizontal measures is most common (Mackie, Hodge & Webster, 1993): horizontal measures force drivers to change their position on the road (e.g. a road narrowing) and vertical measures cause a vertical deflection of the vehicle (e.g. a speed hump). Another way to classify traffic calming engineering measures is based on the level of coercion. In this framework Vis, Dijkstra & Slop (1992) distinguish four different types of measures:

Informative measures alert the road users to the fact that a particular kind of behaviour is expected from them. The most well known informative measure is the maximum speed sign.

Suggestive measures do not physically enforce particular behaviour, but try to achieve this by visual suggestion or illusion, for example by emphasizing an area's residential function through special paving construction or road surfacing or by suggesting a road narrowing through line techniques.

Persuasive measures more convincingly persuade road users to behave in a certain way. Examples of such type of measures are speed humps and other bumpy shapes. With these measures the desirable speed is in the strictest sense not physically enforced, but the inconvenience makes that most drivers do reduce their speed.

Obstructive measures make a higher speed physically impossible, for example by forcing the driver to follow a specific course or creating a blocking mechanism caused by oncoming traffic. Chicanes are a common example of this type of measures.

In this paper the terms vertical and horizontal measures are further used to make distinctions based on location and user groups of measures.

4.2. **Location and design of traffic calming measures**

The location and design of measures and devices determine the effectiveness of traffic calming schemes. What is best to do depends on where it is applied: at roads with a residential function, at roads with a traffic function or at the transition between two different speed zones. The next subsections discuss in more detail the possibilities at each of these types of location. A few basic rules, independent of the location can be identified (Huber & Scaramuzza, 1995). First, the measures and devices should not distract the driver too much, since this may cause that other relevant information from the traffic environment is overlooked. Secondly, and in relation to this, the driver should recognise the measures and understand their meaning immediately. When the measures are easy to understand, the driver will accept them better. Measures that look artificial and strange will not be easily accepted. Thirdly, when drivers do not see the reason of a measure they can get frustrated and react in a negative way on the measures. To improve driver's acceptance traffic calming measures should be placed on 'natural' places like pedestrian crossings. And last but not least, the traffic calming devices should be well visible at all time. This can be realised by proper lighting or by using different colour patterns and reflecting strips. Shiny surfaces when wet should be avoided to prevent blinding by the reflection of sunlight.

4.2.1. *Traffic calming measures in residential areas*

About 25% of the urban accidents occur in residential areas. It is the exception rather than the rule to find black spots in residential areas. Accidents are scattered over the entire area. Therefore, an area-wide approach to solve traffic safety problems in residential areas is the most appropriate.

Traffic calming measures in residential areas generally aim to support the network planning in making residential streets unattractive for through-going motorized traffic and to achieve a constant low speed of the remaining motorized traffic so that it can mix relatively safely with cyclists and pedestrians. Traffic calming measures can be applied at road sections and at intersections.

Road sections that have frequent discontinuities of alignment, width, and height help to induce lower speeds and changing materials and colours and the use of street furniture help to break up the impression of a thoroughfare predominantly for motorized traffic (Mackie, Hodge & Webster, 1993). Furthermore, the placement of two or more vertical measures after each other is dissuaded. To create more diversity and prevent aggressive driving behaviour it is best to alternate vertical and horizontal measures. Horizontal measures are preferably made of the same material as the side area (Huber & Scaramuzza, 1995). Placement of traffic calming measures in curves should be avoided, and if this is not possible, they should be placed in the inner site of the curve to facilitate the detection of oncoming traffic (Huber & Scaramuzza, 1995).

An important issue is the distance between measures at road sections. Ideally, the distance should be such that it results in a more or less constant speed that does not exceed the speed limit (see *Figure 4.1*). There is no overall agreement about the most desirable distance between measures. Huber and Scaramuzza (1995) recommend a distance between measures of 30 to 50 meters, whereas the Ministry of Transport in the Netherlands (1984) and the Danish Road Directorate (Herrstedt et al., 1993) recommend a distance of 70 to 80 meter.

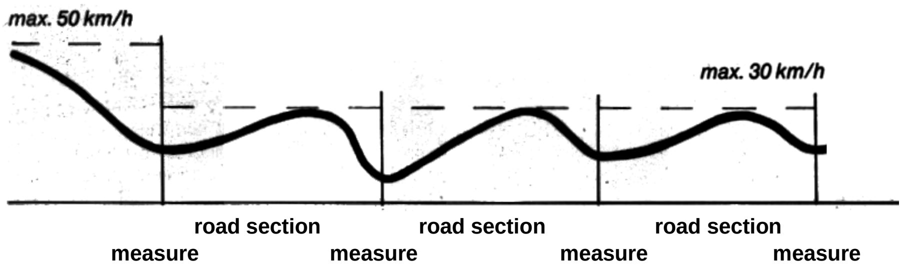


Figure 4.1. *Desired speed behaviour for 30 km/h zones. (From: Ministry of Transport, The Netherlands, 1984)*

Measures at intersections are important since they keep speeds low at places where many urban accidents occur (Mackie, Hodge & Webster, 1993). This placement is also bound by some 'rules'. The measures should not block the view of crossing streets. If the view of crossing streets is less than 60 to 70 meter it is preferable to calm the traffic with a raised area.

According to the Transport Association of Canada (TAC, 1998) the measures with the most substantial effects on speed reduction are the raised pedestrian crossings, speed humps, one-lane chicanes, and roundabouts; in terms of accident reduction they state that the largest benefits can be expected form speed humps, one lane chicanes, round abouts and full closure; the largest benefits in terms of traffic volume reduction can be expected from different sorts of obstruction measures and one way street signing.

Vis, Dijkstra & Slop (1992) evaluated the effects of fifteen 30 km/h areas in the Netherlands in terms of speed, accidents, and traffic volume. They found that the traffic volume decreased by 5 - 30%, with the largest decrease in areas that originally had a lot of through traffic and where engineering measures had affected traffic circulation. Furthermore, they found that after the application of horizontal and vertical measures in residential streets, 85% of the cars had a speed of 30 km/h or less. They conclude that persuasive measures, such as speed humps achieve the largest speed reductions. Also Durkin and Pheby (1992) concluded from an evaluation of traffic-calming schemes in three residential areas in York (England) that the most effective measure for speed reduction is the speed hump. They found an average speed reduction of nearly 15 mph (around 24 km/h). Vis and Kaal (1993) evaluated 150 30 km/h areas in the Netherlands and found an overall accident reduction of about 10-15% and an injury accident reduction of about 22%.The study of Durkin and Pheby in York also showed a decrease of accidents in the three residential areas in York where humps, raised tables, and chicanes were implemented. Macky, Hodge & Webster (1993) even report an accident reduction of almost 70%, with even greater reductions in child casualties in 65 British 20 mph zones (32 km/h). According to these researchers, the accident reduction was mainly the result of the application of combinations of flat and round humps and raised junctions with a few horizontal measures such as chicanes.

