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## Traffic Calming in India

### Report on the theory of Traffic Calming and empirical trials in the city of Jaipur

Hydén, Christer; Svensson, Åse

2009

*Document Version:*

Publisher's PDF, also known as Version of record

[Link to publication](#)

*Citation for published version (APA):*

Hydén, C., & Svensson, Å. (2009). *Traffic Calming in India: Report on the theory of Traffic Calming and empirical trials in the city of Jaipur*. (Bulletin / 3000; Vol. Bulletin 252). Lund University Faculty of Engineering, Technology and Society, Transport and Roads, Lund, Sweden.

*Total number of authors:*

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LUND UNIVERSITY

PO Box 117  
221 00 Lund  
+46 46-222 00 00

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Lund Institute of Technology  
Department of Technology and Society  
Traffic and Roads

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Department of Technology and Society, Lund University, Sweden  
CUTS Centre for Consumer Action, Research & Training (CUTS CART), Jaipur  
TRIPP, Indian Institute of Technology, Delhi

*Keywords:*

Pedestrian safety, traffic calming, conflict studies

*Abstract:*

The pedestrian safety problem is huge in all developing countries. The main aims of the project are therefore: 1/To understand pedestrian safety problem in a developing country, 2/To identify feasible traffic calming measures. International experiences were complemented by field studies at seven sites in the city of Jaipur. A wide range of field studies were made, out of which traffic conflict studies were most important. The main conclusion of the studies is that there is an urgent need for Traffic Calming measures in Indian cities. Pedestrians are extremely exposed and vulnerable, and the speeds are too high to allow a safe and proper communication. One main problem is that road users are not offered any comfortable and safe crossing options e.g. existing pedestrian crossings are not suited for pedestrians. The conclusion from this is that there is a "chaos" that has to be dealt with. The proposed measures are "standardised Traffic Calming measures", primarily by introducing humps at both entrances and exits to intersections and to introduce raised footpaths in all corners to see to it to make the approaches for pedestrians as comfortable and safe as possible by preventing cars from being able to use that space. Pedestrian crossings are located close to the intersections so that pedestrians do not have to make large detours to use them. The measures that are proposed are simple which is the whole idea. Without simplicity **and** low costs there will never be any large scale use. Unfortunately no measures are taken yet in Jaipur, which of course will be next and very important step. When this is done, and after studies carried out, it is time to decide on studies for studying the validity of the results in other parts of India.

*With support from:***Sida**STYRELSEN FÖR INTERNATIONELLT  
UTVECKLINGSSAMARBETE

Institutionen för Teknik och samhälle  
Lunds Tekniska Högskola  
Trafik och väg  
Box 118, 221 00 LUND, Sverige

Department of Technology and Society  
Lund Institute of Technology  
Traffic and Roads  
Box 118, SE-221 00 Lund, Sweden

## Preface

The Department of Technology and Society at Lund University has for two years cooperated with CUTS Centre for Consumer Action, Research & Training (CUTS CART) in the city of Jaipur, both partners financed by grants from SIDA. The team in Jaipur consisted of Mr Azeem ur Rehman, Project Coordinator, Mrs Varsha Rathore and Mr Arjun Kant Jha. Mr George Cheriyan, Associate Director, CUTS International was heading the team. The two teams have had a continuous cooperation with the two experts from Transportation Research and Injury Prevention Program at IIT in Delhi, Professors Dinesh Mohan and Geetam Tiwari.

The project was based on the idea that we would test out a number of traffic calming measures in the city of Jaipur. These measures were selected from the international experience that already existed regarding efficient measures. We were in a second step making large field trials at altogether 24 intersections. Seven of them were selected for intense studies that should give us an understanding of pedestrian problems in an Indian city, and to be able to propose measures. The studies performed were also going to be used as before studies. After implementation of the measures, similar studies were going to be made again, with the ultimate aim to draw general conclusions regarding the feasibility of these measures under Indian conditions.

Measures were proposed based on the findings that pedestrians were extremely vulnerable. We proposed to rearrange the seven intersections to what we called "Standardised Traffic Calmed intersections". (In one case it was a mid-block location). The main principles was to slow down traffic both when entering and exiting the intersections and to locate the zebra crossings so that they become attractive for pedestrians. Unfortunately the authorities did not conclude in time to allow the proposed measures to be implemented within the time frame of this project. Instead traffic calming measures already existing in Jaipur – although in a non-systematic way - were compared with measures proven to be effective in Sweden

We, from the Lund side have had a great experience working in India. We have learnt a lot about how traffic functions in India, what the position is of experts and non-experts and, not the least, learnt a lot about culture and living in India in general. This is all thanks to the enthusiastic collaborators in Jaipur and in Delhi. We highly respect the knowledge about traffic in developing countries carried by our partners at TRIPP. We want to thank you all for two interesting and important years. Let us take it for granted that authorities in India will demonstrate a growing interest for these questions and that they are ready to actually to take steps to try new measures. That is the only possible way forward.

We also want to thank our colleagues in Sweden, for their decisive contribution. We primarily think of Ms Therése Otto who has struggled with all the data for a large part of the project time. We also think of Ms Nina Ceric, Ms Veronika Raguz and Ms Lisa Tull who also have made important contributions regarding analysis of data.

Lund, December 2009  
Christer Hydén and Åse Svensson



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# 1. Introduction

In the light of improving pedestrian safety, CUTS Centre for Consumer Action, Research & Training (CUTS CART) in partnership with Lund University, Department of Technology and Society, Sweden and with the support of Swedish International Development Cooperation Agency (SIDA), New Delhi initiated a project named as "Traffic Calming Strategies to Improve Pedestrian Safety in India". In addition to the two mentioned partners Indian Institute of Technology (IIT) Delhi has been involved as a consultant partner.

The aim of the project was to produce a theoretical and practical background for producing of guidelines for India on Traffic Calming measures. This is done through the following steps:

- Background in terms of general needs from a safety point of view, particularly for pedestrians, in an Indian perspective.
- Background in terms of knowledge about traffic calming measures that have proven successful in Sweden and other OECD countries.
- Field studies at selected sites in the city of Jaipur, Rajasthan, have been carried out. The selection of sites was based on accident data collected from the police districts in Jaipur. Accident prone locations for pedestrians were primarily selected.
- In a first round seven sites (SS) were selected for comprehensive studies. Later on studies were made at another 18 sites, however only one day per site.
- The studies have been carried out, both behavioural, interactional, conflict studies and volume counts.
- The aim was to identify safety related problems for pedestrians and bicyclists, so as to be able to identify the most relevant remedial traffic calming measures for these groups. The aim was also to produce a before study so that the effects of implemented countermeasures could be followed up.
- By combining the experience from field studies in Jaipur with knowledge about successful traffic calming measures from other countries, a set of measures was proposed for each of the studied intersections.
- In order to assess the effects of the measures it was planned to carry out after studies at these intersections. Unfortunately, for unknown reasons, no measures were finally implemented in spite of very comprehensive preparations. Therefore these after studies were replaced by studies of various already existing traffic calming measures in Jaipur, that together could be used to draw tentative conclusions regarding the likely effects of the proposed measures that were not implemented.

Summarising all the activities above, the most promising and relevant traffic calming measures were analysed with regard to their feasibility and possible effects in an Indian context.

## 2. Traffic safety in India.

This section is primarily based on the findings in the report: Road Safety in India: Challenges and Opportunities, Mohan, D., Tsimhoni, O., Sivak, M., and Flannagan, M.J., The University of Michigan. Transportation Research Institute, UMTRI-2009-1.

In summary it can be concluded that the number of fatalities on Indian roads is already high - according to official statistics, 105,725 people were killed in road traffic crashes in India in 2006 (NCRB, 2007) - but will increase for quite a few more years. There has been an increase of fatalities by 5% between 1980 and 2000 and since then the increase is 8%. This is of course partly due to an increase in the number of vehicles on the road - the total motor vehicle population has increased from about 300,000 in 1951 to about 73 million in 2004 - but also to the absence of a coordinated official policy to control the problem. The fatality rate has increased from 36 fatalities per million persons in 1980 to 95 fatalities per million persons in 2006.

Out of the 73 million vehicles in 2004 as much as 71% were motorcycles, and cars only 13%. Out of all sold vehicles in 2007 the motor cycles stand for 78%, and cars for 13%. It may be noted, however, that the actual number of vehicles in operation may be 60-70% of the official statistic as a large number of scrapped vehicles are not deleted from the records (Expert Committee, 2002). Compared with western countries the difference is dramatic. In the U.S. for instance cars stand for 66% of all vehicles while motorcycles only stand for 3%. This does of course give completely different preconditions in India, the implications of which are difficult to predict.

Regarding safety, however, motorcycles represent a smaller part of all fatalities, in Mumbai 7%, in Delhi 26%, and in the smaller city of Kota (a bit less than 800,000 inhabitants) 33%, see table 1. Altogether pedestrians are by far the most involved in fatalities. They represent 79% in Mumbai, 47% in Delhi and 28% in Kota. Third most involved in fatalities are bicyclists; 7%, 10% and 5% in the three cities.

If we look at striking vehicles instead (figure 1) we can see that trucks represent the largest group of vehicles. Then come buses and cars and on fourth place motorized two-wheelers. Regarding the latter group figure 1 shows that they are only the striking partner in 4 to 8% of all fatalities. Regarding their share of vehicles, 38% in Mumbai, 57% in Delhi and 71% nationally, motorcycles do not seem to be overrepresented in fatalities, rather the opposite. More firm conclusions can, however, only be drawn once more is known about ownership and use of motorcycles and cars on a national level.

It should be added that in the report by Mohan et al they use fatality figures for most analyses as these figures are much more reliable than injury statistics.

Table 1. Traffic fatalities by road user and type

<i>Type of road user</i>	<i>Mumbai</i>	<i>Delhi</i>	<i>Kota</i>
Truck	2	3	6
Bus	0	3	1
Car	2	4	19
Three-wheeled scooter taxi	4	3	4
Motorized two-wheeler	7	26	33
Human and animal powered vehicle	0	3	1
Bicycle	7	10	5
Pedestrian	79	47	28
Other (Tractor etc)	0	1	4
<b>Total</b>	<b>101</b>	<b>100</b>	<b>101</b>

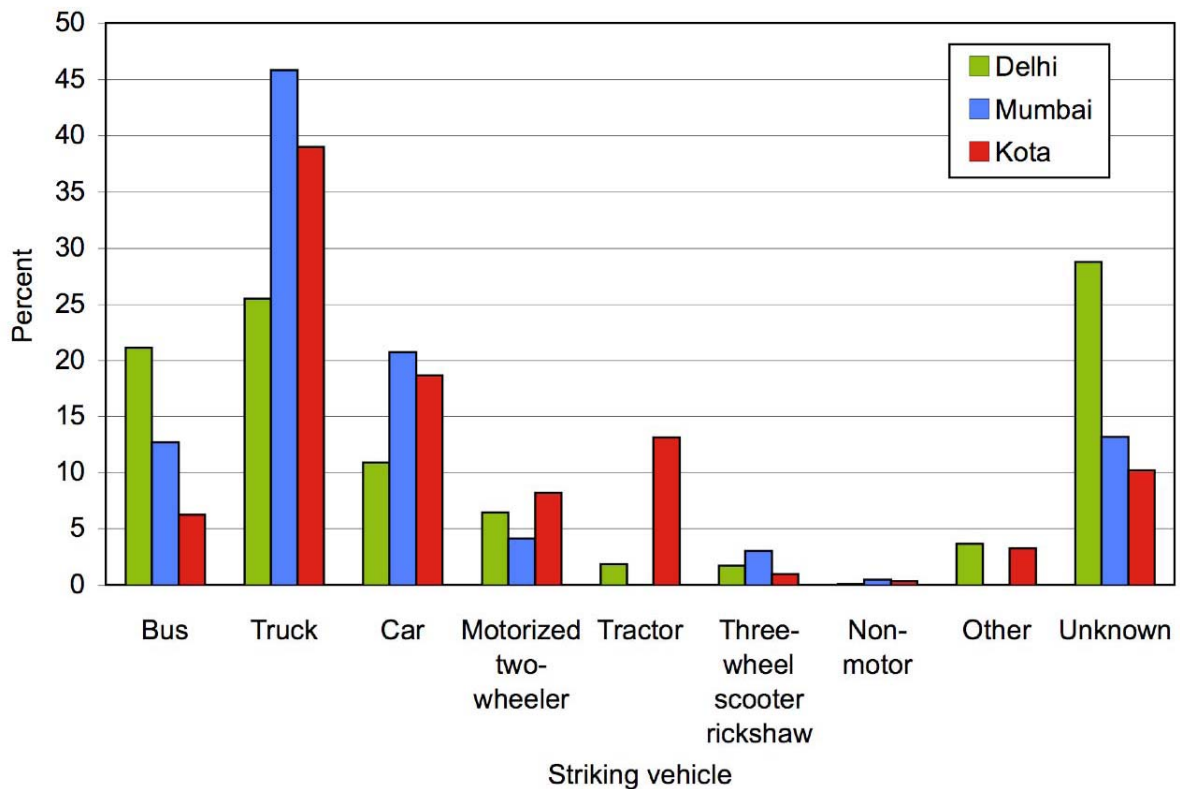


Figure 1. Striking vehicle in fatal crashes in Delhi (2001-2005), Mumbai (1996-1997), and Kota (2007). (Figure no. 24 in Mohan et al 2009)

Undoubtedly pedestrians are by far the most vulnerable group in India in general. The fatality figures are quite high even compared with other developing countries. For instance Sayer and Palmer reported that "more than 40%" of all road fatalities in African countries was with pedestrians, and in Middle Eastern countries the figure was 50%.

