1. INTRODUCTION

Background

The project “Experimental work on traffic safety measures for pedestrians and cyclists in encounters with motorists at meeting points” was started in the spring of 1997, and is being carried out within the framework of the traffic safety reform, “Safer traffic environments in built-up areas” as a part of a series of measures in the national safety programme for the period 1995 to 2000.

Aim

The main aim is to increase safety and security, as well as accessibility and convenience for unprotected road users in encounters with motorists at meeting points, without reducing motorists’ accessibility more than is necessary. This is to be achieved by creating 30 km/h zones with suitable physical measures in built-up areas, that is, 30 km/h as a maximum passing speed for vehicles at pedestrian and cycle crossings on main streets, with a 50 km/h speed limit on roads between such crossings.
Another aim is to evaluate the various effects of measures on safety, the environment and accessibility, as well as how road users react to the adopted measures at meeting points.

**Method**

In order to attain the stated objectives, a large-scale demonstration project has been initiated as a cooperation of: The National Road Administration regions of Borlänge, Stockholm, Mälardalen; the municipalities of Stockholm, Järfälla, Tyresö, Värmdo, Vallentuna, Österåker, Örebro, Greater Stockholm’s Local Traffic Authority and the Department of Technology and Society, Traffic Engineering Section, Lund Institute of Technology and.

By a large-scale demonstration project is meant;

1. Implementing suitable measures at a number of meeting points that appear systematically and consistently in one and the same area/stretch of road in a built-up area.
2. Implementing suitable measures at a number of individual meeting points with varying amounts of traffic and in different types of traffic environment on main streets in one or several areas.

The aim of large-scale use of measures is to minimise the risk of chance in determining the effects. Furthermore, it is important to be able to predict what the effects will be of a large-scale, standardised use of measures with regard to traffic safety, accessibility, the environment, road users’ experience and acceptance and so on.

In order to evaluate the different effects of the measures, a controlled evaluating design has been chosen. This means studying the different effects of measures with ‘before’ and ‘after’ studies at experimental and control-points. It will then be possible to compare conditions before and after implementation of the measures, quantify changes and draw conclusions about the differences. The idea of having control points is to ensure that the stated, possible condition-changes can be ascribed to the introduction of measures at experimental sites and not to any general changes in traffic development in general.

**2. A BRIEF PROJECT DESCRIPTION**

Two basically different types of measures are being studied at meeting points:

1) Structural measures: Pedestrian and cycle crossings are provided with road cushions, narrowing of the carriageway, handrails, lampposts, etc)

2). Active-information measures: relevant and improved information at pedestrian and cycle crossings by using the ITS-function for automatic detection of unprotected road users and warnings to motorists about the presence of pedestrians and cyclists.

**Structural measures**

As part of the project, structural measures are being implemented in large-scale demonstrations in some Swedish municipalities. 18 experimental sites were rebuilt during the summer of 1998. In Örebro, 9 meeting points along an approach road were rebuilt (an experimental site is placed on a connecting road to the experimental stretch of road) using structural measures. In the Stockholm region 9 meeting points were rebuilt in different municipalities. Figure 1, shows, in principle, the design of a meeting point with structural measures that are the basis for the rebuilding of experimental sites in the Örebro and Stockholm regions.
Design of a pedestrian crossing on a stretch of road with road cushions, narrowing of the carriageway etc.

The most important traffic safety elements in figure 1 are road cushions and narrowing of the carriageway at pedestrian and cycle crossings. In order to make the road cushion work effectively, the road is narrowed (or widened) to about 3.2 to 3.5 metres and the road cushion is placed centrally about 5 metres (a car length) in front of the crossing.

The road cushion is designed as a narrowed-hump on the carriageway, making it suitable for use in local streets as well as on main roads with heavy lorry and bus traffic. The latter can drive over the road cushion with less hindrance than cars, but all types of vehicles are hindered to the extent that a uniform passing speed of about 30 km/h is achieved, without inconvenience to either drivers or passengers.