Whereas there is quite some variation in the reported size of the effects of traffic calming in residential areas, it can be concluded that the overall effects are positive. Elvik (2001) concludes on the basis of a meta-analysis of 33 international studies on the effects of traffic calming that both the number of injury accidents and the number of material-damage-only accidents in residential streets with speed reducing devices decreases by about 25%.

4.2.2. *Traffic calming measures on distributor roads*

As already stated, distributor roads are meant to keep the traffic flowing on road stretches between intersections and to allow for exchange at intersections. This type of traffic function would mean that car traffic would be allowed to drive at a higher speed than in residential areas and, hence, that there are separated bicycle and pedestrian facilities. Since at intersections vulnerable road users and motorized traffic have to mix, speed must be lower there. Similarly, speeds have to be low at mid block bicycle and/or pedestrian crossings. Traffic calming measures on distributor roads are best concentrated at those locations where different road user categories mix. Too many measures on road stretches without mixed traffic would decrease the traffic flow and is therefore not recommended. If on road stretches speeds are considered to be unacceptably high, horizontal speed reduction measures are to be preferred above vertical speed reduction, since these measures have less influence on traffic flow.

At intersections the application of roundabouts is a very effective way to reduce speed. In addition, at roundabouts the angle of impact is smaller resulting in less severe consequences in case of a collision. As an alternative, plateaus can be used to reduce speed at intersections, in or not in combination with traffic lights. In the case of a series of this type of intersections with traffic lights, a green wave may help to induce a constant speed on the stretches between intersections. Plateaus can also be used to reduce speed at midblock pedestrians and/or bicycle crossings.

In the design of traffic calming measures, it has to be taken into account that distributor roads also have to accommodate buses and trucks and would need to allow emergency vehicles to pass at high speed (see also *Section 4.3*).

The literature about traffic calming measures on main urban roads is much more limited, and so are the number of evaluation studies. Greibe & Nilsson (1999) report on the experiences in Denmark, the Netherlands and the United Kingdom. For example, the evaluation of traffic calming projects at main roads in 21 Danish small towns showed that in the vicinity of the intersection, roundabouts resulted in a speed reduction of around 30 km/h in comparison to the previous conventional four-armed intersection. Various measures at the road sections resulted in an average speed reduction of around 10 km/h. In the UK, the Transport Research Laboratory studied the effects of speed management schemes on distributors roads at four different locations (Finch, In: Greibe & Nilsson, 1999). The schemes consisted of different physical measures at the road sections, such as speed humps, raised pedestrian crossings, and chicanes, as well as the construction of roundabouts at the intersections. On average, a speed reduction of 11 mph (about 18 km/h) was found and speeds were brought back to or below the 30 mph (50 km/h) speed limit. The traffic calming schemes also resulted in a reduction in traffic volumes of between 13 and 65%. A reduction in accidents was found, although this was not statistically significant due to the small number of accidents.

Angenendt (1991) evaluated traffic calming measures on shopping streets with through-traffic in nine German towns and found hardly any effects on average speed. The measures used for traffic calming were road markings and optical narrowing only.

It can be concluded that traffic calming with physical measures such as roundabouts, chicanes, humps, and raised areas do indeed have a substantial effect on the speed of motorized traffic. For main roads Elvik (2001) found in his meta-analysis that speed reducing measures results in 10% less injury and material-damage-only accidents. As indicated above, it must be noted, however, that too many speed reducing measures at the road sections will reduce the flow of through-traffic.

4.2.3. *Traffic calming measures at transition zones*

Measures sited at the transition from one speed zone to another need special attention, in particular the transition from higher to lower speed zones. These measures are used to indicate the transition from one traffic environment to another, to another traffic behaviour, and primarily to another speed (Herrstedt et al., 1993). Forming a transition, the gateway should be the most prominent element in the transition zone and located at the beginning of a lower speed zone. Public lighting should be placed at the gateway to warn the users about the transition at any moment. The measures at the gateway to residential areas are preferably sited in line with other elements of the traffic-calming scheme. Horizontal measures at the gateway should be avoided because the oncoming traffic can block the entrance.

At the transition on main roads from outside to inside the built-up area, most of the time only a speed limit sign is used. However, in the case of transition zones located on the approach of towns and villages on busy through-routes, additional measures are needed to bring about the desired speed reduction. ETSC (1995) describes two principles for measures in such transition zones. The first principle is that complementary measures along the through-route within the urban area are required. The second principle is that measures at the transition zone should be such that they achieve a cumulative effect, culminating at the actual gateway to the towns or villages. The latter can be achieved, as the ETSC reports says, by a combination of road narrowing and the introduction of trees and other vertical elements, culminating in the gateway. This is an example of a suggestive measure that relies on the driver's perception of the appropriate speed: speeds are lower where the height of the vertical elements is greater than the width of the road.

A special issue of concern, related to transition zones, is traffic calming on major through-roads in villages. In a British evaluation study of nine village traffic-calming schemes (Taylor & Wheeler, 1998) a decrease of 3 - 15 mph (5 – 24 km/h) was found at the gateway from outside to inside built-up areas. A decrease of 3 - 14 mph (5- 22 km/h) was found in the village itself. At the gateways signing, marking and coloured surfacing was applied, and in one case road narrowing and a speed cushion were added to reduce speed. In a later study of 56 traffic-calmed British villages (Taylor and Wheeler, 2000) it was found that schemes with only gateway measures resulted in an overall accident reduction in the villages of 10%. The number of fatal and serious accidents decreased by 43%; however, the number of slight accidents increased by 5%. The accident reduction was higher for pedestrians and cyclists than for motor vehicles. Higher accident reduction rates were reported for schemes with additional physical measures in the villages (chicanes, road narrowing, mini round-abouts, speed humps, and cushions). Here, the number of fatal and serious accidents decreased by about 70% and the number of slight injuries by about 37%.

4.3. Traffic calming and its effect on other road users groups

Traffic calming schemes are primarily meant to affect route choice and/or speed behaviour of cars. But they also affect other road user groups like busses, emergency vehicles, pedestrians, and cyclists. It is important to take their needs and wishes into consideration as well.

4.3.1. *Vulnerable road users*

With respect to pedestrians and cyclists, it is clear that traffic-calming schemes aim to make their life in traffic better and safer. Traffic calming devices should be designed and sited in such a way that they do not have an adverse effect on their travel patterns. For example, pedestrians sometimes complain about poles or other obstructions alongside the pavement (preventing cars to park) or even on the pavement (e.g. flower boxes for aesthetical purposes), blocking their free passage. This is particularly a problem for pedestrians with a visual or motor disability. The latter group may also experience difficulties with height differences, for example at a pedestrian crossing. It is advised that the gradient of a pedestrian crossing should not exceed 6% (Angenendt, 1985). Long crossing distances should be avoided. A refuge in the middle of the road can increase the safety of all pedestrians, but in particular of the elderly and disabled. Furthermore, on the level of single measures, it is advised that traffic signs and street boundaries are clearly recognizable and that the upper layer of the surface is made of non-slippery material (Angenendt, 1985).