Based on Census of India, 2001 and traffic fatalities in India (NCRB, 2007) in 2006 the authors have made a comparison based on age groups. Their main findings are as follows: Children age 14 years and younger comprise only 7% of the fatalities, though their share in the population is 32%. The proportion of fatalities in the age groups 15-29 and older than 60 years is similar to their representation in the population, but the middle-age groups 30-44 and 45-59 are overrepresented by about 70%. The overrepresentation is likely due to that people in these age groups are in their prime working years, and are thus more likely to be present on the road. The low representation of children (2 fatalities per 100,000 persons) (NCRB, 2007) is curious because a significant number of children walk and bicycle to school unescorted, both in urban and rural areas. In comparison, children account for 4.4% of the total fatalities in the U.S. No exposure data for India are available, but the authors claim that children's presence on the road unsupervised is not insignificant. It definitely seems as if children while walking to school are specially protected in one or the other way, either because parents (or other elderly) guide them or because the children themselves are very careful, or because vehicle drivers are particularly careful. The reasons for this low involvement rate, need to be investigated further. There is a special need for empirical studies in the field in order to study exposure and behaviour, including conflicts (this author's adding).

The authors Mohan et al claim that "Theoretical models suggest that the number of fatalities in India is not likely to start to decline for many years to come unless new policies are implemented". Figure 2 shows fatality rates in various countries as a function of per-capita income. The Indian fatality rate (represented by the red square) is in the middle of the range for low-income countries (Mohan, 2004). The fatality rates in mid-income countries range between half that of India to five times greater. As incomes in India increase along with motor-vehicle use, the present trends in India and the experience of some mid-income countries suggest that fatalities could see a dramatic rise before they start to drop, consistent with the so-called Kuznets curve (e.g., McManus, 2007). However, future trends may be altered if vehicle design, road building, and traffic management policies include the latest scientific countermeasures.

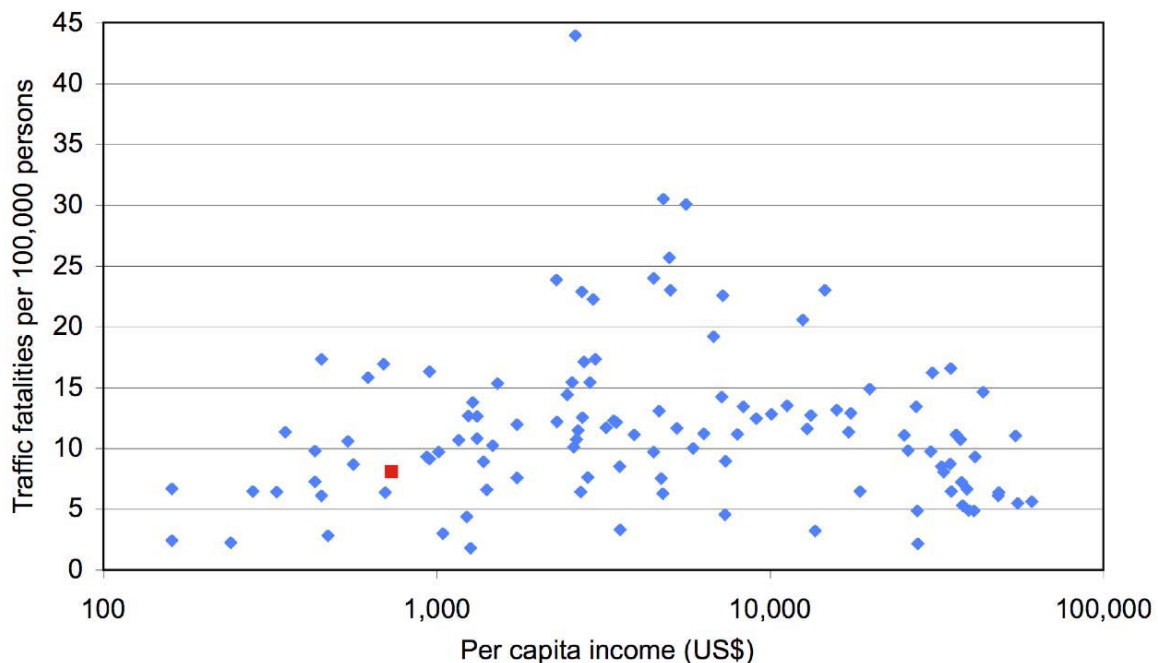


Figure 2. Traffic fatality rates per 100,000 persons in 115 countries. India is represented by the red square.

Based on the analysis made in the report, the following six areas were identified as having the potential for substantially reducing fatalities in India:

- (1) *pedestrians and other non-motorist in urban areas,*
- (2) *pedestrians, other non-motorists, and slow vehicles on highways,*
- (3) *motorcycles and small cars in urban areas,*
- (4) *over-involvement of trucks and buses,*
- (5) *night-time driving, and*
- (6) *wrong-way drivers on divided highways.*

Among these factors the most relevant in our context is of course (1) pedestrians and other non-motorist in urban areas, (3) motorcycles and small cars in urban areas, and (4) over-involvement of trucks and buses, even though it is not said in the last case whether this over-involvement is valid also for urban areas.

The second part of the report outlined in the report by Mohan et al several promising countermeasures for each of these six areas. In this discussion, the authors have organized the treatment of countermeasures in terms of an analysis that describes the total harm from road crashes as the product of three components: exposure, risk, and consequences (Thulin and Nilsson, 1994; Sivak and Tsimhoni, 2008).

Regarding the factors (1), (3) and (4) mentioned above, the following measures were proposed:

Table 2 Summary of promising countermeasures regarding factors (1), (3) and (4).

Problem area	Exposure	Risk	Consequences
Pedestrians and other non-motorists	Separation of motorized and nonmotorized	Speed control Roundabouts Restrictions on	Pedestrian-friendly Front ends of vehicles

in urban areas	traffic on arterial roads	free left turns	
Motorcycles and small cars in urban areas		Daytime running lights Improved lighting and signaling	Enforcement of helmet-use and seatbelt laws Introduction of passive measures like airbags Pedestrian/motorcycle impact standards for small cars
Over-involvement of trucks and buses		Speed control Rest regulations for truck drivers Improved vehicle Conspicuity	Safer vehicle fronts

Of the measures listed for these problems speed control and roundabouts are the two areas which are valid in relation to traffic calming.

## 3. Traffic Calming

### Introduction

Most reports on Traffic Calming (TC) are based on studies conducted outside India e.g. in Europe, Australia, Japan and USA. It is doubtless the same principle that is essential when dealing with TC in India i.e. to calm the vehicle speeds to below 50 km/h in order to reduce injury accidents and pollution and thus making the area for people more pleasant, but it is also important to recognise the partly different circumstances.

Geetam Tiwari at Transportation Research and Injury Prevention programme, Indian Institute of Technology, Delhi, has produced "Guidelines on Traffic Calming measures on national Highways and State Highways Passing Through Town and Villages – State of the Art" based on Indian conditions. Such reports i.e. taking Indian specific conditions into consideration are rare, so therefore is the text here to a great extent is identical to Tiwari's Guidelines.

The car is the predominant mode of traffic in OECD countries while in India the variety is great. In urban areas two-wheelers, three-wheelers and non-motorised traffic comprise a much larger share of traffic than cars. There are also traffic modes like rickshaws, manually pulled vehicles and animal carts that do not exist or at least are very rare in OECD countries. This results in a wide variation of directions, speeds and vehicle mass. This demands that the safety must be ensured with the help of Traffic Calming techniques.

Two main principles for speed reducing measures have been used: visual measures and physical measures. Speed limit signs, painted strips across the road (visual brakes), road surface patterns, plants etc. are examples of visual measures.

The general experience from different European countries indicates that speed limit signs and other visual measures alone are not always sufficient to make the drivers choose an appropriate speed. But when used in combination with other physical speed reducing measures, significant effects can be observed.

### Goals and Objectives

The goals and objectives for traffic calming are more or less similar for all the countries studied for this report. Safety is a key objective for virtually all traffic calming schemes, not only in terms of accidents recorded, but also because of the degree of danger felt by people using the streets concerned.

Environmental improvement has become an objective in its own right for many traffic calming schemes. Concern over the adverse environmental and health effects of traffic has increased considerably in recent years. Reducing the speed and volume of traffic can contribute to a better local environment, but it may often be possible, through imaginative design and the use of appropriate materials, to provide further enhancement.

## Benefits of TC

Experience indicates that traffic-calming programs do significantly reduce the number and severity of traffic crashes<sup>1</sup>. Studies show long-term crash and injury reduction of 15-40 percent, and even greater reduction in pedestrian injuries<sup>2</sup>. One recent before-and-after study found that traffic calming reduced collision frequency by 40 percent, vehicle insurance claims by 38 percent, and fatalities from one to zero<sup>3</sup>. This provided a very favourable six-month payback on project expenses from insurance claims savings alone.

Other researchers conclude that, "small reduction in travelling speed translates into large reduction in impact speed in pedestrian collisions, often to the extent of preventing the collisions altogether<sup>4</sup>". They predict that 5 km/h reduction in urban traffic speeds could reduce pedestrian fatalities by 30 percent. In one case out of ten, the collisions would be avoided and in one out of five an otherwise fatal collision would become non-fatal, with comparable reduction in severity for non-fatal accidents.

## Improved conditions for None-Motorised Modes

Traffic Calming tends to improve pedestrian and cycling conditions<sup>5</sup>. Reduced vehicle traffic speeds and volumes tend to make walking<sup>6</sup> and cycling<sup>7</sup> safer, more comfortable and more convenient. Many people place a high value on street design features that improve safety and mobility for non-motorised transportation<sup>8</sup>.

## Noise, Air Pollution and Aesthetics

Traffic calming generally reduces traffic noise<sup>9</sup>. Speed reduction from 50 to 30 km/h typically reduces noise levels by 4-5 decibels<sup>10</sup>, or more in certain circumstances<sup>11</sup>. Strategies that reduce traffic speeds to about 30 km/h and smooth traffic flow also reduce air pollution.

## Increase in speed influences crashes in four basic ways

- It increases the distances a vehicle travels from when the driver detects an emergency until the driver reacts.
- It increases the distance needed to stop a vehicle once an emergency is perceived Fig 3.
- Crash severity increases by the square of the speed, whereas 85 per cent pedestrians die at 64 km/h, only 5 per cent die from being hit by a vehicle at 32 km/h, Fig 4.
- Higher crash speeds reduce the ability of vehicles, restraint systems, and roadway hardware such as guard-rails, barriers, and impact attenuators to protect occupants. Table 3 derived from different studies over the world shows that the speed limit for safe travel is 30 km/h.

It has been estimated that a reduction of the average speed by 5 km/h on the entire EU road network would decrease the annual number of fatalities in the EU by more than 11,000 and the number of injury accidents by approximately 180,000. The savings are estimated to be 30-40 billion ECU annually.



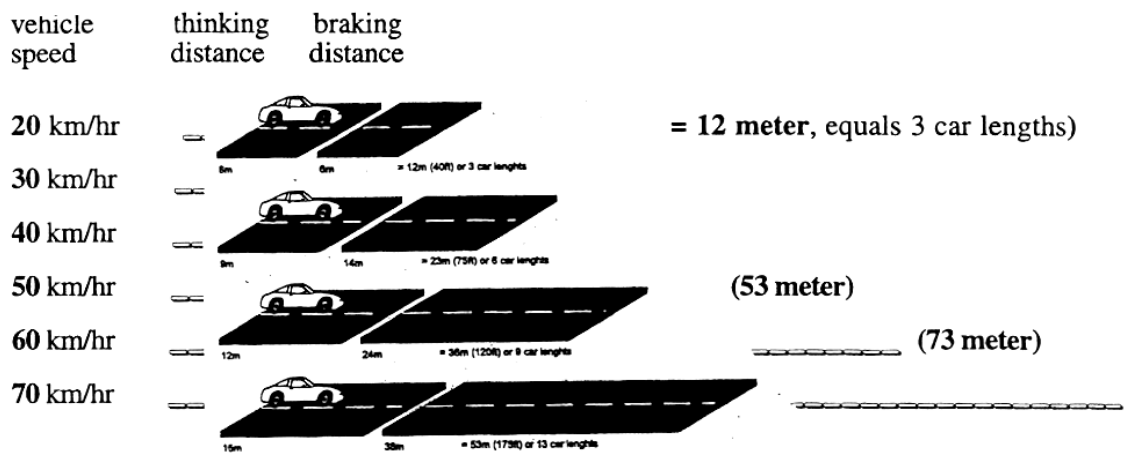


Figure 3: Relationship of speed with braking distance and reaction time<sup>12</sup>.