Active information measures

Two experimental sites in the Stockholm region were provided with active information measures in 1998. Two fibre optic signs (150cm x 130cm x 24.5cm) were set up either 20 metres in front of a crossing or on lattice-work above the crossing, depending on the design. Two signal posts, each with an IR-detector, were placed at pedestrian and cycle crossings. These register changes in the heat radiation within a detection area almost parallel with the crossing (about 2 metres x 70cm). IR-detectors are modified to automatically detect unprotected road users who wish to cross the street. When these road users are detected, the signs display their warning signals which consist of: a warning message ‘stop for pedestrians’: white continuous light, warning triangle with a ‘man’ in the middle, red continuous light and two flashing lamps with yellow lights). The warning message lasts 20 seconds. Figure 2 shows a sketch of a meeting point design with measures where signs are placed about 20 metres in front of the crossing.
Investigation methods and implementation

Evaluations in the form of ‘before’ and ‘after’ studies of 20 experimental and 18 control sites are being carried out over a period of about three years (1997 to 2000). The different effects of the adopted measures are being studied in terms of speed measuring, conflict studies, behavioural studies, traffic counts and interview-based surveys at all the experimental and control sites. These studies are the basis for the hypothesis-testing with regard to safety, environmental and accessibility effects, and road users’ acceptance of the adopted measures at meeting points. The ‘before’ studies were conducted in autumn 1997. The experimental sites were rebuilt in Örebro and the Stockholm region during the summer of 1998, and ‘after’ study I (short-term effects) was conducted in autumn of the same year. Finally, ‘after’ study II (long-term effect = real effect) was carried out in the autumn of 1999.

Within the framework of the project’s evaluations (‘before’ study, ‘after’ studies I and II) the following data were collected at all the experimental and control sites:

- About 18,000 speed-measurements (spot-checks with a radar-gun).
- About 540 hours of conflict-studies at 10 experimental sites.
- About 950 hours of video-filming (intended for studies of interplay-behaviour between road-users, accessibility studies, traffic counts etc).
- About 400 driving patterns along the experimental stretch of road in Örebro. These formed the basis for, exhaust fume-measurement, accessibility studies and production of speed patterns.
- 920 interviews with pedestrians and cyclists, bus passengers, bus drivers and motorists.
- Noise measurements at two experimental sites.
3. THEORY BUILDING

The intention here is primarily to explain and describe, with the aid of theoretical constructions and reference frameworks, the relations between important factors for road-users' behaviour regarding safety and interaction problems at meeting points. Thereafter, theories of measures are dealt with, by means of constructing a model which claims, from given prerequisites (two characteristically different types of measures), to predict how road-users will behave at meeting points. This is done through the construction of overall hypotheses concerning the measures' different effects on road-users' behaviour, which will then be proved empirically within the framework of this thesis.

3.1. Problem-related theory

Formal rules

Special rules for the interplay between motor vehicle drivers and pedestrians are contained in the Road Traffic Ordinance (1972:603, VTK). Regarding the driver's behaviour:

“According to section 83, a driver who approaches a non-signalised pedestrian crossing must adapt his speed so that he does not constitute a danger to pedestrians who are either on or about to step onto the crossing. If necessary, the driver must stop to give the pedestrian an opportunity to cross.”

Regarding the pedestrian's behaviour:

“According to section 136, the pedestrian must only set foot onto a non-signalised pedestrian crossing with the due care demanded by the distance and speed of the vehicle approaching the crossing. Away from the pedestrian crossings, the pedestrian can cross the road only if this can be done without constituting a danger or inconvenience to traffic.”

In principle, the same rule applies to interplay between drivers and cyclists at a non-signalised cycle crossing (Spolander, 1994).

Current Swedish legislation has not been able to regulate interplay between drivers and unprotected road users from a safety viewpoint. Nor does it function in practice, because the interplay-behaviour of traffic users does not function in the manner envisaged by the legislators.

From 1 May 2000 a new rule compels drivers to give way at pedestrian crossings. According to the new rule:

“At a non-signalised pedestrian crossing the driver is obliged to give way to pedestrians who are on or are about to step out onto the crossing.” (Traffic Ordinance chapter 3, section 61)

The introduction of the new rule makes greater demands on drivers than before. Drivers now have to stop for pedestrians who are already on or just about to step onto the pedestrian crossing. In this regard it would be beneficial to carry out a survey of whether drivers will really change their behaviour. However, it is also important to see how pedestrian-behaviour will change if drivers give way, to the extent prescribed by law, to cyclists and pedestrians.
Várhelyi (1996) studied the interaction between pedestrians and drivers at a detached, non-signalised crossing on a main street. His study showed that the pedestrian passed before the car in only 5% (total 824) of all the interactive situations. He also found that drivers maintained the same speed or accelerated in 73% of the cases, and reduced speed in only 27% of all the critical interactions. In such situations the safety and accessibility of the pedestrian are influenced by the driver’s behaviour, since the former must slow down or stop in order to avoid a collision.