Cyclists may experience problems in traffic-calmed streets where they have to use the same space as cars, in particular with humps and other vertical measures. In these situations, their comfort and safety can be improved by concentrating the vertical elements in the middle of the street, leaving space at both sides, so cyclists can avoid the traffic-calming device. Vertical measures in streets that are built on a slope should be totally avoided. Horizontal measures such as a road narrowing can also leave a separate space for cyclists so they can pass in a straight line (Huber and Scaramuzza, 1995).

4.3.2. *Public transport*

Buses, probably the most common form of public transport in urban areas, form a specific issue in relation to traffic calming. Traffic calming devices may result in a loss of comfort for the passengers and an increase in travel time. For that reason, bus companies and bus drivers are generally not in favour of traffic calming devices along their routes. Whereas some loss of comfort and time is unavoidable, there are possibilities to minimise the disadvantages, in particular on main streets where, ideally, the majority of bus kilometres are covered. Obviously, roundabouts need to be designed in such a way that buses can easily pass. For buses, raised areas or plateaus are more comfortable then humps. Plateaus longer than 10 meters allow that all tyres are simultaneously on the plateau and, hence, improve comfort (Herrstedt et al., 1993). An option for bus routes in residential areas is the use of so-called combi-humps. These humps are designed as a circular hump using different radii corresponding to different track widths. This will give buses the same comfort as cars, where normally the comfort would be less (Herrstedt et al., 1993). Similarly, one could use narrow speed cushions, which only affect the cars with a small track width and not buses (Ministry of Transport, The Netherlands, 1984), although additional measures might be needed to make sure that buses also drive at an appropriate speed.

4.3.3. *Emergency services*

Emergency vehicles (ambulances, fire trucks and police) generally have an obligation to reach a particular destination within a limited amount of time. Traffic calming seems to counteract this obligation. However, a number of considerations may help to minimise the delays of emergence vehicles by traffic calming measures. As for buses, extended plateaus or humps on main roads allow them to pass faster and more comfortably. For example, an experimental study in Portland (USA) showed that the delay time for a fire truck was less on a 6.70m speed hump than on a 4.25m speed hump (Portland Bureau of Fire, Rescue and Emergency Service, 1996). Especially to meet the complaints of the emergency services, the Netherlands started a trial with what could be called 'intelligent' humps. The principle is that when cars approach too fast, a hump will automatically raise from the ground. However, emergency vehicles have a special device to switch the 'intelligent' hump off when passing in an emergency situation. Whereas some people (e.g. Datta & Datta, 1997) state that delay for emergency services caused by traffic calming measures is often more a perceptual problem than a real problem, it would be unwise to neglect their complaints as well as those of bus companies in the planning stage (see also *Section 5.2.*).

4.4. **Environmental effects**

Speed reducing traffic calming measures may have secondary effects on the amount of noise and exhaust-gases.

With respect to noise, an overall decrease in speed results in a decreased noise level. This was confirmed by data from Taylor and Wheeler when evaluating British traffic calming schemes in villages. In addition to a reduction in average speed (see *Section 4.2.2*), they also found a reduction in noise of around 10%. The fear that traffic calming devices will result in more noise due to increased gear-changing and speed alternations has, according to Pharoah and Russell (1989), not been proved. The noise level is negatively affected when more noise producing surfaces are used in traffic-calmed areas or near traffic calming devices. However, when the traffic calming measures also result in reduced car traffic volumes, this may at least be partly compensated for.

The driving style is very important because a relaxed driving style will decrease air pollution in every mentioned way, where a more aggressive style will decrease the level of HC- and NO_X -emission and potentially will increase the fuel use and occasionally also the level of CO-emission (Holzmann, 1985). The emission of exhaust-gases correlates with speed behaviour. Regular acceleration and deceleration increases the emission of carbon monoxide (CO) and to a lesser extent also of hydrocarbon (HC), but reduces the emission of nitrogen oxides (NO_x). When driving at a constant speed, overall exhaust levels are lower. The traffic calming schemes in the Dutch cities of Rijswijk and Eindhoven showed that at some locations there were negative effects in terms of exhaust-gases, but that overall the effects were positive, mainly because the traffic calming measures reduced car volumes in residential areas (Kraay, 1985).

So it can be concluded that traffic calming engineering measures can cause some undesirable side effects in relation to emission of exhaust-gases and traffic noise of individual cars, but that the net effect is positive, in particular in residential areas, due to decreased traffic volumes.

4.5. **Conclusions**

The effects of traffic calming measures are very positive. Different studies showed a reduction of speed and accidents in residential streets and on main streets where traffic engineering measures were implemented. Besides, the use of combinations of different measures enlarges the effects. The location and design of the measures is of influence of the size of the effect. However when implementing traffic calming measures, negative side effects on pollution and noise should also be taken into account.

5. Implementing traffic calming: public participation

Roelof Wittink

The current section focuses on approaches for public participation, information exchange and negotiation with the aim to involve citizens in the policy process of traffic calming and bring about a positive attitude. As discussed in the *Chapters 3 and 4*, much is known about the principles and criteria of traffic calming, both at the level of network planning and at the level of engineering measures. However, getting traffic calming schemes actually implemented is not that easy. One of the difficulties, and the issue of the current section, is that traffic-calming schemes evoke many controversies among the public and other stakeholders due to different rested interests and preferences. Whereas the public support for traffic calming has grown steadily in a general way, concrete initiatives for traffic calming often run up against resistance. For example, although the principle of traffic calming may be accepted, the introduction of humps may be rejected in one area, whereas the decision not to introduce humps may be a problem somewhere else. Similarly, some people or interest groups claim that city centres and their economic and social activities depend on the accessibility for cars, while others, for the same reason, claim that city centres need to be pedestrianized.

The starting point for implementation of traffic-calming schemes is to accept that many rested interests are involved and that compromises are inevitable. Therefore, an open and explicit dialogue about these different rested interests and preferences with citizens and all relevant stakeholders is needed to get compromises understood and accepted. Inviting individual citizens and interest groups to participate this type of policy development has proven to be an effective way of dealing with contradictory rested interests and beliefs and coming to acceptable compromises. In the following Sections the structure for participation and negotiation is discussed in more detail, based on the principles of social marketing.

5.1. Social marketing, an orientation on needs and preferences

Social marketing is the application of the economic marketing philosophy to the marketing of social aims. The value of making use of social marketing is that it structures the process of taking into consideration all rested interests involved. Social marketing is also helpful in finding the ways along which power can be enforced to influence the process of policy development and policy implementation.
The OECD has produced a report how to make social marketing applicable for road safety (OECD, 1993). *Figure 5.1* shows the step-by-step approach of social marketing.