Table 3: Acceptable "confrontation" speeds in built up areas

	Pedestrian	Cyclist km/h	Moped km/h	Car km/h
Toddlers	-	10	X	X
Under 6	-	-	10	10
6-12	-	-	25	25
Adult	-	-	50	50
Elderly	-	-	25	25
Cyclist	-	-	25	25

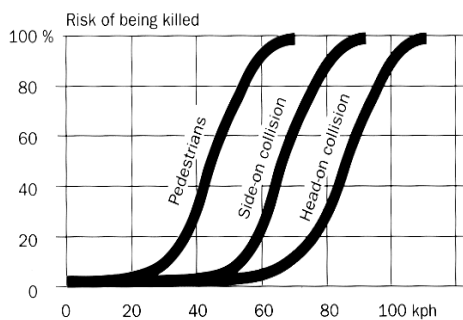


Figure 4: Relation of impact speed with fatality risk<sup>13</sup>.

### Issues on Traffic Calming for India

Traffic calming (TC) emerged as a formal area of road engineering and design in Europe mainly to control the conflicts in traffic, to ensure less erratic driving cycles and to promote safety in urban areas. This was further extended to intercity roads passing through towns but much less work has been done in this area as compared to urban streets. TC measures have been applied informally in all countries of the world for a long time but the effectiveness and efficiency of these measures were not systematically measured and evaluated until it emerged as a formal "official" activity. In the last two decades, these activities have been taken up formally outside Europe

in the USA, Australia and Japan also. In India too, local communities have instituted TC measures on national highways and on urban streets in the form of speed breakers, rumble strips and road closures (in urban areas) mainly as speed reducing measures and to reduce volume of through traffic. However, the issues of conflict among road users, smooth flow of traffic and environmental concerns have not been taken into account. This is because there are no formal guidelines available yet for traffic and highway engineers for the provision of traffic calming measures.

Traffic calming measures in India can be based on the experience of OECD countries provided measures are developed which are suitable to the Indian traffic mix and characteristics of roads and highways. The European TC measures have been based largely on traffic systems in which motor cars are the dominant mode. However, this is not true for India which has a much more varied mix of traffic. Some of the differences in Indian and traffic conditions in OECD countries are summarised in Table 4.

Table 4: Traffic in India vs in OECD countries

<b>Feature</b>	<b>India</b>	<b>OECD countries</b>
<b>1.Modal mix of traffic in urban areas</b>	Two-wheelers, three-wheelers and non-motorised traffic comprise a much larger share of traffic than cars	Cars are the dominant mode
<b>2.Modal mix on intercity roads</b>	Trucks and buses constitute a larger share than cars on most highways. Presence of tractors and non-motorised traffic. Large variation in speeds.	Cars are the dominant mode. No tractors and non-motorised traffic. Little variation in speeds.
<b>3.Highways passing through townships</b>	Almost all intercity roads pass through townships and villages at present. Therefore, all intercity traffic has to interact with local traffic when passing through these areas. This situation is likely to remain for quite some time.	Extensive network of limited access highways ensures that most long distance traffic uses the same. Traffic on intercity roads passing through townships is generally not long distance traffic and hence has slightly different characteristics and needs.
<b>4.Vehicle characteristics</b>	The suspension systems of vehicles and their sizes vary greatly. Thus horizontal TC measures like lane narrowing and staggering would need care to deal with narrow vehicles. Vertical measures like humps (speed breakers) would affect cars, motorcycles, trucks and buses differently.	Since the vast majority of vehicles are cars and vehicles larger than them, horizontal measures are effective. Vertical measures have to be tailored to cars, buses and trucks and two-wheelers are not a major issue.
<b>5.Traffic segregation</b>	At present roads in India have very little segregation of traffic. TC measures in India should consider segregation as one of the important measures. This is, however, only valid on roads where design speed is >30 km/h	A large proportion of roads in Europe now have segregation of traffic, especially the provision of bicycle lanes. This makes traffic calming measures easier to implement.

The aspects discussed in Table 5 have to be considered in assessing the viability of TC measures in India. Given below is a listing of various measures and the possible implications for Indian conditions.

### Most efficient Traffic Calming measures

As discussed earlier Traffic Calming measure include volume control measures for motorised traffic as well as accident reducing measures where speed reducing measures are the most efficient but where complete separation of directions and modes also might be a solution.

#### **Volume control**

##### ***Full Closures (dead ends), Half Closures (partial closures, one way closures)***

These measures would be as effective in India as elsewhere, except that care should be taken that non-motorised traffic is not discouraged. These measures are relevant in residential areas. In metropolitan cities such measures have been implemented by local residents due to safety concerns.

#### **Separation of directions and / or modes**

##### ***Median Barriers***

These are effective in reducing probability of head on collision between two vehicles. However, distance between gaps in barriers needs to be determined carefully. In urban areas if gaps are more than about 500m apart, pedestrians are likely to either jump over them or find ways of destroying them. If gaps are too far apart, it may also encourage vehicles going in the wrong direction. Median barriers may cause inconvenience at locations where there is heavy pedestrian traffic crossing the road because of commercial developments on both sides and especially if convenient pedestrian crossings have not been provided. Median barriers must be combined with convenient pedestrian crossing locations and waiting islands for pedestrians. The pedestrian crossings must be designed not to allow for motorised two-wheeler to pass through e.g. by introducing racks in the passage of the barrier.

#### **Speed reducing measures**

##### ***Speed Humps and Raised Pedestrian Crossings***

The classical Watts hump is a circular-shaped speed hump measuring 3.7 meter long and 0.1 meter high. These humps which were recommended in 1973<sup>14</sup> (Elvik et al., 2009) give increasing discomfort when driven over at increasing speeds. Speed humps may be designed so that they can be used as raised pedestrian crossings. Speed humps have been found to reduce injury accidents by about 41% (see Table 5)<sup>14</sup>. This result is based on methodologically weak studies and may be influenced by regression to the mean. Studies have found reduced traffic volumes in roads where speed humps have been constructed. The accident rate on roads in the area around the road with speed humps does not increase (see Table 6). On average for all studies where information is available about speed, mean speed was reduced from 47.7 to 36.6 km/h in streets where speed humps were installed. This corresponds to a 24% reduction in speed. Based on knowledge about the relationship between speed and accidents, this corresponds to an expected reduction of injury accidents by 42%.

Thus, speed humps and raised pedestrian crossings are very effective. However, specific geometrical designs need to be determined for Indian traffic mix. Shapes, sizes and frequency need to be determined taking into account effectiveness of humps on motorcycle operations. Where volume of rickshaws and manually pulled vehicles is high, arrangements need to be made so that humps do not cause traffic hold up or undue inconvenience to these road users. In IIT Delhi many speed humps have been constructed which are about 2.2 - 2.5 m wide and 100 mm high. This was done mainly due to cost reasons. Even though not scientifically evaluated the expert opinion is that they are reasonably effective.

### ***Raised junctions***

There is unfortunately a widespread misinterpretation regarding the safety effect of raised junctions. It may be assumed that a raised junction as well as for instance a raised pedestrian crossing should reduce speeds and thus reduce injury accidents. Traffic safety research, however, concludes that "the best estimate" is that raised junctions do not reduce speeds and injury accidents but rather the contrary. According to the meta analysis referred to in Table 6<sup>14</sup> raised junctions increase the number of injury accidents although the results are not significant. The studies have not used any comparison group and the authors advice against generalizing the results<sup>14</sup>.

### ***Speed zones***

Speed zones refers to co-ordinating several speed-reducing devices within one area, e.g. 30 km/h zones, speed humps, raised junctions, road narrowing, bollards to prevent cars from driving on pavements, chicanes (narrowing alternate sides of the road), rumble strips, (mini) roundabouts, portals etc.. This measure is known as the "30 km/h zone" or "quiet roads". The zone can include major residential areas and villa areas. Speed-zones appear to reduce the number of injury accidents by around 27% (see Table 6)<sup>14</sup>. For property damage only accidents, the decrease appears to be somewhat smaller, around 16%. It must be emphasised that the majority of results are based on simple before- and after- studies. Regression to the mean was not controlled for.

### ***Roundabouts***

Several studies from all over the world show that roundabouts have a favourable effect on motor vehicle safety<sup>15</sup>. A meta-analysis of 28 studies revealed a best estimate reduction of 30-50% of injury accidents<sup>16</sup>. For pedestrians existing studies also indicate safety-improvements. Before-and-after studies of the construction of 201 roundabouts in Holland show a significant drop of 47% in the number of pedestrian accidents and a drop of 89% of causalities<sup>17</sup>. A Swedish study found a decrease of expected pedestrian accidents of 80%<sup>18</sup>.

Qualities of roundabouts can differ extensively depending on the design<sup>15</sup>. Low speed is one of the most important qualities for safe roundabouts<sup>19,20,21</sup>. The size of the roundabout and the entry and exit path curvatures determines the vehicle speed through the roundabout. The speed is generally lower in one lane roundabouts than

in multiple lane roundabouts and the speed is lower if the radius of the central island is 10-20 meters than if it is smaller or larger. The number of accidents gets higher with higher speeds in these cases<sup>22</sup>. Traffic islands have a speed reducing effect and make it easier and safer for vulnerable road users to cross the street<sup>20</sup>.

Roundabout design differs also extensively between countries. Because of this and the fact that driving culture, volumes of different kinds of road users and informal rules also vary, research results from one country does not necessarily apply to another country. For roundabouts in India it is therefore very essential that the geometric design and details are worked out carefully to ensure compliance with priority rules and safe crossings of non motorised traffic. The detailed design in order to obtain this is still to be tried out.

Table 6: Effects on accidents of speed-reducing devices<sup>14</sup>.

Accident severity	Types of accidents affected	Percentage change in the number of accidents	
		Best estimate	95% confidence interval
<b><i>Speed humps</i></b>			
Injury accidents	All accidents on roads with speed humps	-41	(-57; -34)
Injury accidents	All accidents on roads nearby roads with speed humps	-7	(-14; -0)
<b><i>Raised junctions</i></b>			
Injury accidents	Accidents at junctions	+5	(-34; +68)
Property damage only accidents	Accidents at junctions	+13	(-55; +183)
<b><i>Rumble strips in front of junctions</i></b>			
Injury accidents	Accidents at junctions	-33	(-40; -25)
Property damage only accidents	Accidents at junctions	-25	(-45; -5)
Unspecified	Accidents at junctions	-20	(-25; -5)
<b><i>Speed zones</i></b>			
Injury accidents	All accidents	-27	(-30; -24)
Property damage only accidents	All accidents	-16	(-19; -12)

## 4. Field studies at the seven sites - before

### 4.1 Introduction

As was mentioned field studies in a first step were focussing on seven sites where traffic calming measures should be proposed. The sites differ with regard to design and conditions for pedestrians and bicyclists. Photos are presented in Figure 5 below. At each of these sites four days of video recordings were performed, approx 6,5 hours per day. These video recordings were used to analyse conflicts, interactional behaviour and magnitude of traffic flows. In addition to these analyses speed measuring was made on site at all seven sites.

The analyses mentioned above form the basis for identifying safety related problems and link them to possible traffic calming measures.

In this chapter we will report everything related to the seven sites. Video recordings have also been made at 15 more sites as was mentioned earlier. There have, however, not been any analyses of these recordings. The main aim of the studies at the seven sites was to end up implementing measures on an experimental basis. Initially we therefore focused entirely on the seven sites, and when we failed to have measures implemented there, our resources had to be spent on a Plan B where we added other studies in Jaipur that could give us a better understanding of the feasibility in an Indian context of measures developed and used in many western countries – see chapter 5. The point is that there are quite a few traffic calming measures implemented in Jaipur, however not in a systematic way. The results from measuring at sites where traffic calming has been introduced is used to draw conclusions regarding speed level at different sites and to compare these levels with levels at similar measures in other countries.

All studies but the ones at the seven sites are reported separately. Figure 5 gives a photographic idea about the seven sites.



Site 14 Sector 3



Site 15 Haldi Gahti Marg



Site 21 Galta Gate



Site 23 Phakeero ka Mohalla



Site 29 Gopalpura



Figure 5 View over the seven sites

## 4.2 Methods

The main ingredient in the field studies is the conflict studies. In brief one can conclude that conflicts work as a necessary complement to accidents. The information on accidents from the police is not complete; there is a lot of missing data, and the information regarding situational and behavioural aspects is very incomplete. To understand why (pedestrian and pedal cyclist) accidents occur, and thereby to be able to propose measures that could ease the problems identified, we therefore need a complement (and also supplement) to accidents.