In the report “In-depth analysis of traffic accidents, automobile – unprotected road user”, (National Road Administration, Skåne-region 1993-1994) there are detailed accounts of 16 accidents between unprotected road users and drivers. Frequent comments from drivers, involved in accidents, included in the report are: “I suddenly noticed that the bicyclist/pedestrian appeared on the cycle/pedestrian crossing” or “I suddenly noticed that something flew over the hood” or “A pedestrian/bicyclist came out suddenly onto the pedestrian/cycle crossing”. What do these statements indicate? Not only that drivers are ill-prepared to interact with unprotected road users at meeting points, but also that the latter sometimes behave unpredictably in interactions.

The characteristic that is most decisive for the development of the course of events in accidents covered by the above report is thought to be road users’ behavioural errors in interactions.

In two studies:

- The OECD report (Traffic Safety and Unprotected Road Users, 1998) which makes a study of a large number of accidents in OECD countries.
- Inger Marie Bernhoft’s (1998) qualitative study (interviews with people involved in accidents) of 105 accidents between drivers and unprotected road users in three large cities (Copenhagen, Amsterdam and Barcelona).

The studies postulates that mistakes committed by the road users involved are important factors for the occurrence of accidents. According to the studies mentioned above, the most important road user-mistakes that are the causes of accidents are the following:

**Regarding the motorists’ mistakes:**

- High speeds when driving past meeting points and unprotected road users,
- Lack of respect for pedestrians and bicyclists when driving straight ahead, turning left or right,
- First directing attention to other motorists and thereafter to pedestrians and bicyclists,
- Overtaking another stationary vehicle that has stopped to give way to pedestrians and bicyclists.

**Regarding pedestrians and bicyclists’ mistakes:**

- Unpredictable (especially the elderly and children) and can quickly change direction.
- Misjudge other road users’ manoeuvres in interactions, e.g. motorists’ giving-way behaviour
- Take great risks by challenging motorists in interactions,
• High speeds (bicyclists),
• Sudden manoeuvres e.g. cycling in front of cars (older and younger bicyclists),
• Lack of respect for traffic rules, e.g. cycle or walk against a red light and bicyclists’ lack of respect for give way rules,
• Suddenly run across the street (pedestrians - especially children) in the little time gap between cars.

Unprotected road users constitute a heterogeneous group with great variations in capacity.

It has been observed in two studies (Ampofo-Boateng, 1991 and 1993) that children up to 9 nine years of age are subject to risks, since they do not have the capacity to judge whether a crossing is dangerous, even if they are aware of the rules that apply. On the other hand, older children between 9 and 11 show greater awareness of what can constitute a safe or dangerous road, and they are more willing to reduce risk by going to a safer place.

Howarth (1985) studied driver and pedestrian behaviour in Nottingham, England. His study, based on the speed behaviour of drivers and avoidance manoeuvres of the road users involved in interactions, showed that drivers most frequently laid the responsibility for avoiding a collision on the pedestrian, even if the latter was a child in a residential area and/or the vicinity of a school, where most of the collisions with children took place.

Rämä (1993) studied schoolchildren’s (7-8 years old) passage-behaviour at four pedestrian crossings with a rather high amount of traffic (on average 142 - 237 vehicles/hour) and observed the following: About every fourth child had to wait on the pavement because of the traffic. The children often looked out for vehicles only after they had started walking over the crossing, and they were inclined to run over the crossing, especially the last part of it. A number of the youngest children ran straight out onto the carriageway. There was no consistency observed in the children’s passage behaviour from one measurement session to another, and the children in groups looked out less for vehicles from the left than those who were on their own.

According to Englund et al, 1998, traffic situations for the elderly are much too complicated when they want to cross a street. For example, they must turn their attention firstly to obstacles on the ground, “negotiate the first risk – falling down” rather than an approaching car. It has been pointed out (Chaloupka et al, 1993) that an elderly pedestrian often underestimates the speed of approaching cars at the same time as he overestimates their distance, especially on wide streets with non-signalised pedestrian crossings. It is probably difficult for an elderly person to try and make these judgements with cars approaching from both directions at the same time.

The conclusion is that unprotected road users’ “errors in interactions with drivers” should be regarded as behavioural faults that are difficult to eliminate.

