Public Works, Ports and Inland Water Transport Department

Blackspot Investigation *Field Guide*

Edition One - 2103

Foreword

This Blackspot Investigation Field Guide has been developed to assist PWP&IWTD engineers and others to investigate blackspots on the roads and highways of this State. The Field Guide reflects knowledge and experience in this valuable field of that has been gathered from around the world. It emphasises:

- Using Police crash data (where it exists) to reveal crash patterns at the blackspot.
- Applying road safety review skills (where Police crash data does not exist) to identify high risk sites and to assess likely crash patterns at those sites.
- The need for road safety engineers to be like doctors – diagnosing what is wrong with the site (the illness) and what countermeasures (the medicine) should be applied to make the site safer.
- Using low cost/high benefit countermeasures so that maximum crash savings can be obtained for minimum costs.
- How to write a blackspot report.
- Calculating the expected benefits and costs of a blackspot treatment.
- Some local blackspot examples - to emphasise common road safety issues in this State and to give practical safety tips to help you to reduce crashes at the site in the future.

This Field Guide is your focal point for the development and growth of the blackspot investigation program in Karnataka. I commend this guide to those with a responsibility for road safety and management in Karnataka. It is an essential tool for safer roads in our State.

I thank Mr. Phillip Jordan, Road Safety Expert and Dr. Robert Smith, Team Leader for the assignment representing VicRoads, Melbourne, Australia for their efforts in the preparation of this guide.

Other field guides cover Road Safety Audit, Road Safety Review and Traffic Control at Works on Roads.

Mr H.S. Prakash Kumar
Project Director
PIU, KSHIP

Table of Contents

PART A - BLACKSPOT INVESTIGATION PRINCIPLES

This Field Guide explains the basic principles of how to undertake a blackspot investigation. It has been written as a reference for engineers of the PWP&IWTD and others who are involved in undertaking investigations of hazardous road locations (commonly called blackspots).

A blackspot investigation is a *systematic process for identifying locations with an unusually high incidence of crashes, diagnosing the contributory factors, and then designing and implementing engineering countermeasures.*

This program is quite new to Karnataka but is sure to make a large contribution to improved road safety on Karnataka roads in the years ahead.

Crash investigation programs are proven and highly cost-effective programs to reduce crashes. Simple measures such as better signs, road markings and minor improvements have often "paid for themselves" within a year through crash savings. It is only recently that this kind of work has started in India and there is still a lot to be learnt. It is expected that, with more experience, it will be possible to improve the effectiveness and suitability of the practices and procedures outlined in this field guide.

1. WHAT IS A “BLACKSPOT”?

The term “blackspot” evolved many years ago (before computers) when Police used black coloured pins to indicate the locations of fatal road crashes on a wall mounted map. In time, the worst crash locations became the blackest – and the term “blackspot” was born.

The term exists today to describe locations that have the highest number of casualty (which includes both fatal and injury) crashes.

The definition of how many crashes are needed for a site to become a blackspot varies from region to region, country to country, and state to state. It is best to think of a "blackspot" as a location on the road which has a high number of casualty crashes. The location may be an intersection, a short section of road (at a curve or a bridge) or some other road section. If there is a section of road typically more than 500m long and which has a history of many casualty crashes the site is called a "blacklength".

Note that there is a significant difference between a blackspot investigation and a road safety audit. Blackspot investigations (a reactive process) use crash data to look for patterns in crashes at a blackspot. They look at what went wrong and ask why. They then develop a package of low cost countermeasures to reduce the number/severity of future crashes.

Road safety audits apply similar technical skills and judgement but at the design stage of a road project (a proactive process) to prevent crashes from occurring when the road is built. Auditors ask what might go wrong, and make recommendations to reduce the risk.

2. WHAT IS A CRASH?

A road crash can be defined as "a rare, multi-factor event always preceded by a situation in which one or more road users have failed to cope with their environment, resulting in a vehicle collision."

The key words for you are "failed to cope with their environment". Engineers help road users to more easily cope with the road - its layout, features, facilities, etc. Engineers can do this by providing better geometrics, safer intersection layouts, clearer signing and marking, footpaths, and pedestrian facilities. In some cases it may be necessary to change the layout or alignment in order to make the road simpler to understand and use.