For this purpose we have used the Swedish Traffic Conflicts Technique, developed at the Department in Lund (Hydén 1987). The technique is based on manual recording of certain types of conflicts. Conflicts are defined by "a situation where two road users would have collided if they had continued with unchanged speed and direction ('collision course')". Serious conflicts represent a sub-group of conflicts where a collision is imminent. These conflicts are defined with the help of their Time to Accident (TA) and Conflicting Speed (CS) values. Time to Accident is the time (in tenths of seconds) that spans the period when somebody starts an evasive manoeuvre, until the time a collision would have occurred if the two involved road users had continued with unchanged speeds and directions. Conflicting Speed is the speed (km/h) of the road user who takes evasive action, just prior to the evasive manoeuvre actually starts. The distinction between non-serious and serious conflicts is illustrated in the graph in figure 6.

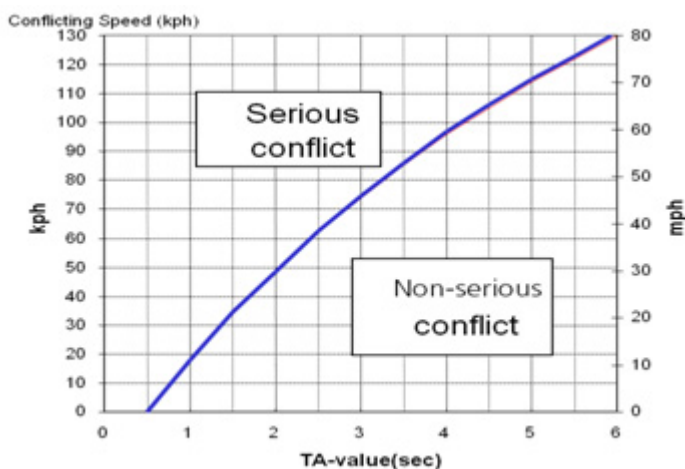


Figure 6 Conflict diagram including definition of serious conflict

In operational terms one can say that serious conflicts are characterised by the suddenness and harshness of the evasive action. In interviews with road users who just had been involved in a serious conflict they said that they would not like to be involved in such a serious event once more. This statement was considerably more frequent with road users involved in serious conflicts compared with road users involved in other – less serious – conflicts.

Conflicts have traditionally been recorded by trained observers standing at the location. Gradually manual observation on the ground has been taken over by recording from video recordings and manual (in-door) analysis of these recordings.



This is in line with the general development of automated video analysis of behaviours and conflicts.

At the seven sites half of the recordings were analysed by the Swedish Team (ST) and half by the Indian Team (IT) in Jaipur. The latter were trained by Christer Hydén and Aliaksei Laureshyn from ST in March 2008. The training program is attached in Appendix 1.

## 4.3 Results

### 4.3.1 Serious conflicts

Below follows an overview of all the conflict recordings at the seven sites, both by ST as well as IT. Detailed results can be found in Appendix 2.

Table 7 Total number of recorded serious conflicts at the seven sites

	Pedestrian conflicts				Bicycle conflicts				Other confl	Total	Obs. Hours
	Cars	MC	Other	Tot	Cars	MC	Other	Tot			
Riico Gate (11)	9	14	2	<b>25</b>	6	5	1	<b>12</b>	<b>79</b>	<b>116</b>	25.5
Goshala (13)	7	12	1	<b>20</b>	7	6	1	<b>14</b>	<b>66</b>	<b>100</b>	25.6
Sector 3 (14)	9	56	6	<b>71</b>	3	0	0	<b>3</b>	<b>8</b>	<b>82</b>	44.9
Haldi Ghati Marg (15)	4	12	0	<b>16</b>	3	13	0	<b>16</b>	<b>127</b>	<b>159</b>	50.7
Galta Gate (21)	18	16	12	<b>46</b>	4	4	2	<b>10</b>	<b>61</b>	<b>117</b>	52.1
Phakeero ka Mohalla (23) (ST only)	15	7	8	<b>30</b>	5	1	1	<b>7</b>	<b>64</b>	<b>99</b>	26,1
Gopalpura (29)	23	34	2	<b>59</b>	24	18	1	<b>43</b>	<b>79</b>	<b>181</b>	49.5
<b>Total</b>	<b>87</b>	<b>158</b>	<b>34</b>	<b>279</b>	<b>50</b>	<b>45</b>	<b>5</b>	<b>100</b>	<b>470</b>	<b>847</b>	274.0

Table 8 The number of serious conflicts per hour at the seven sites

	Pedestrian conflicts				Bicycle conflicts				Other confl	Total	Obs. Hours
Riico Gate (11)				1.0				0.5	3.1	4.5	25.5
Goshala (13)				0.8				0.5	2.7	3.9	25.6
Sector 3 (14)				1.9				0.1	0.2	2.1	44.9
Haldi Ghati Marg (15)				0.3				0.3	2.5	3.1	50.7
Galta Gate (21)				0.9				0.2	1.2	2.2	52.1
Phakeero ka Mohalla (23) (ST only)				1.1				0.3	2.5	3.8	26.1
Gopalpura (29)				1.2				0.9	1.6	3.7	49.5
Total				1.0				0.4	1.7	3.1	274.0

Predicted number of **injury** accidents per year, based on **Swedish** conversion factors, average per location:

Pedestrians: 1.9 accidents, Bicyclists: 0.7 accidents, Motor Vehicles: 0.6 accidents

In order to compare the scorings by the Indian team and Swedish Team respectively one day of analysis from the same video recordings was done in India and in Sweden. Below, in table 10, you find the overall results. Details of the scorings can be found in Appendix 2. In Appendix 3 there is a comparison of Indian and Swedish conflict scorings and in Appendices 4 and 5 there is a mapping of the conflicts. These three appendices are not attached to the report but can be obtained from the department in Lund.

Table 10 A comparison of Indian and Swedish conflict scorings

Site no. 23, Wednesday the 4<sup>th</sup> of July 2009

	Pedestrian conflicts				Bicycle conflicts				Other confl	Total
	Car	Motor Bike	Other	Tot	Car	Motor Bike	Other	Tot		
Indian Team	2	7	2	11	3	3	0	6	15	32
Swedish Team	4	2	1	7	0	0	1	1	25	33

The table shows a high degree of similarity, but only on the total level. At a detailed level one can see that there are quite large discrepancies. However, the figures are small and the differences are likely due to random variation. In any coming project, however, a more comprehensive comparison has to be done. As all scorings are based on video recordings it will be quite easy to harmonise scorings of the two teams by just extending the training until a sufficient degree of harmonisation has been achieved.

### 4.3.2 Speeds in conflicts

Table 11: Speeds in serious conflicts (km/h), averages

	Pedestrian conflicts		Bicycle conflicts		
	Cars	Motorbikes	Cars	Motorbikes	
Riico Gate (11)	<b>25</b>	<b>22</b>	30		
Goshala (13)		31	<b>32</b>	<b>18</b>	
Sector 3 (14)		18			
Haldi Ghati Marg (15)	<b>26</b>	<b>16</b>		18	
Galta Gate (21)	<b>29</b>	<b>24</b>	16		
Phakeero ka Mohalla (23)	<b>39</b>	<b>24</b>	39		
Gopalpura (29)	<b>18</b>	<b>24</b>	<b>21</b>	<b>17</b>	

One can see that in all cases but one, where speeds are existing both for cars and motor bikes in the same type of conflict (marked with bold red, e.g. car-pedestrian and motor bike-pedestrian), the speed is between three and fifteen km/h higher for cars.

### 4.3.3 General speeds on approaches (km/h)

Table 12: General Speeds on Approaches to the Seven Sites

Only CARS appr. 50 in each direction i.e. 100 in total per site

	FROM Jaipur			TOWARDS Jaipur			Both dir.	
	Mean	85perc	Max	Mean	85perc	Max	Mean	85perc
RIICO Gate (11)	46	57	65	39	48	56	43	52
Goshala (13)	43	50	62	41	50	57	42	50
Sector 3 (14)	47	56	63	43	52	56	45	54
Haldi Ghati (15)	47	54	60	44	53	67	45	54
Galta Gate (21)	44	54	65	37	44	48	41	50
Phakeero ka Mohalla (23)	45	54	58	35	43	49	40	50
Average							42,7	51,7

Only MOTORCYCLES appr. 50 in each direction i.e. 100 in total per site

	FROM Jaipur			TOWARDS Jaipur			Both dir.	
	Mean	85perc	Max	Mean	85perc	Max	Mean	85perc
RIICO Gate (11)	45	54	67	37	43	50	41	50
Goshala (13)	41	48	56	42	48	57	42	48
Sector 3 (14)	44	52	65	41	49	57	43	51
Haldi Ghati (15)	45	53	64	43	50	57	44	52
Galta Gate (21)	41	47	61	38	44	49	39	46
Phakeero ka Mohalla (23)	40	47	58	43	50	52	41	48
Average							41,7	49,2

Only TRUCKS appr. 50 in each direction i.e.100 in total per site

	FROM Jaipur			TOWARDS Jaipur			Both	
	Mean	85perc	Max	Mean	85perc	Max	Mean	85perc
RIICO Gate (11)	37	46	49	27	33	51	32	42
Sector 3 (14)	35	42	61	30	37	49	33	40
Phakeero ka Mohalla(23)	36	42	54	33	40	46	34	41

Also when we compare general approaching speeds at the seven sites we can see that in almost all cases cars are travelling with higher speeds than motor bikes. The 85-percentile speeds of cars are 50 km/h or above at all sites, while the corresponding speed for motor bikes is on average somewhat lower. Table 12 also shows that the speed of trucks is around 10 km/h lower than that of cars.

#### 4.3.4 Traffic Volumes

Table 13 Incoming road users per hour

	Car / Motor- Rickshaw/LCV/Truck/Bus	Motor cycles	Bicycles	Pedestrian	Total
Riico Gate (11)	1340	2020	192	854	4406
Goshala (13)	1558	2780	344	299	4981
Sector 3 (14)	1562	2809	305	156	4832
Haldi Ghati Marg (15)	854	1438	148	224	2664
Galta Gate (21)	429	392	35	375	1231
Phakeero ka Mohalla (23)	965	1123	137	573	2798
Gopalpura (29)	1378	2403	414	697	4892
<b>Total (n)</b>	<b>8086</b>	<b>12965</b>	<b>1575</b>	<b>3178</b>	<b>25804</b>
<b>Total (%)</b>	<b>31</b>	<b>50</b>	<b>6</b>	<b>12</b>	<b>99</b>

It is interesting to see that pedestrians and bicyclists only represent 12 and 6% respectively, which is much smaller than their share of accidents. Motorbikes represent a big part of all motor vehicles, namely  $12965/8086 + 12965 = 62\%$ .

#### 4.3.5 Interactional studies

A special analysis has been made of the behaviour of pedestrians, and motorised road users at interactions, i.e. at situations where the road users are very close to each other. The aim was to try and describe how respective road users reacted on meetings with other road users. How did pedestrians manage to cross streets and to what extent were the behaviours by all the road users triggered by the other partner in the interactions. The analysis is made as a qualitative description of a number of interactions randomly selected. The pedestrian behaviour is described as a sequence from the moment the pedestrian starts trying to cross, via the different interactions during the crossing to the moment the pedestrian reaches the other side. The behaviour of the drivers is described in relation to the interaction with the pedestrian. Figure 7 gives an example of the classification from Site no. 11. The interactions are also stored as video clips. The results are summarised in table 14 below.



MC shows no reaction to pedestrian who is about to cross the road.



Pedestrian stops and waits.



MCs show no reaction to pedestrian.



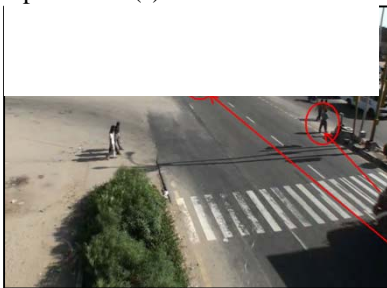
MC shows no reaction to the pedestrian(s).



Pedestrian walks diagonally.



Pedestrian runs diagonally.



Pedestrian ran because neither MC nor truck showed any reaction to the pedestrian(s).



Pedestrian stops and waits. The motorized rickshaw shows no reaction to the pedestrian waiting at the refuge.



Neither of the MCs show any reaction to the pedestrian waiting at the refuge.

Figure 7 Pedestrian and motorised road user behaviour. Example from Site no. 11

Table 14 Pedestrian and driver behaviour at interactions. Based on random examples from sites no.11, no.15, no.21, no.23 no. and no.29

### Pedestrian behaviour

Before entering		Crossing – normal pace		Crossing - running			
Stops/ Waits	Walk parallel	Straight	Diagonal	Straight	Diagonal	Stops while crossing	Number of pedestrians
58	17	43	36	6	4	24	76
76% <sup>1</sup>	22%	57%	47%	8%	5%	32%	-

### Driver behaviour

Road user/ type/behaviour	Show no reaction to pedestrian	Brakes	Swerves	Total
Motor Bike	73	3	4	80
Car/Motor Rickshaw	69	2		71
Truck	23			23
LCV	7			7
Bus	8			8
Other	3	1		4
TOTAL	183 (95%)	6 (3%)	4 (2%)	193 (100%)

The pedestrian counts, Appendix 6 (not included in the report), can be used to produce quantitative results regarding parts of the pedestrian behaviour. Site no. 11 and Site no. 15 can be used to see how many pedestrians are crossing in the middle of the intersections. For Site no.11, Riico Gate:  $628/854 = 74\%$  are crossing in the middle zones while at Site no.15, Haldi Ghati Marg:  $108/224 = 48\%$ , are crossing in the middle of the intersection.