Rimmö and Åberg (1997) note, in their investigations of drivers’ self-reported behaviour, that the errors they make as drivers can be divided into four different types, namely:

Rule-breaking: for example, driving too fast or against a red light or intentionally not giving way to a pedestrian who is about to cross the road at a crossing (intentional error).

Judgement error: such as failing to notice pedestrians when turning left or right or misjudging the possibility of overtaking (unintentional error).
Observation error: such as following the rhythm of traffic without knowing the speed limit or driving incorrectly because of a missed road sign (unintentional error).

Routine error, such as using the incorrect gear while driving (unintentional error).

Based on Fuller’s (1984) “risk-avoidance theory” one can point out important explanations for the interaction behaviour of motorists and unprotected road users at meeting points. Car drivers do not regard unprotected road users as risk factors for their own safety. “Motorists are not afraid of bicyclists”, see e.g. Näätänen and Summala 1976 and Summala (1996). On the other hand, pedestrians and bicyclists are afraid of motorists’ speed behaviour and lack of consideration at non-signalised crossings (Towliat 1999).

The behavioural faults of motorists do not normally have negative consequences for themselves, and it is often the motorist himself/herself who is unaware of the mistakes, for example, his or her speed and give way behaviour at non-signalised crossings. The driver carries out a large number of manoeuvres in traffic in a routine manner and more or less automatically, depending on experience and knowledge (see e.g. Rasmussen 1986 and Michon 1985). Rasmussen (1986) takes into account the mental decision processes and divides driver-behaviour into three levels based on experience, namely skill-based, rule-based and knowledge-based. Michon (1985) considers the driver’s task and also divides driver-behaviour into three levels, namely strategic, tactical and operative. According to these theories the explanation for drivers’ bad speed and give way behaviour towards unprotected road users at meeting points is that drivers have become accustomed to a certain behavioural-pattern. In the large majority of cases the unprotected road user stops while the driver continues when they meet at crossings where the driver can apply experienced behavioural patterns, that is, choice of speed and give way behaviour. The process of sequential actions occurs automatically since the time, in which to deal with the available information and take a decision with regard to appropriate behaviour, is very short, a second or so for rule-based behaviour and a millisecond for skill-based behaviour. The problem is accentuated by the fact that the driver is more or less unaware that he/she has taken a decision while, for example, driving at a constant speed or accelerating past one or more crossings when unprotected road-users are present. It is only when the decision is taken on the strategic level, or something happens to break the automatic behaviour, that the driver becomes aware of what is happening, that is, when something goes wrong! The disadvantage of automatic behaviour in drivers is that they become less alert and observant with regard to the presence of unprotected road-users at meeting points.

The conclusion drawn from the discussion above is that automatic behavioural faults in motorists at meeting points, that are negative from a safety point of view, must be changed to automatic reactions that are positive from a safety point of view, especially since we cannot eliminate the automatic behaviour of drivers. This means that motorists approaching a meeting point must automatically reduce speed, take in information from the surroundings and be prepared to interact with unprotected road-users who are either there or might suddenly appear; that is, a sequence of positive automatic reactions.

This is considered the most crucial factor in achieving a satisfactory safety standard for all, but in particular unprotected road-users, at meeting points.
3.2. Measures-related theory

Attempts are often made to solve safety problems by influencing road-users’ knowledge and motivation, i.e. influencing attitudes which in turn should influence road-users’ behaviour from a traffic-safety point of view.

Nonetheless, the design of the traffic environment, in which the road-user is active, is at least equally important in influencing road-users’ behaviour. According to Petersson et.,al. (1992), regardless of the level of behaviour – strategic, tactical or operative – that one is interested in, behaviour can be assessed from the manner in which road-users deal with the information they need. Figure 3.1 shows a schematic description of this information process based on some central concepts that must be considered if understanding of the relation between the design of road traffic environments and traffic users’ behaviour is to be enhanced.

Figure 3  A schematic description of the information process of the road user (adapted freely from Pettersson et.al. 1992).

According to theory, the road user’s behaviour is determined by; the objectives (motives) he/she wishes to attain, the prerequisites provided by the road and traffic environment as well as the vehicle and traffic rules – the surroundings – towards attaining these goals and the knowledge (experience) he/she has about how to go about realising these goals. This means that there are, in principle, three possibilities:

1. One can try to change road-users’ objectives or motivation; i.e. influence their attitudes.

2. One can, by means of information campaigns and instruction, try to influence road-users’ knowledge and the demands and prerequisites that prevail.