Situation analysis

Target group segmentation

Aims

Marketing Strategy

Implementation

Monitoring and evaluation

Figure 5.1: *Ladder of approach of social marketing (From: OECD, 1993).*

The first step, the situation analysis, involves a set of procedures to get to know different policy alternatives. Four aspects are important: problem analysis, external factors of influence, internal factors of influence, and consumer analyses:

- Problem analysis: what are the reasons to put traffic calming on the political agenda: this may be the city climate, the inner city economy, protection of the environment, road safety, liveability in neighbourhoods, etc.
- External conditions: considering that a local administration has the authority to take decisions, what power do other organisations and institutions have to influence the policy development, how to make allies, and how to counteract opposition.
- Internal conditions: this regards the internal decision making process at political and administration levels and includes the participation process and procedures that have to be followed to take decisions.
- Consumer analysis: this regards the analysis of road users, their needs, attitudes, and active role towards traffic calming, and the use they will make of the road.

The situation analysis leads to a first exploration of interventions, e.g. regarding the limitation of roads that enable the flow of motorized traffic, and regarding the kind of measures that can be used to make traffic calming effective.

The second step, target group segmentation, is needed because road users, interest groups, and other stakeholders are not a homogenous group. The rested interests and preferences of the road users differ according to, for example, their transport mode and trip destination. In their position as road user, people may have other perceptions than in their position as resident or retailer or truck driver. There is even a difference within individuals themselves when they are driving a car and when they are walking or cycling. All these differences have to be taken into account to establish a good contact with people. Segmentation into target groups has to take place along the most relevant differences.

The third step is the formulation of aims. Aims have to be reasonable, taking into account all the opportunities and benefits as well as the constraints.

Aims need to be evaluated regularly with parties concerned to see if the investments were sufficient and working in the right direction. Aims give structure to policy and measures. Long-term aims may serve to create inspiration and involvement. Short-term aims are needed to guide the implementation of the policy and to define the monitoring of developments.

Now we have ingredients for the definition of the marketing strategy: the fourth step. The instruments for the marketing strategy are the product, the price, the place, and the promotion:

- The product may be, in the current context, improved safety, more street activities, health promotion, environmental improvements.
- The price may be the decreased accessibility of destinations by cars.
- The place means here the area affected by the measures and the channels for exchange with the people, organisations and other stakeholders affected by traffic calming.
- The promotion includes all the information to people about the offer, the benefits, and the price of traffic calming.

The fifth step concerns implementation. Flexibility regarding the measures is allowed as long as the policy aims and the effectiveness of measures are safeguarded.

Monitoring and evaluation, the last step, is needed to know about effects and to keep in touch with the dynamics of people and society.

The step-by step-approach can be exploited to a full extent or lesser extent depending on the need to involve citizens and organizations. Social marketing with its step-by-step approach is a tool to link social aims with different preferences of individuals or groups. At least it can be used as a checklist to learn from citizens and other stakeholders which measures what they want and are prepared to defend, thereby minimizing resistance and maximizing support.

5.2. Interactive participation

Social marketing presumes a certain amount of participation by the citizens. As already indicated, traffic-calming measures directly affect the daily activities of people and they touch their freedom as road users. As such they can count on a high degree of involvement, either in a constructive or a destructive way. When the policy makers can create cooperation by making room for active involvement in policy development, the opportunities for success will grow. This makes interactive participation of citizens an important policy tool for traffic calming policy.

According to Van Woerkum (1997), the government has to become aware that expertise developed within its administration is not superior to what citizens have in mind. This is probably especially true when it comes to the identification of (subjective) problems. At this point, the citizens are the experts in practice. However, it is not uncommon that the government and the citizens have different rationalities, both with a distinguished significance. Interaction is therefore the obvious tool to improve the quality of policy making. This also will make transparent uncertainties about policy intentions and policy options, as well as interdependencies between public bodies and other organizations and the citizens. This way, actions and reactions can be better anticipated. In fact, a social learning process emerges.

To make interactive policy making actually work, Van Woerkum (1997) sets three conditions:
1. Policy making has to be flexible and open for other arguments;
2. The process has to be transparent so that citizens understand the policy aims and know how their contribution will be used;
3. Different means for communication and consultation must be available.

In residential areas, interactive participation can be realised by, for example, establishing platforms of the residents and, if relevant, other stakeholders, including representatives of the public bus companies and emergency services. They should be invited to help develop the design principles of measures to allow for tailor-made solutions. An interesting and attractive way to discuss the design of potential traffic calming measures is by animation on a personal computer: show a street or show an area with different kind of measures so that people actually see what it will look like and how it will work. This way, the future comes alive. Also at a city-wide level, a platform of stakeholders can be established with the aim to identify and prioritize safety, mobility, and accessibility problems at the city level and to discuss the pros and cons of possible solutions. Again this provides an opportunity to take the needs of bus companies and emergency services into consideration. Clearly, plans and measures for residential areas must be in line with the urban-wide plans and measures.

Interactive participation requires a structured form of communication and discussion. People often start immediately to discuss the solutions without having had a proper orientation on the problems and aims. The main aim of participating is often to convince others of one's own idea or product, making an integrated strategy practically impossible.

In the Netherlands, there has been good experience with a model to structure the discussion in participation sessions (Tjepkema, 2000). Five subsequent steps are distinguished:

1. Exchange about *problems*: the participants are only allowed to exchange information about the problems they face or see; this will clarify why the participants did come together; mostly, many participants develop a broader perspective on the problem and are better able to change perspectives of the problem area;
2. Exchange about the *factors of influence*: when the problems are well defined, the underlying causal factors can be traced; this results in a collection of causes that have to be tackled one way or the other;
3. Exchange about *aims*; since the problems and their causes are now defined, it is possible to formulate in a realistic way the common aims of a project, action programme, etc.;
4. Exchange about *solutions*: based on the steps before, an inventory of solutions can take place; they have to be related to the aims and the problems with their background;
5. *Evaluation*: the discussion may be concluded by an evaluation: what did they learn from the exchange and which commitments were made by (groups of) participants.

5.3. **The Negotiating Government**

The previous section discussed the need for public participation when aiming to get public support for specific policies and measures. Also in a more general way, a structural platform on an issue such as traffic policy, with representatives from public, private, and social organizations, can strengthen the participation of the society in policy making and implementation. In the Netherlands, at a regional level, so-called road safety platforms were established in the 1980s. In addition to strengthening public participation, the road safety platforms were meant to support a process towards decentralisation and privatisation of the implementation of policy measures. This alternative strategy leads to what is called the 'Negotiating Government' (De Vroom et al. 1995). A negotiating government organizes an exchange of information between public and private organizations and interest groups, not only to identify problem areas and potentially useful measures, but also to consider who is best able to implement the identified measures. The process involves negotiations and compromises. The initiative for such a platform has to come from the public authorities. But they delegate and facilitate interventions by public and private organizations.