The results clearly indicate that there is a lack of proper behaviour both with the pedestrians as with the drivers. Table 14 shows e.g. that half of the pedestrians walk diagonally and Appendix 6 indicates that in some of the intersections at least half of the pedestrians are crossing in the middle of these intersections. At the same time Table 14 also shows that almost all drivers show no reaction to pedestrians even though they pass quite close to the them.

Altogether the results produce an image of no communication between the road users and a lack of understanding of the need for some kind of "play rules". It is of course difficult, and without any point at all, to pin point one of the groups; that is not very constructive. Instead we must conclude that none of the groups seem to have any strong incentives to change behaviour. At the same time it is obvious that drivers feel themselves as the strong partner. They most often just blow their horn instead of trying to adjust to the pedestrian.

<sup>1</sup> Percentage related to the number of pedestrians observed. Different behavior within the same group can be performed by the same pedestrian, i.e. the total percentage is more than 100%

## 4.4 General conclusions from the field studies

### 4.4.1 Conflict studies

The number of pedestrian conflicts is fairly similar at all of the seven sites. In order to get a general idea about the results, we have used the conversion factors between serious conflicts and accidents. They are the only factors available, so even though they are produced for completely different conditions there is reason to believe that the expected number of injury accidents produced with these conversion factors somehow indicates the magnitude of the problem. Specifically there is all reason to believe that a comparison between the seven intersections regarding pedestrian and bicycle accidents is justified.

Our prediction of the average number of injury accidents with pedestrians involved for all the intersections is 1.9 injury accidents per year and intersection. The smallest number is estimated at Phakeero ka Mohalla (15) – where the expected number of pedestrian injury accidents is less than one third of the average number. The largest expected number of pedestrian injury accidents is estimated at site no. 14, Riico Gate. The expected number here is almost double the average. The validity of these predictions can only be studied if valid accident data can be collected for a number of years ahead.

In Appendices 4 and 5 all the conflicts are mapped. The most obvious conclusions from these maps are – fairly generally – that conflicts mainly occur in the central parts (middle) of the intersections. This is particularly true for pedestrian conflicts. Another obvious finding is that vehicles (including bicycles) are quite often involved in conflicts at locations in the intersections where they “are not supposed to be” regarding driving direction.

On the whole there is an obvious pedestrian safety problem at all seven sites. Studies have demonstrated pedestrian problems as a basis for discussing feasible Traffic Calming measures.

It must be stressed that we as a whole strongly believe that those problems we have identified and demonstrated are “general enough”. This is based among other things on the large number of visits to different sites in Jaipur, and it also fits with the safety problems for pedestrians described for India according to the report we have summarised in the beginning of this report.

There is fewer expected number of injury accidents with bicyclists than pedestrian accidents, on average only 40% compared with pedestrian accidents. This corresponds fairly well with the share of bicyclists in these intersections compared with pedestrians, they are only half as many as pedestrians.

Table 15 compares the involvement of different striking vehicles in serious pedestrian and bicycle conflicts. The table shows that regarding pedestrian conflicts the share of conflicts is about the same as the share of the total volume as the three types of vehicles represent. For bicycle conflicts, however, cars are much more represented in



serious conflicts than their share of the volume, while both motor cycles and trucks/etc are less represented in conflicts.

Table 15 Involvement in serious conflicts in relation to volumes at the seven sites

	Car / Motor-Rickshaw	Motor cycles	/LCV/Truck/Bus	Total
Total volumes per site; average (n)	800	1852	363	3015
Share (%)	<b>27</b>	<b>61</b>	<b>12</b>	<b>100</b>
Striking vehicles in pedestrian conflicts (%)	<b>31</b>	<b>57</b>	<b>12</b>	<b>100</b>
Striking vehicles in bicycle conflicts (%)	<b>50</b>	<b>45</b>	<b>5</b>	<b>100</b>

One more indication of the problems related to private cars is that cars have a higher approach speed to these intersections than motorcycles. Table 12 above shows that the approach speeds at the seven sites for cars is on average around 43 km/h while it is around 42 for motorcycles. The 85-percentile speed is around 52 km/h for cars and around 49 for motorcycles. In addition our conflict studies indicate that the speed of cars involved in conflicts is considerably higher than the speed of motorcycles involved in conflicts. These speeds are much too high to ensure safe crossings of pedestrians. This is particularly true in view of the fact that pedestrians cross "everywhere" in the intersections and quite often they also cross more or less diagonally.

The pedestrian behaviour somehow indicates that they do not feel very stressed when crossing. This we do not know, however. The reason for their behaviour may simply be that they are not offered any comfortable and safe crossing. The infrastructure in terms of pedestrian crossings is not suited for pedestrians. To use the crossing they often have to climb a high median, often equipped with some kind of obstacles (like bushes etc). Furthermore, the behaviour of the motorised drivers do not promote the idea of communication between the two parties. Our interpretation is that the interaction studies show that motorised drivers pass the intersections with the general idea that it is the pedestrians who have to take the responsibility for avoiding problems/risks. It is a tremendous challenge to change the present situation but as it is a long-term process it has to get started as soon as possible. Traffic calming is a fundament in such a process.

#### **4.4.2 General observations**

##### **RIICO Industrial Gate (Site no. 11)**

Missing

##### **Gaushala (no. 13)**

Pedestrians are crossing everywhere, probably because motorised vehicles are blocking a lot of the area inside the intersection. Zebra crossings are located outside the intersection area and, besides, crossing of the median is almost impossible due to obstacles there.

Vehicle speeds are high as soon as there is no jam in the intersection.

##### **Sector 3 (Site no. 14)**

Speeds are often very high. No proper crossings for pedestrians are offered. Neither proper waiting areas for bus passengers.

##### **Haldi Ghatati Marg (no. 15)**

The intersection is extremely disorganised and "spread out", thus creating very "ad-hoc" behaviour by pedestrians, pedal cyclists and – actually – all other road users as well. There is one marked zebra crossing. It does not seem to be frequently used – only 25% of all crossing pedestrians cross there. Most pedestrians cross in the middle of the intersection. One reason is that there is no clear connection between a foot-path or other pedestrian arrangement. On the contrary, using the zebra results in inconveniences for the pedestrians in the form of obstacles to climb over and a fairly long detour compared with the wished for crossing paths.

Also the gap between the medians is too big i.e. the area of the intersection is too extensive thus encouraging people to use it in an unorganized and non-channelised manner.

##### **Galta Gate (Site no. 21)**

This location is quite "undefined" thus creating a lot of problems for all road users passing it. The area which is possible to use for any kind of traffic is much too big, making movements very unpredictable. This is particularly true for pedestrians who seem to cross in a much unorganised way. This spacious intersection creates long crossing distances and thus long crossing times for all road user categories but particularly for pedestrians. The intersection is signalized but traffic move with high speed, especially when traffic approaches when the green light is just about to turn red. This creates high risks, especially for pedestrians. The design of the intersection does not give any guidance at all. This is valid for e.g. the markings and location of zebra crossings, lack of foot-paths, lane markings, location of traffic lights, etc.

##### **Phakeero ka Mohalla (Site no. 23)**

At this location many pedestrians wait on the road for buses, etc. They are also crossing at different places in a rather disorganised manner. The distance of interest (= where pedestrians are crossing) is around 500 metres (?). As it is in the outskirts

of the city vehicle speeds are quite high, and much too high with regard to all the children and other vulnerable persons who are crossing in this area.

### **Gopalpura Chaurah (Site no. 29)**

This location is facing the same type of problems as most of the other intersections studied. Designated areas for pedestrians are non-existing. Besides there is a labour market in one of the corners quite often forcing people to stand on the road. Existing (very poorly painted) zebra crossings indicate a pedestrian crossing that – when it comes half way – is blocked by various obstacles on the central median.

## **4.5 Conclusions regarding feasibility and efficiency of traffic calming measures in India**

Based on the general knowledge about Traffic Calming Measures and the conclusions we have drawn based on the problems identified at the selected sites in Jaipur – and the results of all studies at the seven sites - we have drawn the following conclusions:

- The space available is in most cases extremely large and there is no real guiding of road users where to be located while passing intersections. The result is that all sorts of road users appear almost everywhere at these intersections, often at the wrong place and in the wrong direction. The main principle seems to be to find the easiest way through the intersections with the smallest delay.
- This is also very valid for pedestrians. They are left without any incentives or physical guidance to behave in a certain, safe, way.
- The same applies to bicyclists, who may cross just about anywhere.
- The same applies to motorised drivers. Besides they seem to more or less neglect the presence of pedestrians or bicyclists, and do also try to minimise stopping.
- The speed of vehicles is very high - 85 percentile speeds above 50 is much too high at potential interactions with pedestrians and bicyclists.
- One basic conclusion we have drawn after all our studies is that there is a great need for a better organisation of traffic at intersections. This is the only way of making it possible for road users to interact with others, and thereby being able to predict the behaviour of others. We know at the same time from studies in Sweden that there is a great risk that more organisation may result in a risk that road users become less attentive. This may even jeopardize the potential safety benefits. Our conclusions based on studies in Sweden is that the only way to solve this problem is to ensure lower speeds.

The high speeds and their implication on safety for India (as well as elsewhere) deserves a section of its own. Research results show that the risk for a pedestrian being killed is increased from around 15% at an impact speed of 30 km/h to 55% at an **impact** speed of 50 km/h (adapted from Elvik 2004 who has adapted the results from Adapted from Ashton 1980, Walz et al 1983, Otte and Suren 1984, Interdisciplinary Group 1986.). A similar very strong relationship between speed and safety is illustrated by the power model that relates to the **travel** speed. If the average travel speed is decreased from 52 km/h – which is the average speed at our seven sites – to e.g. 40 km/h, the risk for a pedestrian of being killed is reduced by

55% according to the power model, see figure 8 below. (Elvik et al 2004). A reduction to 30 km/h instead would result in an 80% (!) reduction. There is no reason to believe that this general power model would not be valid in India as well.

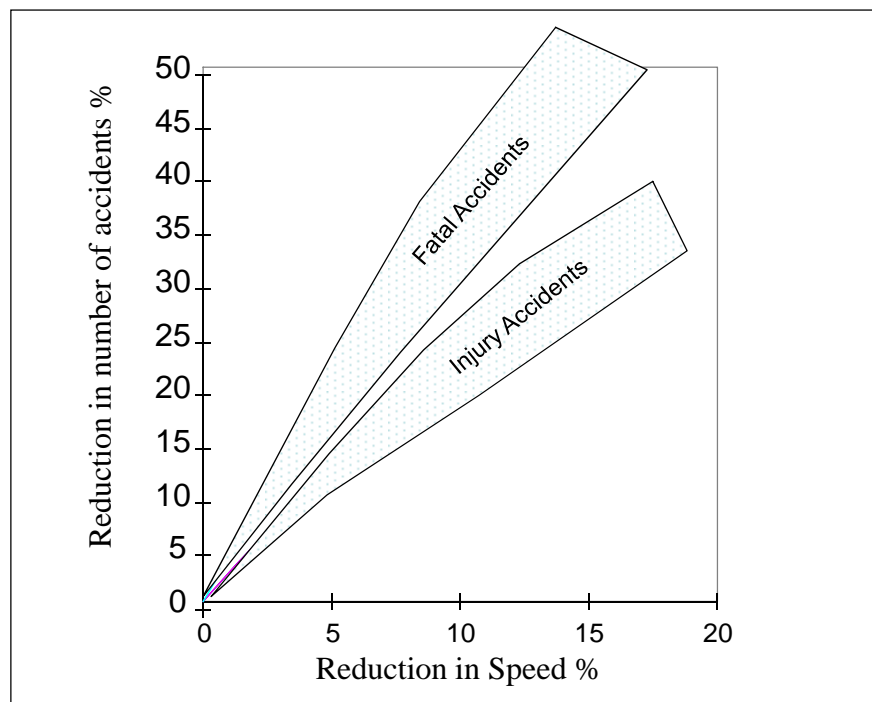


Figure 8 The power model (Nilsson 2004)

These problems altogether formed the strategy we have chosen for the first Traffic Calming attempts in our project. We have therefore proposed to test a so called standardized traffic calming solution, one version at intersections (figure 9) and one mid-block (figure 10). The reasons behind are summarised in the principles behind these proposed solutions:

- General speed reduction at these critical points in the system is central
- Motorised traffic entering intersections will have to slow down because of the humps at the intersection entrances
- Leaving the intersections the zebra crossing is raised. This is very important as it is found that a large majority of pedestrian safety problems are occurring when motorised vehicles are leaving the intersections with too high speeds
- Raised foot paths will see to it that motorised traffic will be kept away from the areas designated to pedestrians
- All areas will be minimised making it more difficult for motorised traffic to select "unexpected routes"
- Thanks to all this the hypothesis is that the raised foot paths will be a strong incentive for pedestrians to use the new zebra crossings for crossing. The intention is to see to it that pedestrians change behaviour when given appropriate choices (crossing in the middle of the area where motorised traffic is moving in many directions, crossing diagonally, etc).