Road crashes are complex events and there is rarely ever a single cause. Several studies have shown that there are three main groups of contributing factors:

- Human factors (which are present in 95% of crashes)
- Road environment factors (which are present in 30% of crashes)
- Vehicle factors (which are present in 10% of crashes)

With human factors so heavily involved as the cause of crashes, some people suggest we would be better concentrating on these? Unfortunately, human factors are the most difficult to change. Although it is important to try and improve road user skills and attitudes, it is likely to take a long time. Experience has shown that it is much more effective to focus on the interaction between the human and the road environment. In short – make your roads "simple to understand" and "forgiving" for when people make a mistake!

As an engineer you are concerned with improvements to the road environment. Your task in a blackspot program is to improve the road environment so that fewer crashes and/or less serious crashes happen into the future compared to the past.

3. WHAT CAN ENGINEERS DO TO REDUCE CRASHES?

A vehicle ran off a road at a sharp bend. The Police investigation revealed that the driver had been travelling too fast and had been drinking alcohol, so they concluded that the crash was due to dangerous driving.

Road safety engineers inspected the site. They found that the sharp bend came after a long straight section, and that the "Sharp Curve" warning sign had not been replaced after it had been struck by a truck several weeks earlier. There were no edge line markings on that road, and the centre line marking through the curve had been worn out by many vehicles passing over it.

Experience has shown that, if the warning sign had been in place, and if good line marking existed around the curve, the driver would likely have been aware of the curve. He/she would likely have entered it aware of the need to travel at an appropriate speed and remain within the travel lane. In doing this, he/she would have avoided the crash.

This is an example of a crash problem where there is a simple, effective remedy that is not directly related to the main "cause" of the crash (the alcohol). This example helps to illustrate why it is important to focus on solutions, rather than the direct causes.

Engineers can reduce the number and severity of road crashes by building and maintaining safe roads. A safe road incorporates good design principles, appropriate geometric standards, good delineation under all conditions, effective drainage and a roadside free of hazards.

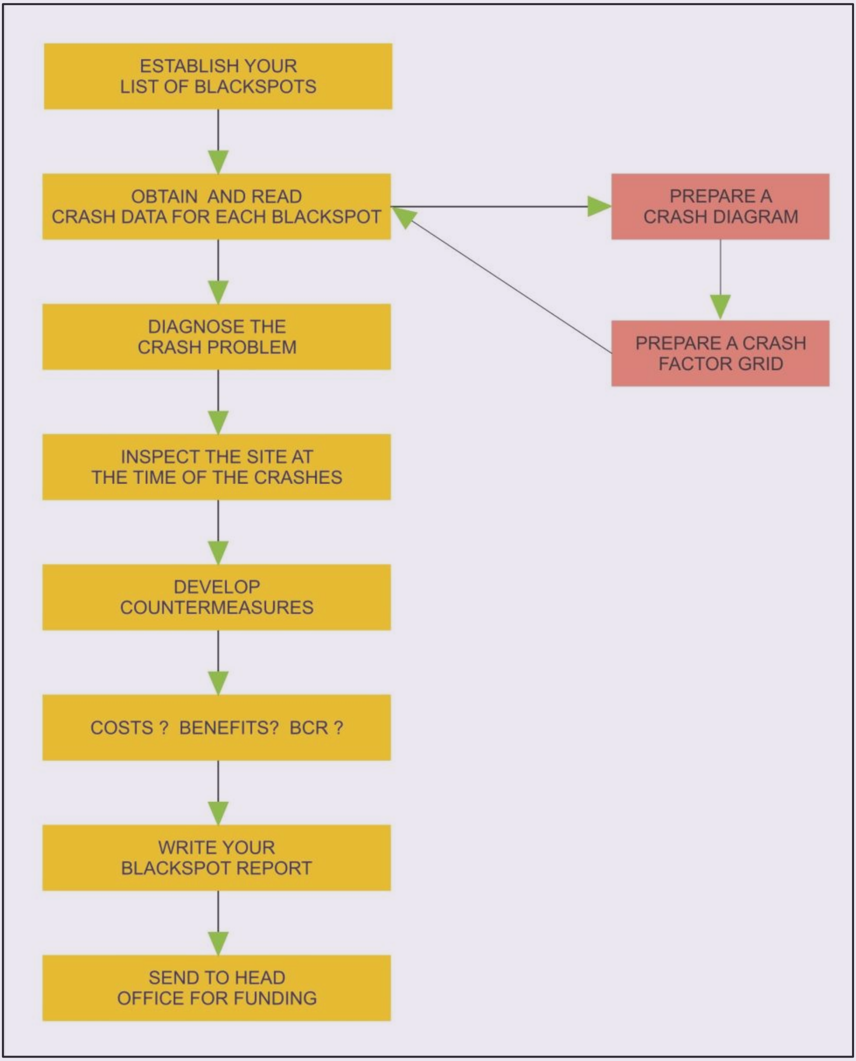
A safe road is a well maintained road, which serves the safety needs of all its users. To achieve a safe road you should:

WARN	road users of substandard or unusual features.
INFORM	road users of conditions that may be encountered.
GUIDE	road users through unusual sections of a route.
CONTROL	road users through areas of conflict.
FORGIVE	road users when they make a mistake.