The steps to set up a platform for a negotiating government are specified in short, with the result of each step specified in italics:

Stage 1: Start and design of the platform

1. The local government has to secure social aims and rights. It will establish the conditions and the autonomy of the platform: *the Mandate*: guidelines for the targets to achieve, participants to involve, and the procedure to operate.
2. The local government establishes the area of operation where the policy will be developed and implemented and assign a platform co-ordinator who can guide the process in a complex social and policy environment: *the Domain*.
3. A study is assigned to make an inventory of:
   - the public problem: *Problem map;*
   - groups that are influenced by the collective problem, the social differentiation: *Social map;*
   - all relevant public and private organisations related to the problem, the institutional structure: *Institutional map.*
4. The local government sets out realistic aims, backed by research on the problem: *the Norm*.
5. The maps define the selection and invitation of relevant organisations to form *the Platform*.

Stage 2: Exchange and Negotiations

6. The platform has to arrive to a common problem orientation; by exchange they can broader their own perspective and arrive to a more common perspective, without having to loose the link with their own interests: *Integrated Problem definition*.
7. Each participant of the platform will be invited to formulate options for behavioural alternatives and search for co-operation with other participants: *Options for Solutions*.

8. The aggregation results from the problem focus, the options for solutions in relation to mandate and the norm leading into an *Integrated Problem definition and Solution*.
9. The participants are invited to articulate their contributions to the aims and to formulate which support is required to further these aims. This enables the allocation of means: *Mix of products and interventions*.
10. Evaluation of the results will take place in relation to the Norm; also evaluation of the platform process takes place: *Review of the effects of the Platform*.
11. The evaluation will be followed by a check on the platform membership, on the analyses of behaviour, on the problem definition and on the solutions provided by the products, and interventions: *Review of Mandate, Norm, Domain and Platform Participation*.

5.4. Conclusions

There is a contradiction between the support in society for traffic calming as a principle and support for concrete measures. Fine-tuning of measures to the specific interests and preferences of citizens and organisations is a way to make the implementation of traffic calming schemes easier. This is not a self-fulfilling process, even if residents and other stakeholders asked governments to undertake measures. Interactive participation is needed, to bring different rationalities about problems and aims together. Not all politicians will embrace such an approach immediately and it is not easy either to get full co-operation of the administration. The process for this type of policy making takes more time and energy. However, by taking the expertise and creativity of citizens and private bodies on board, measures can be identified that have a high cost-benefit ratio and can count on the highest possible acceptance.

Platforms at a neighbourhood level or at a city-wide level provide a workable structure for the participation process. Expertise and experiences in the field of communication and negotiation can be used to make these platforms contribute to the policy making process in an efficient way. A platform with public and private bodies, including interest groups at a more general level, is very helpful to make policy making a process of the society itself.

6. Implementing traffic calming: information and education

Roelof Wittink

Because participation and negotiation are important instruments to facilitate the acceptance and, thus the implementation of policies such as traffic calming, it is impossible to reach all people this way. Public information and education remain essential instruments to back up traffic calming policies and to realise the desirable behaviour and positive attitudes. As discussed in the following Sections, public information and education are needed to support the achievement of the social and behavioural objectives of traffic calming, but they will not be sufficient as stand-alone measures.

6.1. The process of behavioural change

The traffic calming principle presumes that road users adapt their travel behaviour in different respects: they are supposed to choose more often for alternative transport modes; when travelling by car they may have to choose another route in order not to intrude a residential area; when entering residential areas they have to adapt their speeds and show more consideration for other, vulnerable road users. Whereas there are various network planning and engineering measures that will more or less enforce this type of behaviour change, a certain amount of intrinsic motivation is necessary to achieve a more sustainable change.

The social marketing approach distinguishes different ways to bring about a sustainable behavioural change in relation to a social aim. Each way consists of the same three components: to learn (information, knowledge), to feel (attitudes, beliefs) and to do (the actual behaviour), but the sequence may be different (Kotler & Roberto, 1989):

- The sequence of learn-feel-do: the acceptance of a social aim takes place after understanding the significance of this aim, followed by a valuation of the pros and cons (a rational and/or affective valuation), followed by the adoption of the behaviour itself.
- The sequence of do-feel-learn: a change starts with the behaviour itself, provoked by a stimulus (that can be offered by rewarding or punishing). On the basis of the behaviour, a valuation of the pros and cons takes place and an attitude develops. This may also lead to knowledge about and understanding of the social aims.
- The sequence of learn-do-feel: the acceptance of other behaviour comes after information, such as the observation of an example. By practising that behaviour, the evaluation starts. The social environment plays the key role here in bringing about a change.

Which sequence is most appropriate depends on the issue at hand. Just providing new information or knowledge will often be insufficient to bring about a behavioural change, because people are selective in their information processing and they easily misinterpret the information to bring it in line with their habits. This is particularly true when there is no strong involvement with the social aim in question, or when people have very strong habits. Traffic calming measures affect many individuals in their daily life and hence can be expected to evoke a high degree of involvement. In that case, providing information may arise understanding and be the trigger for behavioural change. On the other hand, for example, it is known that modal choice is largely determined by habituation and is as such very difficult to influence when starting with information. However, it is important to realise that knowledge, attitudes, and behaviour interact and may reinforce each other.

An example of how the components of doing, learning, and feeling can be combined is the organization of a festivity to celebrate the finalisation of a traffic-calming scheme. Such a festivity offers the opportunity first of all to present the scheme as a positive development in the area, which has to be celebrated: a 'gift' to the community. Secondly, it offers an opportunity for the residents or whoever is directly involved to exchange experiences, to learn (again) about the rationale of this type of measures and the way to deal with it, both by means of information or by means of actually experiencing it, i.e. by doing. For example, demonstrate the appropriate behaviour at a roundabout or a road narrowing and let the users experience it themselves and let them discuss their experience between each other and with planners and designers. This way people are not left alone in their evaluation of the measures. And last but not least, such a celebration offers the opportunity to planners and designers to get direct feedback from their clients, the road user, so they can learn from it, prevent misinterpretations and help to solve problems people experience. Direct feedback from the road users might be the best incentive a local administration can give itself.

6.2. Functional use of public information

Public information in its classical form remains an indispensable instrument for policy makers even though information as a stand-alone instrument does not easily make a difference. Public road safety campaigns alone, for example, rarely bring about a behavioural change, but they do contribute to the understanding and effectiveness of other measures, e.g. police enforcement. So, in principle, information should be considered as an important instrument to add value to other measures and to contribute to a good process of policy making and implementation.