- The location of the zebra crossings is done with the aim of seeing to it that the pedestrians will cross in the most obvious – and safe - areas for crossing, so that drivers are able to be alert in relation to the pedestrians
- The zebra crossings have to be well marked and logically located in the beginning and the end of the intersection area and in an as short distance as possible between the crossings, not to demand too long detours for pedestrians
- The general philosophy behind this design is to start a communication with both pedestrians and drivers, in order to present the message that these standardised intersections are specifically designed in order to not only safe guard pedestrians but also encourage a proper interactional behaviour between the different groups, i.e. for drivers, to slow down, letting pedestrians being “first at the meeting point” to pass before the car/Mc. At the same time pedestrians are obliged to pay attention to motorised traffic and not stepping out in front of a car without any communication with the driver. In simple terms, the aim is to encourage/“force” a decent meeting between road users. One important element is of course the speed reduction. Studies from Sweden show that low speeds encourage a spontaneous improvement of the interaction. Another very important observation from Sweden and elsewhere is that, even though car drivers are forced to slow down, they fairly quickly adapt to the situation and they “have to accept” the rationale with the measures. We think that to-days situation is the result of lack of considering these aspects in planning earlier, which in turn has led to behavioural habits primarily based on the premature rule “the heaviest is the strongest”.. When these habits are broken other habits are quickly established and drivers find, for two reasons, it easy to accept these new habits. One is that they understand that they cannot conquer these new measures, and therefore the best is to accept them as quickly as possible. The other reason is that even drivers find these new “play rules” quite reasonable. Of course these are hypotheses based on experiences from abroad so they have to be tested in connection with introducing these new measures.

### Traffic Calmed Standardised T- and Four Arm Intersection

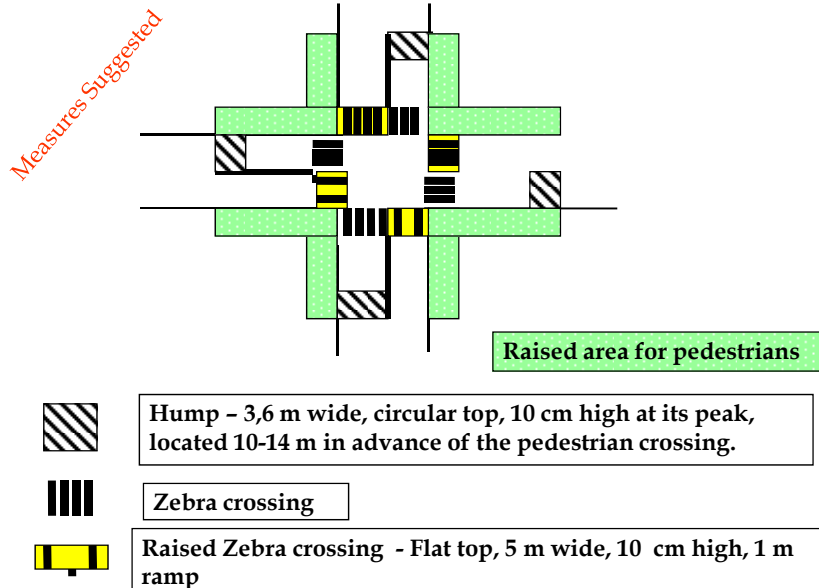


Figure 9 Proposed Standardised Traffic Calmed intersections

### Traffic Calmed Standardised Mid-block Pedestrian Crossing

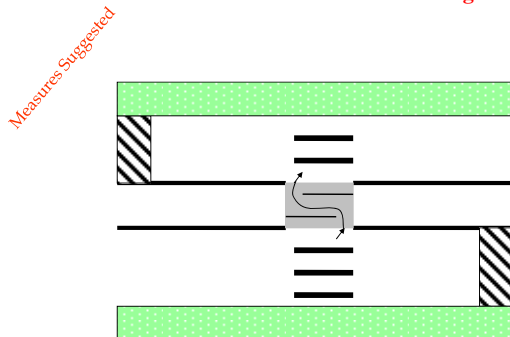
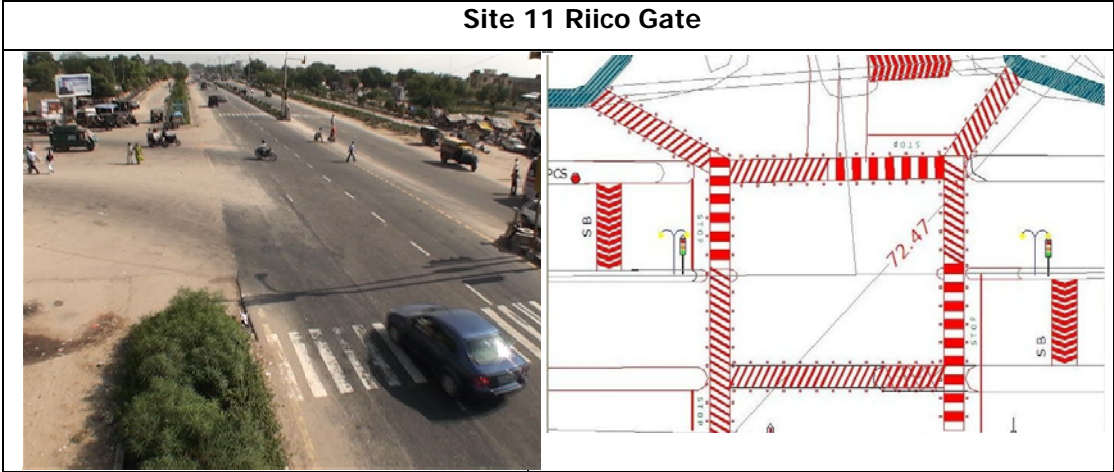


Figure 10 Proposed Standardised Traffic Calmed section between intersections

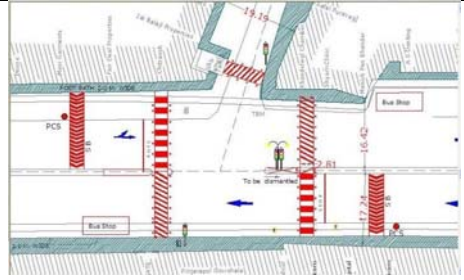
## 4.6 Proposed measures for the seven sites

Based on the arguments presented above it was concluded that we - **in a first round** - would propose measures conforming with the ideas behind the standard solutions. Seven sites, redesigned with regard to the same principles, would allow us to make a proper assessment of the measures at some different sites. This was thanks to the comprehensive plan for measuring that we had followed in the before study. After discussions among the teams, including several site visits, tentative

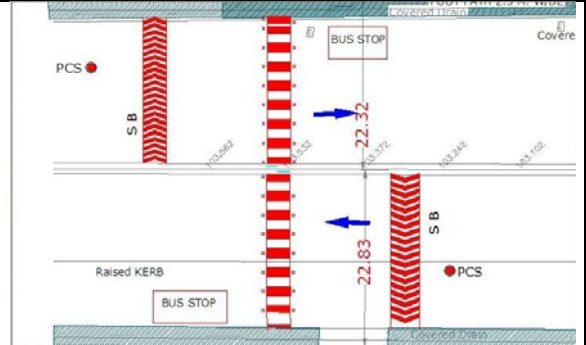
sketches covering the measures proposed was produced. After that a consultant produced scale-correct drawings of the intersections and thereafter auto cad-based drawings of the proposed measures. On the following pages, figure 11, a photo of each of the seven sites is followed by the auto cad proposals, the latter primarily to allow readers to understand the implications of the measures at each intersection.



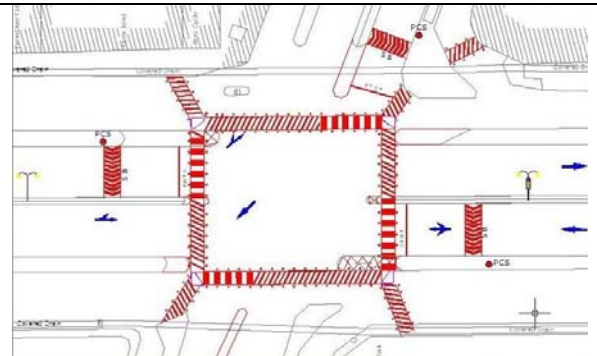
Site 13 Goshala



Site 14 Sector 3

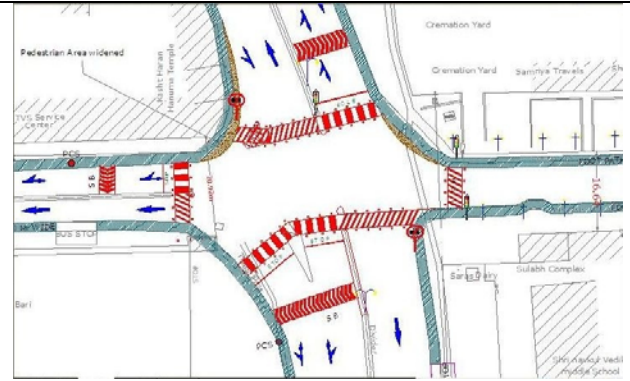


Site 15 Haldi Ghati Marg

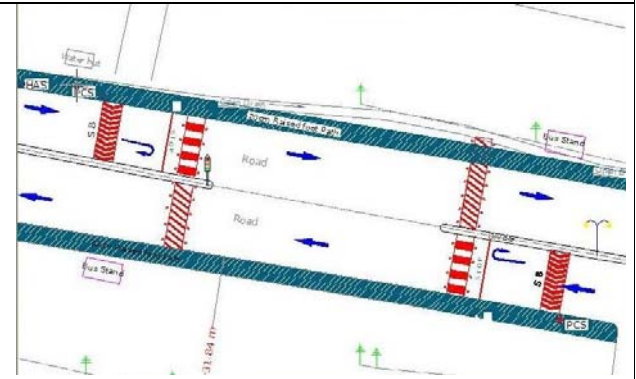




Site 21 Galta Gate



Site 23 Phakeero ka Mohalla



Site 29 Gopalpura Chaurah

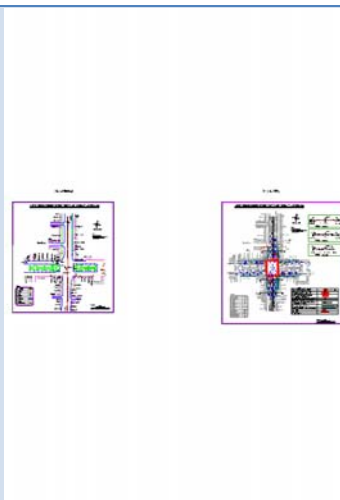


Figure 11 Photos of each of the seven sites and auto-cad drawings with proposed measures

## 5 Speeds at different speed reducing measures

### Location and type of speed reducing measure

Table 16 Location, type and dimensions of speed reducing measure in Jaipur

Location	Type	Dimension		Comment
		Length (mm)	Height (mm)	
Near Temple	hump	3048	89	
Chinkara Canteen	hump	3048	114	Rather close to intersections
Near to BJP office	speed breaker	356	51	
University Road	hump	3962	89	
Near to JNN (Tonk Rd)	short hump	1422	76	Something in between a hump and a speed breaker
Lalkothi	hump	3759	114	Rather close to intersections
4 seasons	2 hump	2794	102	Two humps close to each other and close to crossing roads
Jhotwara	hump	3048	102	Rather close to intersections
Collectorate	hump	3759	102	
Iddhagha	rumble strips	635	76	6 strips (625mm/strip) – total length 4877mm
Ridhi Sidhi	rumble strips	381	76	3 strips (381mm/strip) – total length 1473mm
Classical Watts (just for information)	hump	3700	100	

## Results

Speeds were measured for both cars and motorcycles. Speeds were only measured for “free” vehicles i.e. vehicles either first in a queue or if in a queue with at least a time-gap of 3 seconds to the vehicle in front thus vehicles that were able to choose their own speeds. Speeds were measured for both directions, approximately 50 vehicles of each group in each direction.