3. One can change these very prerequisites by changing the design of the road and traffic environment.
The ambition of this project is, by means of changes in the design of meeting points (changing the traffic environment), to create prerequisites for appropriate interactive behaviour between road-users from a safety viewpoint.

To be able to predict how the design of meeting points will influence the behaviour of road-users, it is important that meeting points are designed according to principles that are important from a traffic safety perspective. The principles taken up here are based on the problem-related theory, and will be reformulated into behavioural forms (hypotheses) and tested for their relevance for two different designs, depending on the measures chosen for meeting points. The principles regarding road user- behaviour:

**Low speed:** The main hypothesis is that speed adaptation and safety can be improved by reducing the speed of all vehicles that pass a meeting point. A second hypothesis is that low speed influences other behaviour, e.g. motorists’ give-way behaviour towards unprotected road users and their willingness to interact with them. A third hypothesis is that speed reduction influences both accessibility for all road users and environmental effects at meeting points.

**No priority:** All road users must, in so far as it is possible, feel equal and no road user should have obvious feelings of priority. Such feelings only lead to higher speeds and lower readiness. The principle of no priority varies with that of low speed. The hypothesis is that a good speed adaptation by all road users is a prerequisite for the functioning of the principle of no priority.

**Improved and relevant information to motorists of the presence of pedestrians and bicyclists at meeting points:** The hypothesis is that the provision of relevant and improved information, only to drivers, about the presence of unprotected road users at meeting points, can increase their awareness. This should result in motorists’ adapting their speeds and giving way to unprotected road users about to cross the carriageway.

Since road users’ behaviour will be influenced by changes in the design of meeting points, it is important to take into account the individual road user’s motive, experience and acceptance of changes resulting from the redesigning of meeting points.

A problem that can jeopardise safety improvement with regard to the changed behaviour of motorists, according to the discussion above, that is, that motorists “do the right thing” at meeting points, is that unprotected road users will probably “do the wrong thing”. That is, they will become less observant and “help themselves” by walking onto the carriageway without watching out for approaching cars at meeting points. This argument is supported by Wilde’s (1988) risk compensation theory, which suggests that there is a real risk of compensating behaviour when a road user realises that there has been a safety improvement, and predicts that road users will exploit safety-increasing measures in the traffic system to increase their own accessibility. The implication here is that we would like to limit accessibility for motorists, but no more than is necessary to increase the safety of unprotected road users at meeting points. However, an improvement in standards may induce the latter to take advantage of the increased accessibility instead of the improved safety in encounters with motorists.

Much of the problem can be eliminated if the principle of low speed is applied at meeting points. Furthermore, unprotected road users evaluate the outcome of behaviour according to whether it produces the expected result or not. Here the feedback process is of considerable importance for their ability to adapt to the possibilities that the design of meeting points offers according to Pettersson’s (1992) model, figure 3.
4. PRELIMINARY RESULTS

It should be noted that these are purely preliminary results with the aim of providing general information rather than detailed outcomes of the project according to the hypotheses and problem and measure-related theories.

The general results of the ‘before’ and ‘after’ studies show that the road-cushions, in combination with narrowing of the carriageway and so on, function well from a safety viewpoint, keeping in mind that:

- Car speeds were reduced to roughly 30 km/h (85-precentile) at pedestrian and cycle crossings after having been between 45 - 65 km/h (85-precentile) at different sites.
- Serious conflicts between motorists and unprotected road-users decreased in number and degree of severity at the experimental sites.
- Motorists’ give-way behaviour improved considerably at the experimental sites after the introduction of the measures, but remained unchanged at the control sites.
- Most of the pedestrians and cyclists thought that it had become more convenient, simpler and safer to cross the street at the experimental sites. Most of the bus-passengers thought that comfort on the buses remained unchanged during passage over the road cushions.
- SL (Stockholm’s Buss Company) thought that municipalities in the Stockholm region could use the type of speed reducers (road-cushions), that we had developed for this project, on streets and roads with bus traffic.

Everything points to the fact that the meeting-point design and structural measures, developed as part of this project, are promising traffic-safety measures on main streets in built-up areas, and will be used on a large-scale basis both in Sweden and other countries in the not too distant future.
REFERENCES


Traffic safety and vulnerable road users (1998), An OECD report by the RS7 Group.