For information, both the messages and the media are of importance. With respect to the message it is important that it is instructive. Not only may people get a better understanding, it is also the best way to learn. Lack of knowledge may simply be a result of not understanding. Furthermore, in the past, road safety messages have been associated too much with the need to make offers. However, many road safety measures also have positive, rewarding aspects and this is certainly the case with traffic calming measures. The rewarding aspects of road safety measures must not be pushed aside but receive a central position. Information concerning specific measures is best accompanied by information about the general background and aims of those measures. It may help for agenda setting, it may result in a better understanding, and, in combination with an emphasis on the positive effects, it may more easily evoke positive attitudes.

There is a wide range of media for the dissemination of information. The best combination depends on the aims to be reached with the information, the kind of messages, the complexity of the contents, the range of people to

target, the availability of media, the budget, and the like. Newsletters, posters, advertisements, articles, and direct mailing are most easy, but this is a one-way process. A public meeting will reach a smaller group of people, but enables exchange and explanations. Websites provide an opportunity for an interactive process but is very time consuming.
The role of intermediate organisations can be of high importance, since they might be much more 'near' to the target group than the government.

6.3. Education

In comparison to information, education has the advantage that it is provided on a bilateral or small group basis and that it allows for direct interaction between 'pupil' and 'tutor'. The transfer of knowledge is much more intense and can go more in-depth. Education also provides the possibility to improve social skills and to explain formal rules in combination with informal rules (Wittink, 1993). However, the road user groups that can be reached by education are more limited, generally to school children, novice drivers, and people participating in follow-up driver training courses.

The specific characteristics of the educational setting allows discussion and information transfer on issues such as combining the collective needs for social traffic behaviour and environmental protection with individual needs for efficiency, attractiveness, comfort and safety; the advantages and disadvantages of a particular transport mode or route in relation to trip destination, trip motives, and circumstances; the balance between the intended positive effects of traffic measures and potentially or seemingly negative side effects (e.g. why traffic calming may result in the need for small detours). Education also serves as an instrument for agenda setting, policy making, and evaluation. The target group may be invited to develop their own solutions for their own or for collective problems. This has, for example, been applied with success with school children analysing and defining solutions for the (traffic) problems they experience in their neighbourhood and on their way to and from school.

Traffic calming has not only a traffic safety component, but also an environmental component and a component of social well-being. In an educational framework, the relationship and interdependence of these components can be clarified and explained. In this respect, in the Netherlands, seven principles for traffic and environmental education were developed that can be applied well to traffic calming policies (Hegger, Van Schagen & Wittink, 1993):
- A sustainable environment is very significant for the well-being of man and society.
- Mobility is a precondition for the well-being of man and society but this well-being must condition mobility.
- Liveability, safety, and accessibility are all influenced by mobility choices of individual people.
- Individuals and society are both responsible for solving the problems created by transport and traffic.
- Mobility choices are conditioned by physical, social, mental, and economic factors.
- Individuals have to value their mobility choices to favour liveability, safety, and accessibility.

- Precautions may help prevent the risk of traffic accidents but can never exclude completely that accidents may happen.

It becomes clear that the distinction between information and education is not very strict. Education encompasses the dissemination of information and the dissemination of information can have an educational, instructive message. For example, television spots can become instructive when they show how traffic behaviour can be more respectful to other road users, such as children, elderly, and the handicapped.

6.4. Conclusions

This section discussed the role of information and education in explaining policy measures and achieving that these measures have the intended effect. The interaction between knowledge and understanding, affections and attitudes, and behavioural choices is a complex one. The best way to bring about a sustainable behavioural change is to intervene on each of these factors by dissemination of information and, if possible, by education.

7. Summary and conclusions

The current report aimed to provide a concise overview of the technical issues and the implementation strategies of traffic calming measures in urban areas. Traffic calming aims to alleviate the adverse effects of motorized traffic. Over the years the scope of traffic calming has broadened. In the beginning, in the 1970s, traffic calming was limited to a single residential street or a series of adjacent residential streets and the adverse effects of motorized traffic were mainly defined in terms of safety. Later on traffic calming principles were also applied to main urban streets, city centres, shopping streets, and even urban-wide. The aims of traffic calming were not longer limited to safety, but included objectives for environmental, social, and liveability improvements. More specifically, it can be stated that traffic calming in residential areas aims to discourage motorized through-traffic from entering the area and to achieve an appropriate, safely of the remaining motorized traffic. Traffic calming at main urban roads mainly aims to achieve an appropriate, safe speed, in particular at those locations where motorized traffic has to mix with vulnerable road users. Urban-wide traffic calming aims to reduce the volume of motorized traffic by providing safe and attractive facilities for alternative transport modes, such as cycling, walking, and public transport. In Sweden, in the second half of the 1990s, the 'Vision zero' policy and the resulting 11-point road safety programme gave a new impulse to traffic calming in urban areas. Whereas road safety is still the main element, according to the local authorities and their recent handbook *Calm Streets!*, traffic calming also explicitly aims to make urban areas more eco-friendly, pleasant and attractive, by integrating traffic planning with a city's social and cultural programme.

Network planning

The starting point for traffic calming has to be found in the characteristics of the urban road network; characteristics which, in turn, may need to be supported by physical engineering measures. A first step at the urban network level is the functional categorization of its roads. With regard to urban traffic calming, it is important to distinguish between two functions: a residential function and a traffic function. Streets and roads with a residential function cater for walking, playing, shopping, etc. Motorized traffic may be allowed, e.g. to provide access to the properties and houses in residential areas, but it should not in any case interfere with the residential function. In practice this means that motorized traffic should drive at a low speed, so that pedestrians, cyclists, and cars can safely mix. Accident studies show that with a collision speed of below 30 km/h the probability of serious injury for vulnerable road users is very low. Therefore, a speed limit of 30 km/h or lower in areas with a residential function is crucial. At roads with an important traffic function (distributor roads or main urban roads) the flow and circulation of motorized traffic remain the main purpose. From that perspective, higher speeds are desirable to allow an efficient flow of through-traffic. However, as a consequence, for safety reasons, car traffic has to be physically separated from vulnerable road users. At locations where cars and vulnerable road users have to mix, and this is often the case at intersections, car speeds have to be lower. Based on this distinction between a residential function and a traffic function, the urban network can be classified into areas with a residential function and roads with a traffic function. It has been found that from a traffic calming perspective, large residential areas are to be preferred. However, if the size of a residential area exceeds 100 hectare it may result in very high traffic volumes on the surrounding distributor roads; if the size of a residential area exceeds 200 hectare the traffic volumes on the residential streets may become too high.

Not only the size of an area is of importance, also the structure of the streets in the area and the number of connections to distributor roads affect traffic volumes and safety. For several reasons, an organic network structure, consisting of a central street winding through the area with many dead-end side streets, is considered to be best. First of all, such an organic structure is unattractive for through-traffic because of the relative large detour and the limited number of access points. Secondly, an organic network structure has only short straight road sections and, as such, it more or less automatically results in low speeds, making a large number of special speed reducing devices superfluous. Thirdly, in the area all intersections are T-intersections, being much safer than X-intersections. Lastly, the number of connections and, hence, the number of generally unsafe intersections with the main road network is limited. A disadvantage is that the distance for destination traffic is longer than in other network structures such as the conventional grid structure, and that car traffic will concentrate on the central street.