Table 17 Speeds at the different speed reducing measures

Location	Dimensions		Road user	Speed both directions (km/h)		
	Length (mm)	Height (mm)		Mean	85perc	Max
Near Temple	3048	89	Car	25	29	44
			MC	27	33	46
Chinkara Canteen	3048	114	Car	22	26	29
			MC	26	31	42
Near to BJP office	356	51	Car	20	24	34
			MC	24	27	51
University Road	3962	89	Car	27	32	39
			MC	31	37	47
Near to JNN (Tonk Rd.)	1422	76	Car	18	23	26
			MC	24	27	35
Lalkothi	3759	114	Car	18	23	30
			MC	22	28	37
4 seasons	2794	102	Car	19	24	38
			MC	18	23	31
Jhotwara	3048	102	Car	16	19	23
			MC	24	28	37
Collectorate	3759	102	Car	21	24	33
			MC	22	26	29
Iddhagha*	635	76	Car	<10	12	15
			MC	<10	12	12
Ridhi Sidhi**	381	76	Car	14	20	37
			MC	26	31	45

\* 6 strips (625mm/strip) – total length 4877mm

\*\* 3 strips (381mm/strip) – total length 1473mm

Average, over all humps, mean speed for cars is 19,1 km/h while it is 23,1 km/h for motorcycles, thus on average 4 km/h higher for motorcycles than for cars.

### Humps and rumble strips reduce speeds

The 85<sup>th</sup> percentile speeds of both car drivers and motorcycle drivers are most often below 40 km/h – most often even below 30 km/h - which must be regarded as very satisfactory. Compared with speeds over humps in Sweden it seems as if speeds in India are very similar to those in Sweden. Table 18 presents a comparison between two of the humps from table 17 and some sites in Lund, Sweden where very similar humps have been used. (Bjarnason 2004)

Table 18: Speeds at sites with comparative humps in Jaipur, India and Lund, Sweden

	Length (m)	Height (m)	Mean speed (km/h)	85-percentile speed (km/h)
Collectorate, Jaipur	3,8	0,10	21	24
Lalkothi, Jaipur	3,8	0,11	18	23
Kulgränden, Lund Direction: South	3,5	0,07	21,0	25,0
Kulgränden Direction: North	3,6	0,08	18,7	22,3
hump nr. 1 at Måsvägen, Lund Direction North-east	3,6	0,11	18,1	19,9
hump nr. 1 at Måsvägen, Lund Direction South west	3,6	0,12	17,0	20,1
hump nr. 2 at Måsvägen, Lund Direction North-east	3,6	0,12	16,9	19,3
hump nr. 2 at Måsvägen, Lund Direction South west	3,6	0,09	17,5	19,9
Average, Lund	3,6	0,10	18	21

The table indicates that there are very small differences in car speeds at the studied humps in Jaipur compared with speeds at the humps in Lund. Speeds are at most two to three km/h higher in Jaipur. This may be due to the fact that humps in Jaipur are 0, 2 meters longer. Even though no humps are exactly similar, the general conclusion must be that the effects of humps in Jaipur and Lund seem to work in almost the same way with regard to speed reduction. The finding that there are very small differences in speeds when cars are passing humps in Jaipur and Lund is very encouraging. As speed is the most important determinant regarding safety effects, this means that we will be able to predict safety effects of proposed measures in Jaipur with a quite good precision. However, there is a difference in effects that also has to be discussed, and that is the speeds of motor cycles.

### **Humps affect car drivers' speeds more than motorcycle drivers' speeds**

Many of the results regarding the good safety effects of speed reducing humps come from field studies in OECD countries. As traffic in Jaipur (and the rest of India) has a higher share of motorcycles compared to traffic in OECD countries it has been of concern to find out how the humps affect the speeds of the motorcycle drivers. The results show that the mean speeds and 85<sup>th</sup> percentile speeds on average at the studied humps are 0-5km/h, on average 4 km/h, higher for motorcycle drivers than car drivers. The implications of this have to be find out when implementation of the standardised sites have been introduced. One comforting aspect may be that

motorcycles are comparatively less involved in conflicts than cars at our seven sites, especially regarding bicycle conflicts. Still special emphasis must be put on the role of motorcycles, also in view of the fact that predictions made at IIT claims that the increase of motorcycles will be higher than that for cars in coming years.

### **Longer rumble strips increase the speed reduction**

The rumble strips at both "Iddhagha" and "Ridhi Sidhi" are 76 cm high. At "Iddhagha" there are, however, twice as many strips (6 compared to 3) and each strip is longer (635mm compared to 381mm) which adds up to a total length of 4877 mm at "Iddhagha" compared to 1473mm at "Ridhi Sidhi". The rumble strips at "Iddhagha" force both motorcycle drivers and car drivers to reduce their speeds more than at "Ridhi Sidhi". The effect is however greater for motorcycle drivers than car drivers i.e. motorcycle-drivers have to slow down at rumble strips but are able to pass the shorter one in significantly higher speeds compared to the longer one.

Generally one can conclude that the speed reduction of these rumble strips is extremely high. They can of course not be used generally on the roads, but at particularly sensitive points – like where many children, and e.g. blind people cross the road – they can really serve an important purpose.

### **The dimension is of importance**

There are two locations that show higher speeds compared to the other locations – 85<sup>th</sup> percentile car driver speeds around 30km/h compared to around 25km/h at the other locations. These locations are "Near Temple" and "University Road". One explanation might be the dimensions of these humps. It turns out that the other humps with comparable lengths and lower speeds are approximately 10-20 mm higher.

### **Location**

Besides that the dimensions of all the humps and rumble strips differ, the conditions at the sites also differ i.e. some are located close to intersections, others on stretches, some are located on slopes, others close to bends, etc. All-in-all all these discrepancies makes it impossible to make "fair" comparisons between the sites and thus suggest **the** optimal solution.

### **Overall strategy**

When these results are combined with general conclusions from studies in other countries there are some important remarks to be made with regard to overall strategy: To meet all the requirements regarding safety, environmental and energy effects it is important to operate in a area-wide scale. Ideally humps should be located at a maximum distance of 75 meters. This will ensure a minimum of accelerations and retardations, and thereby reduce noise, air-pollution and energy consumption. Another aspect has to do with the optimal speed when passing the humps. The details here have to be tried out once experiments are starting. It may be so that the most optimal design is a somewhat modified hump compared with the classical hump (3,6 meters long, 10 centimetres high), allowing **somewhat** higher speeds (mean speed of around 25 km/h and 85-percentile speed just below 30 km/h). Our measurements showed that speeds were much lower in some cases. This is a strategy that may produce more accelerations and retardations. It should

therefore only be used should where there is an extraordinary need for (extraordinarily) low speeds, e.g. outside children's' schools or kindergartens. As crossing problems rarely appear only at one single location along a street – especially not in Jaipur according to our experience - the general strategy must be to apply measures area wide as proposed above, safeguarding speeds over the whole stretches of roads.

## **Conclusions**

The studies show that it is important to see to that the length to height relation is correct when a hump is introduced. It is also worth noticing that the humps that have been included in these studies all have passed the test – speeds are reduced significantly. It is our conclusion that these humps have a far more effective design and thus speed reducing effect than is the case for many humps in OECD countries. The apprehension that motorcycle drivers are less affected by the speed reducing measures than car drivers turned out to be correct even if the speed difference did not turn out to be that great.

## **Optimised design**

As there will be a need of large-scale, area-wide applications of measures, it is important to reduce costs per unit. One option is to try and reduce the use of asphalt by reducing the length of the hump, may be as much as half its length. Test trials have then to be made with different heights, producing the same target speed as with the longer hump, i.e. a mean speed of 25 km/h.

# 6. Conclusions

The case is clear; based on our studies there is an urgent need of Traffic Calming measures. We believe that studies in Jaipur work well enough to be generalised for (a lot of) Indian conditions. However, there is always a need for local decision makers to be convinced about this. It only means that implementation in a new environment must be followed by an initial assessment. After some new implementations like this one can gradually build up a general model for India.

The conflict studies clearly show that pedestrians are extremely exposed and vulnerable, among other things indicated in the speed in the serious conflicts that are observed. General speed studies at the same time show that speeds are much too high to make the interactions safe enough.

The communication between different road users is very premature. The most basic principle is obviously to be able to come through with least loss of energy and as little anxiety as possible. This is most visible in the communication between a stronger and a weaker road user. It is valid in all these relations, but most suffering is pedestrians. Instead of slowing down and yielding for pedestrians motor vehicle drivers blow their horn with the clear message (at least for the pedestrian) "watch out because I am not going to slow down or anything else". One problem is that this

strategy seems to work well, at least after a second blow in the horn if the pedestrian have not yet changed his/her behaviour (= stopped or swerved). Again, this kind of behaviour seems to be very universal in Jaipur, no matter what road users are involved. And – even though our experience from other cities is limited we strongly believe that the similarities are quite big.

One important point is that it's not only a matter of safety. The quality of life for pedestrians is much deteriorated; they can never relax when they are at or close to a road.

At the same time it must be said that pedestrians also have developed a strategy that is indicating that they too are primarily interested in crossing roads without in any way they can since road designs do not give them any signals to do otherwise.

Even though it is probable that most road users find this situation as the way it must be. To change these attitudes will take very long time as long as mainly soft measures are used. This emphasizes the need for hard measures along with information, campaigns, education, etc which explain the benefits of the hard measures. The Traffic Calming measures we have proposed will be an interesting start in trying to change behaviours and attitudes. Of course a small scale trial as we have proposed will not change anything over night. However, if the measures produce a clear change of behaviours, then there will definitely be a discussion among the public, involving pedestrians, car drivers, motor bike riders, etc, hopefully with a lot of opinions for and against. This should be used to encourage people to continue the discussion. The learning from the trial can be strongly improved if authorities from other parts of India will come and visit the sites. Then the research results should be used to tell what has happened so that visitors can draw their own conclusions but based on scientific data.

We know that the way forward is narrow and twinkling, but we are convinced that what we have proposed for these sites in Jaipur will be a necessity in the future. History tells us that country by country have – sometimes slowly – followed the path of the “inventors” (e.g. Holland and England). There has been a strong development in Europe and is now followed by countries in all other parts of the globe. The may be best indication of what will emerge in the future is the reported private initiatives in villages in India where speed reducing humps are produced by inhabitants in small villages. It is quite obvious that decision makers cannot stay passive in a situation where citizens are quite desperate. What arguments can these citizens be met with, and what can authorities offer except for humps and similar measures? In view of this it is urgent that trials will be carried out as soon as possible. We hope that all the efforts made by the Indian and Swedish teams, will be used to a next step, even though we were not able to enjoy the opportunity to study the outcome of the measures we so carefully have prepared. But again, it will not be in vain, our before studies is still a very solid base for being able to predict how this kind of measures – combined as we have proposed – may interfere with the less favourable elements in road users behaviours. To conclude; we hope that relevant authorities and sponsoring bodies will appreciate this first step into an inevitable development. There is always the attractive element of being a pioneer. We all will support you in all possible ways.

## References

Ashton, S. J. (1980). A preliminary assessment of the potential for pedestrian injury reduction through vehicle design. Paper 801315. Proceedings of Twenty-Fourth Stapp Car Crash Conference, 609-635. US Department of Transportation, National Highway Traffic Safety Administration, Washington DC.

Bjarnason, Sigurdur: Round top and flat top humps - The influence of design on the effects. Thesis 125, 2004

Elvik R., Christensen P., Amundsen A. 2004. Speed and road accidents, An evaluation of the Power Model. TOI report 740/2004. The Institute of Transport Economics (TOI), Oslo

Expert Committee. Report of the Expert Committee on Auto Fuel Policy. 1-98. 2002. New Delhi, CSIR, Government of India.

Hydén, C. (1987). The development of a method for traffic safety evaluation: the Swedish traffic conflict technique. Department of Traffic Planning and Engineering, Lund University. Bulletin 70.

Interdisciplinary Working Group for Accident Mechanics (1986). The Car-Pedestrian Collision. Injury Reduction, Accident Reconstruction, Mathematical and Experimental Simulation. Head Injuries in Two Wheeler Collisions. University of Zürich and Swiss Federal Institute of Technology, Zürich

Mohan, D., Tsimhoni, O., Sivak, M., and Flannagan, M.J.. Road Safety in India: Challenges and Opportunities, The University of Michigan. Transportation Research Institute, UMTRI-2009-1.

Nilsson, G. (2004A). Traffic safety dimensions and the Power Model to describe the effect of speed on safety. Bulletin 221. Lund Institute of Technology, Department of Technology and Society, Traffic Engineering, Lund.

Otte, D. and E. G. Suren (1984). Medizinisch/technische Aspekte bei der Unfallrekonstruktion des PKW-Fussgänger-Unfalles. Verkehrsunfall und Fahrzeugtechnik, 22, Fachblatt 5, 131-137.

Peden, M; Scurfield, R; Sleet, D; Mohan, D; Hyder, A.A; Jarawan and Mathers, C. World Report on Road Traffic Injury Prevention 2004, 224 pages [E, F] ISBN 92 92 4 156260 9



Sayer, I A AND Palmer C J. (1997). Pedestrian accidents and road safety education in selected developing countries. I A Sayer and C J Palmer

Overseas Centre, Transport Research Laboratory, Crowthorne Berkshire United Kingdom. PA3229/97. 3rd African Road Safety Congress, Pretoria , 14 - 17 April 1997.

Walz, F. H., M. Hoefliger and W. Fehlmann (1983). Speed limit reduction from 60 to 50 km/h and pedestrian injuries. Paper 831625. Proceedings of Twenty-Seventh Stapp Car Crash Conference, 311-318. US Department of Transportation, National Highway Traffic Safety Administration, Washington DC.