When aiming to promote other more eco-friendly transport modes, such as an alternative to car trips, network planning aspects and land use characteristics at an urban-wide level have to be considered. Pedestrians and cyclists would need to have a coherent, direct, safe, attractive, and comfortable network at their disposal avoiding traffic barriers between origins and important destinations for residents of a particular area. A high quality and reliable service of public transport, preferably in combination with limited parking facilities in city centres, may further contribute to an urban-wide reduction of car travel.

Road engineering measures

Whereas road categorization and other network planning elements of traffic calming, road engineering measures may be required to support the general speed limit and to achieve a safe speed of remaining car traffic. This is particularly the case in residential areas where, as indicated above, speeds should not exceed 30 km/h. Just a speed limit sign has found generally to be insufficient to achieve that goal. Frequent discontinuities of alignment, width, and height, such as road narrowing, plateaus and humps, physically impose car drivers to reduce their speeds; the use of different materials and colours help to break up the impression of a through-road for motorized traffic. These types of measures not only aim to reduce driving speeds, but also make streets less attractive for through-traffic. Evaluation studies generally report on substantial decreases in speed, traffic volumes, and accidents, although there is a large variation in effects. A meta-analysis of the results of a number of evaluation studies (Elvik, 2001) showed that in residential streets with speed reducing measures, the number of injury accidents and the number of material-damage-only accidents decreases by about 25%.

Speed reducing measures at roads with an important traffic function (distributor roads) are best concentrated at those locations where different road user groups have to mix, i.e. at intersections and midblock pedestrian or bicycle crossings. At intersections, the application of roundabouts is a very effective way to reduce speed. In addition, at roundabouts, the angle of impact is smaller resulting in less severe consequences in the case of a collision. As an alternative, plateaus can be used to reduce speed at intersections with or without with traffic lights. In the case of a series of intersections with traffic lights, a green wave may help to induce a constant speed at the stretches between intersections. Plateaus can also be used to reduce speed at midblock pedestrians and/or bicycle crossings. In the design of traffic calming measures it has to be taken into account that distributor roads also have to accommodate for buses and trucks and would need to allow emergency vehicles to pass at high speed.

The transition from one speed zone to another needs special attention, in particular the transition from higher to lower speed zones, e.g. when entering a town or village. At the transition, a prominent gateway with high vertical elements alongside the road such as trees in combination with a road narrowing help to bring about the desired speed reduction. Additional measures along the through-route within the built-up section are required to keep speeds at the desired level. In particular at through roads in villages this type of traffic calming schemes have found to be effective in terms of both car speeds and injury.

Bus companies and emergency services are often not very positive towards traffic calming engineering measures because they would result in a reduction in comfort and an increase in travel time. Whereas some loss in comfort and time is unavoidable, the engineering measures can be designed and located in such a way that the disadvantages are kept to a minimum. Examples are the use of plateaus rather than humps, and where humps are considered to be necessary, to use so called combi-humps or narrow speed cushions. The design and location of traffic calming engineering measures must also take account of cyclists and pedestrians, in particular those with visual and/or physical disabilities. Obstructions alongside or on the pavement should be avoided, as should large height differences and long distances at (pedestrian) crossings. The comfort and safety of cyclists in streets with many physical traffic calming measures can be enhanced by leaving space at both sides of the devices, so they can pass the devices in a straight line, both vertically as horizontally.

Implementing traffic calming schemes

It can be concluded that much is known about the technical possibilities of network planning and road engineering measures to realise the principles of traffic calming. It can also be concluded that traffic calming is effective in reducing car speeds, car traffic volumes and road traffic accidents. However, getting traffic calming schemes actually implemented at a local level may appear to be difficult. In general, the support in society for the objectives and principles of traffic calming has been steadily growing, but at the level of concrete measures there are often controversies among the public and other stakeholders due to different rested interests and preferences. An effective way to deal with contradictory interests and beliefs and to obtain the support of the public is public participation based on the principles of social marketing. The social marketing approach aims, in parallel to commercial marketing, to 'sell' a product, be it that the product can be defined as a social aim, e.g. road safety benefits, more street play facilities for children, environmental benefits, etc. Analysis of the situation, segmentation of the target groups, definition of the aims, and development of a marketing strategy are the first four steps of the social marketing approach that are necessary to achieve to a successful implementation.

Participation in the process of policy making of citizens who are directly (e.g. residents) or indirectly (e.g. interest groups) involved is a useful instrument to identify the existing and experienced problems and the preferences and dislikes with regard to specific measures. This way, resistance may be minimized and support may be maximized. Platforms at a neighbourhood level or at a city-wide level provide a workable structure for the participation process. They allow for a systematic exchange of information between participants about the problems, the underlying causal factors, the aims, and in relation to that, the possible solutions. This will shed light on the different ideas and rationalities and provides an opportunity to bring these together. Expertise and experiences in the field of communication and discussion are needed to ensure that these platforms contribute to the policy making process in an efficient and constructive way.

Whereas public participation is an important instrument to facilitate the acceptance and, thus, the implementation of policies such as traffic calming, it is impossible to reach all people this way. Public information and education remain essential instruments to back up traffic calming policies and to realise the desirable behaviour and positive attitudes. Public information as a stand-alone measure generally does not influence behaviour to a large extent, but by increasing understanding and knowledge about the problem, the aim, and the measures, it does add value to other measures, such as police enforcement and road engineering measures. Public information is a one-way process that hardly can take account of different groups and different opinions in society. Education has the advantage that it is provided on a bi-lateral or small group basis and allows for direct interaction between the 'messenger' and the 'receiver(s)'. Education also has the advantage that the effects of measures and/or particular behaviour strategies can be experienced and trained in practice. However, the education instrument can only be used for a limited number of road user groups, generally school children, learner drivers, and people participating in follow-up driver training courses.

The Dutch experience: concluding remarks

Much is known about the technical opportunities of urban traffic calming. In particular in residential and shopping areas, network characteristics have to be supported by road engineering measures, so that through-traffic is avoided and remaining motorized traffic drives at a low speed and is subordinate to the other users of the area. On urban main roads, the possibilities of traffic calming are much more limited. The efficient processing of motorized traffic is one of the major functions of this type of roads. This would require higher speeds at the road sections and, hence physically separated pedestrian and bicycle facilities. Speed reduction, however, would need to be realised at intersections and at midblock pedestrian and bicycle crossings, since at these locations cars and vulnerable road users have to mix. At an urban-wide level a traffic calming policy aims at a reduction of the number of car trips. Safe and comfortable facilities for pedestrians and cyclists, reliable, dense, and cheap public transport facilities and restricted parking facilities in the city centre will make alternative transport modes more attractive.