### References to chapter 3:

<sup>1</sup> Clarke A., Traffic Calming, Auto-Restricted Zones and Other Traffic Management Technique: Their Effects on Bicycling and Pedestrians, National Bicycling and Walking Stud, #19, FHWA (Washington DC; [www.bikefed.org](http://www.bikefed.org)), 1994, in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>2</sup> Proctor S., "Accident Reduction Through Area-Wide Traffic Schemes, " Traffic Engineers and Control, Vol., 32, No. 12, Dec. 1991, pp. 556-572, in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99.

<sup>3</sup> Zein R. Steve, Erica Geddes, Suzanne Hemsing and Mavis Johnson "Safety Benefits of Traffic Calming," Transportation Research Record 1578, 1997, pp. 3-10. , in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>4</sup> McLean A. J., et al., "Vehicle Travel Speeds and the Incidence of Fatal Pedestrian Collisions," Accident Analysis and Prevention, Vol. 29, No. 5, 1997, pp. 667-674. , in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>5</sup> Roth R., Getting People Walking:: Municipal Strategies to Increase Pedestrian Travel, WSDOT (Olympia; [www.wsdot.wa.gov/ta/t2/t2pubs.htm](http://www.wsdot.wa.gov/ta/t2/t2pubs.htm)), 1994. in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>6</sup> Vanderslice E., Portland Pedestrian Design Guide, Pedestrian Transportation Program, City of Portland ([www.trans.ci.portland.or.us](http://www.trans.ci.portland.or.us)), 1998. in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>7</sup> Harkey L. D., Donald W. Reinfurt, J. Richard Stewart, Mathew Knuiman and Alex Sorton, The Bicycle Compatibility Index: A level of Service Concept, Federal Highway Administration ([www.hsrc.unc.edu/research/pedbike/bci](http://www.hsrc.unc.edu/research/pedbike/bci)), 1998 in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>8</sup> Carlson D., Lisa Wormser and Cy Ulberg, At Road's End: Transportation and Land Use Choices for Communities, Island Press (Washington DC; [www.islandpress.org](http://www.islandpress.org)), 1995. in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>9</sup> Traffic Calming: Traffic and Vehicle Noise, Department of the Environment, Transport and the Regions (UK; [www.roads.detr.gov.uk/roadnetwork/ditm/tal/traffic/06\\_96/item1.htm](http://www.roads.detr.gov.uk/roadnetwork/ditm/tal/traffic/06_96/item1.htm)), 1996. in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>10</sup> Tim Pharoah and John Russell, Traffic Calming: Policy and Evaluations in Three European Countries, South Bank Polytechnic (London), February 1989. in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>11</sup> Take Back Your Streets, Conservation Law Foundation (Boston; [www.clf.org](http://www.clf.org)), May 1995, p.27. in Litman T., Benefits and Costs, Evaluating Traffic Calming Benefits, Cost and Equity Impacts, Victoria Transport Policy Institute, 1997-99

<sup>12</sup> Figure III.1/6 Vehicle Stopping Distance, Langen M de., Liveable African Cities, A guideline for Urban Pedestrian and Bicycle Traffic in Africa, World Bank Sub-Saharan Transport Programme, October 1999 (page III.21)

<sup>13</sup> Risk of being killed, Quality Demands, Calm Streets, A planning process for safer, more eco-friendly, pleasant and attractive streets in urban areas (page 22), The Swedish Association of Local Authorities, 1999

<sup>14</sup> Elvik, R., Erke, A., Sørensen and Vaa, T. (2009) Handbook of Road Safety Measures, TØI,

<sup>15</sup> Sakshaug, L. (2009) "Designing roundabouts for cyclist safety and accessibility for visually impaired". Licentiate thesis. Department of Technology and Society, Traffic and Road, Lund University, Sweden (*in press September 2009*).

<sup>16</sup> Elvik, R. (2003). "Effects on Road Safety of Converting Intersections to Roundabouts: Review of Evidence from Non-U.S. Studies." Transportation Research Record: Journal of the Transportation Research Board **1847**: 1-10.

<sup>17</sup> Schoon, C., Van Minnen, J. (1994). "Safety effects of roundabouts in the Netherlands." Traffic Engineering and Control **Vol. 35**: 142-148.

<sup>18</sup> Hydén, C., Várhelyi, A. (2000). "The effects on safety, time consumption and environment of large scale use of roundabouts in an urban area: a case study." *Accident Analysis and Prevention* **32**: 11-23.

<sup>19</sup> Brüde, U., Larsson, J. (1999). Trafiksäkerhet i cirkulationsplatser för cyklister och fotgängare. VTI meddelande 864. Linköping, VTI.

<sup>20</sup> Herland, L., Helmers, G. (2002). Cirkulationsplatser - utformning och funktion. Linköping, Väg- och trafikforskningsinstitutet.

<sup>21</sup> Hels, T., Orozova-Bekkevold, I. (2007). "The effect of roundabout design features on cyclist accident rate." *Accident Analysis and Prevention* **39**(300-307).

<sup>22</sup> Brüde, U., Larsson, J. (2000). "What roundabout design provides the highest possible safety?" *Nordic road and transport research* **2**: 17-21.

**SCHEDULE FOR TRAINING ON CONFLICT RECORDING**

For the Project “Traffic Calming Strategies to Improve Pedestrian safety in India”

**Jaipur June 2008**

Day	Date / Time	Agenda	
I	08.06.02	Afternoon /Evening	Introduction and first indoor training from video
		Afternoon /Evening	Further in-door training and out-door training of speed estimation.
II	08.06.03	Morning	Further out-door training of speed estimation and first out-door training of conflict recording
		Afternoon /Evening	In-door follow up of recordings, based on video recorded events
III	08.06.04	Morning	Out-door training on conflict recording. Selected location covering different aspects as compared to the first location.
		Afternoon /Evening	1/ In-door follow up of recordings, based on video recorded events 2/ Out-door video recording
IV	08.04.05	Morning	1/ Follow-up on the use of recording protocol 2/ Out-door training on conflict recording. Selected location covering different aspects as compared to the first location.
		Afternoon /Evening	In-door follow up of recordings, based on video recorded events
V	08.06.06	Morning	Out-door training on conflict recording – Exam
		Afternoon /Evening	In-door follow-up of recordings, based on video recorded events - final scores. Final discussions, conclusions regarding further use of the recording

## APPENDIX 2

### Results per site

#### Site No.11 - Overview of field studies

##### *Conflicts*

4th and 5th of October 2008, 25.5 hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	7	12	1	<b>20</b>	7	6	1	<b>14</b>	<b>66</b>	<b>100</b>
Number of conflicts per hour				1.0				0.5	3.1	4.5

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

##### *Speeds in conflicts*

<b>Pedestrian conflicts</b>	Cars: 25 km/h	Motorbikes: 22 km/h
<b>Bicycle conflicts</b>	Cars: 30 km/h	Motorbikes: -

##### *Flows*

##### Incoming road users per hour

Car / Motor-Rickshaw	807	18%
LCV	83	2%
Truck	306	7%
Bus	144	3%
Motorcycle	2020	46%
Bicycle/Rickshaw	192	4%
Pedestrian	854	19%
<b>Total</b>	4406	99%

Motorcycles represent 60% of all motor vehicles.

## Site No. 13 - Overview of field studies

### *Conflicts; Swedish and Indian scorings*

27th, 28th of July and 28th of August 2008, 25.6 hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	9	12	3	<b>24</b>	7	4	1	<b>12</b>	<b>65</b>	<b>101</b>
Number of conflicts per hour				0.8				0.5	2.7	3.9

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

### *Speeds in conflicts*

<b>Pedestrian conflicts</b>	Cars: -	Motorbikes: 31 km/h
<b>Bicycle conflicts</b>	Cars: 32 km/h	Motorbikes: 18 km/h

## *Flows*

### Incoming road users per hour

Car / Motor-Rickshaw	1082	22%
LCV	82	2%
Truck	226	4%
Bus	168	3%
Motorcycle	2780	56%
Bicycle/Rickshaw	344	7%
Pedestrian	299	6%
<b>Total</b>	<b>4981</b>	<b>100%</b>

Motorcycles represent 64% of all motor vehicles.

## Site No. 14 - Overview of field studies

### *Conflicts, Swedish scorings*

7th and 10th of July 2008, 44.9 hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	9	63	8	<b>80</b>	3	0	0	<b>3</b>	<b>3</b>	<b>86</b>
Number of conflicts per hour				1.9				0.1	0.2	2.1

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

### *General speeds*

<b>Pedestrian conflicts</b>	Cars: -	Motorbikes: 18km/h
<b>Bicycle conflicts</b>	Cars: -	Motorbikes: -

### *Flows*

#### Incoming road users per hour

Car / Motor-Rickshaw	1042	22%
LCV	63	1%
Truck	195	4%
Bus	234	5%
Motorcycle	2809	58%
Bicycle/Rickshaw	305	6%
Pedestrian	156	3%
<b>Total</b>	4804	99%

Motorcycles represent **65%** of all vehicles.

## Site No.15 - Overview of field studies

### *Conflicts*

17<sup>th</sup>, 20<sup>th</sup>, 30<sup>th</sup> and 31<sup>st</sup> of July 2008, 50.7hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	5	12	0	<b>17</b>	3	13	0	<b>16</b>	<b>122</b>	<b>155</b>
Number of conflicts per hour				0.3				0.3	2.5	3.1

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

### *Speeds in conflicts*

<b>Pedestrian conflicts</b>	Cars: 26 km/h	Motorbikes: 16 km/h
<b>Bicycle conflicts</b>	Cars: -	Motorbikes: 18 km/h

### *Flows*

#### Incoming road users per hour

Car / Motor-Rickshaw	570	22%
LCV	49	2%
Truck	126	5%
Bus	91	3%
Motorcycle	1438	54%
Bicycle/Rickshaw	148	6%
Pedestrian	224	8%
<b>Total</b>	<b>2646</b>	<b>100%</b>

Motorcycles represent **63%** of all vehicles.



## Site No.21 - Overview of field studies

### *Conflicts*

11th and 13th of July 2008, 52.1hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	18	16	12	<b>46</b>	4	4	2	<b>10</b>	<b>61</b>	<b>117</b>
Number of conflicts per hour				0.9				0.2	1.2	2.2

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

### *Speeds in conflicts*

<b>Pedestrian conflicts</b>	Cars: 29 km/h	Motorbikes: 24 km/h
<b>Bicycle conflicts</b>	Cars: 16 km/h	Motorbikes: -

### *Flows*

#### Incoming road users per hour

Car / Motor-Rickshaw	262	22%
LCV	37	3%
Truck	60	5%
Bus	52	4%
Motorcycle	392	32%
Bicycle/Rickshaw	35	3%
Pedestrian	375	31%
<b>Total</b>	1213	100%

Motorcycles represent **49%** of all vehicles.

## Site No.23, 23(1) - Overview of field studies

### *Conflicts*

4th, 5th and 7th of July 2008, 26.1 hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	15	7	8	<b>30</b>	5	1	1	<b>7</b>	<b>64</b>	<b>99</b>
Number of conflicts per hour				1.1				0.3	2.5	3,8

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

### *Speeds in conflicts*

<b>Pedestrian conflicts</b>	Cars: 39 (ST), km/h	Motorbikes: 24 km/h
<b>Bicycle conflicts</b>	Cars: 39 km/h	Motorbikes: ?? km/h

### *Flows*

#### Incoming road users per hour

Car / Motor-Rickshaw	588	21%
LCV	93	3%
Truck	101	4%
Bus	135	5%
Motorcycle	1123	41%
Bicycle/Rickshaw	137	5%
Pedestrian	573	21%
<b>Total</b>	<b>2750</b>	<b>100%</b>

Motorcycles represent **55%** of all vehicles.

## Site No.29 - Overview of field studies

### *Conflicts*

18th of July and 4th of September 2008, 49.5 hours

	Pedestrian conflicts				Bicycle conflicts				Other conflicts	Total conflicts
	Car	Mc	Other	Total Ped	Car	Mc	Other	Total Bic		
No. of serious conflicts	23	34	2	<b>59</b>	24	18	1	<b>43</b>	<b>79</b>	<b>181</b>
Number of conflicts per hour				1,2				0.9	1.6	3,7

\*/ Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

Exposure for pedestrians/bicyclists= (no. of peds/bicyclists x no. of motorized vehicles)<sup>1/2</sup>.

### *Speeds in conflicts*

<b>Pedestrian conflicts</b>	Cars: 18 km/h	Motorbikes: 24 km/h
<b>Bicycle conflicts</b>	Cars: 21 km/h	Motorbikes: 17 km/h

### *Flows*

#### Incoming road users per hour

Car / Motor-Rickshaw	1248	26%
LCV	43	1%
Truck	24	0%
Bus	52	1%
Motorcycle	2403	49%
Bicycle/Rickshaw	414	9%
Pedestrian	697	14%
<b>Total</b>	<b>4881</b>	<b>100%</b>

Motorcycles represent 64% of all vehicles.