Despite the existing knowledge and despite the good experiences internationally, the actual implementation of traffic calming schemes appears often to be not that easy. Nevertheless, Dutch experience shows that it is possible. The extension of 30 km/h zones, in first instance to be realised by low-cost measures only (i.e. measures at the gateway/entrance + speed reducing measures at the junctions), is one of the elements of the Dutch sustainable safety policy. In 1997, when the implementation of sustainable safety measures got started, approximately 10% of the potential 30 km/h zones were actually realised. In the next five years, between 1997 and 2002, the proportion of roads treated increased to around 50%, i.e. to almost 20,000 km road length (Koornstra et al., 2003). It is impossible to demonstrate empirically which factors, to what extent, have been responsible for this rapid increase. It was, however, a strategic decision to start the implementation of sustainable safety with the extension of low-cost 30 km/h zones. First of all, 30 km/h zones could count on a relatively high level of public acceptance and support. Also local authorities were positive towards 30 km/h zones. The central government stimulated the extension of 30 km/h zones by providing attractive subsidies to local authorities, based on concrete plans. All Dutch municipalities submitted a plan and applied for the subsidy. By requiring low-cost solutions only, it was aimed to realise in a short-term period a considerable extension of the 30 km/h zones. The idea was that, if at some locations the low-cost solutions would appear to be insufficiently effective, the public would demand additional measures. This type of public pressure on the local policy is generally successful. As indicated several times in this report, the implementation of 30 km/h zones presupposes that the urban road network is categorized into areas with a residential function and areas with a traffic function. Hence, in order to be eligible for the state subsidy, local authorities were more or less forced to recategorize their road network first. So, this approach not only resulted in a large increase in the number and size of 30 km/h zones; it also resulted in a recategorized urban network based on the monofunctionality principle, which by and large, is the foundation of a sustainably or inherently safe traffic system.

A more general analysis of the implementation of the sustainable safety approach in the Netherlands showed that specific policy elements were supportive or even a prerequisite for successful action (Wegman & Wouters, 2002), many of which also seem to apply to the implementation of large scale traffic calming schemes:

– "The conviction that the current policy was not sufficiently effective in reaching the road safety targets. Thus, something 'new' was needed: a new concept to solve the road safety problem.
– Road safety experts and the professional world should express themselves in full accordance with the new concept. If experts disagree, policy makers and politicians will feel uncertain and decisions might be postponed.

- The concept has to appeal in both the short and the long term. Of course, no concept is drawn up for all eternity.
- From the start the concept has to enhance creativity and not resistance. An important element with respect to this: appealing directives and no obvious drawbacks.
- Road safety organizations and pressure groups (stakeholders and 'actors') have to consider the concept as offering new opportunities.
- Implementation of the concept must be integrated in existing budget streams.
- Structural opportunities to connect the concept to other activities should be looked at and created: drafting guidelines for road design, education curricula for schools, etc.
- Last but not least, intelligent ways to commit stakeholders have to be found." (Wegman & Wouters, 2002; p. 15).

Applying these Dutch 'lessons learned' to the implementation of a traffic calming policy in Sweden, it can be concluded that many of the 'prerequisites' are fulfilled or can be realised without too much effort. Also in Sweden the national road safety target is not yet in reach. Professionals internationally agree on the large potential of traffic calming measures and widespread technical knowledge is available to apply the traffic calming principles. A successful traffic calming policy has many advantages with respect to road safety, the environment, personal health, and, more generally, to the liveability of a town or city. In other words, traffic calming provides many opportunities to make urban life more attractive for the citizens. At an individual level, traffic calming may have drawbacks since it may be felt that it has a direct limitation of a person's freedom of choice. Interactive public participation in an early stage of the planning process, as well as information and education, emphasising the expected positive effects can contribute substantially to the level of support for traffic calming measures.

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Appendix Theoretical relation between the size of residential areas and traffic volumes (Van Minnen, 1999)

Size of area (ha.)	Density (houses per ha.)	Number of houses	Volume (ADT)	Maximum volume for given number of connections								
				1	2	4	6	8	10	12	16	20
10	30	300	1500	1500	900	450	300	225	180	150	113	90
10	45	450	2250	2250	1350	675	450	338	270	225	169	135
10	60	600	3000	3000	1800	900	600	450	360	300	225	180
20	30	600	3000	3000	1800	900	600	450	360	300	225	180
20	45	900	4500	**4500**	2700	1350	900	675	540	450	338	270
30	30	900	4500	**4500**	2700	1350	900	675	540	450	338	270
20	60	1200	6000	6000	**3600**	1800	1200	900	720	600	450	360
40	30	1200	6000	6000	**3600**	1800	1200	900	720	600	450	360
30	45	1350	6750	6750	**4050**	2025	1350	1013	810	675	506	405
30	60	1800	9000	9000	5400	2700	1800	1350	1080	900	675	540
40	45	1800	9000	9000	5400	2700	1800	1350	1080	900	675	540
60	30	1800	9000	9000	5400	2700	1800	1350	1080	900	675	540
40	60	2400	12000	12000	7200	**3600**	2400	1800	1440	1200	900	720
80	30	2400	12000	12000	7200	**3600**	2400	1800	1440	1200	900	720
60	45	2700	13500	13500	8100	**4050**	2700	2025	1620	1350	1013	810
100	30	3000	15000	15000	9000	**4500**	3000	2250	1800	1500	1125	900
60	60	3600	18000	18000	10800	5400	**3600**	2700	2160	1800	1350	1080
80	45	3600	18000	18000	10800	5400	**3600**	2700	2160	1800	1350	1080
120	30	3600	18000	18000	10800	5400	**3600**	2700	2160	1800	1350	1080
100	45	4500	22500	22500	13500	6750	**4500**	**3375**	2700	2250	1688	1350
150	30	4500	22500	22500	13500	6750	**4500**	**3375**	2700	2250	1688	1350
80	60	4800	24000	24000	14400	7200	**4800**	**3600**	2880	2400	1800	1440
120	45	5400	27000	27000	16200	8100	5400	**4050**	**3240**	2700	2025	1620
100	60	6000	30000	30000	18000	9000	6000	**4500**	**3600**	3000	2250	1800
200	30	6000	30000	30000	18000	9000	6000	**4500**	**3600**	3000	2250	1800
150	45	6750	33750	33750	20250	10125	6750	5063	**4050**	**3375**	2531	2025
120	60	7200	36000	36000	21600	10800	7200	5400	**4320**	**3600**	2700	2160
150	60	9000	45000	45000	27000	13500	9000	6750	5400	**4500**	**3375**	2700
200	45	9000	45000	45000	27000	13500	9000	6750	5400	**4500**	**3375**	2700
200	60	12000	60000	60000	36000	18000	12000	9000	7200	6000	**4500**	**3600**