These five principles are easy to remember and understand, and they summarise your work as a road safety engineer.

Through this work, a road safety engineer will improve the road environment in ways that enhance road safety, and save lives and injuries. Road safety engineers are some of the unsung heroes of Indian road network.

PART B - KEY STEPS IN A BLACKSPOT INVESTIGATION



Traffic Police investigate serious individual crashes (for instance multiple fatality crashes) and they seek evidence to charge guilty road users with offences. But engineers look for patterns of crashes at a blackspot. Engineers do not seek the guilty party but rather they attempt to find patterns within the crash history so that they can develop cost effective countermeasures that can then be funded and implemented.

Low cost, high benefit countermeasures are emphasised. Anyone can suggest a package of expensive countermeasures, and which may have questionable safety benefits. But a good road safety engineer will develop low cost countermeasures with proven safety benefits that target the main crash pattern(s).

Let’s say for an example there is a cross road intersection, on a State Highway, where there is a history of right angle crashes involving buses and motorcycles during daytime hours. An inexperienced engineer may recommend that street lighting be installed, together with a pedestrian crossing and a cross roads warning sign. Of this package of treatments, the street lighting will only have an effect at night time, and the pedestrian crossing will not benefit the right angle crashes. Only the warning sign may have a positive effect – and even then only a small effect as the crash reduction of a warning sign is quite low.

An experienced engineer would develop a package of low cost countermeasures with proven safety benefits. This may include renewing line marking for both roads, installing direction signs in advance of the intersection (these alert drivers/riders to the presence of the intersection and they give information about where to go) and to relocate the bus stop further from the intersection.

1. Establish your list of blackspots

In Karnataka there are two ways to define a blackspot:

- A point system
- Road safety review system

The point system gives points for each reported crash based on the severity of that crash. More points are awarded for more severe crashes, and the locations with the highest number of points become your “blackspots” to be investigated.

One suggestion for a point system for use in Karnataka is:

- Make a list of all known "safety problem sites" on your roads.
- Count all known fatal crashes* at each site in the past 3 years and give them 10 points each.
- Count all the serious casualty crashes at the site in the past 3 years and give each 5 points.
- Count all the other known crashes at the blackspot in the past 3 years and give them one point.
- Add up all the points, and prepare a list of locations staring from the highest to the lowest number of points.
- Repeat this for all the known blackspots throughout your Circle.

When you have done this for 40 or 50 sites, list them all in a table from the highest number of points to the lowest number. Look closely at your resources so that you have an idea how many sites can be treated within your annual blackspot works program. This is your blackspot list.

**NOTE: A fatal crash is not the same as a fatality. Some fatal crashes have 2, 3 or more fatalities. Others have one. For the point score, give 10 points to a fatal crash (regardless of how many people died in the crash).*

The second way of defining a blackspot is to determine the risk at a notorious location that is brought to your notice by Police or members of the public. At these locations you may not know the number or the type of crashes. You may be told about some crashes but much of the details of these will be lost in the passing of time. So without crash data you must use your road safety review skills to determine the risk at the location, then the most likely pattern of crashes at the location and, in turn, what you can recommend as suitable countermeasures.

- ❖ Decide how many of the locations found in the points system and how many found from the road safety review system you wish to investigate in detail.
- ❖ Double check that there have been no duplications in the sites (same location but different road names), and that no "obvious" blackspots have been missed.

- ❖ Then, starting at the highest point score sites first, work down the list – site by site – investigating each site in detail (using the process described below).

2. Obtain all crash data for the site

Obtain all the possible crash information from the local Traffic Police. To do this, firstly speak with the local Traffic Police and ask them for their records of crashes at the blackspot – at least for the past 3 years (longer if available). The Traffic Police have an important role to play in recording crash information. They are an important ally for road safety engineers because without good crash data it is difficult to develop cost effective countermeasures for a blackspot.

Police and engineers working together can make blackspots much safer for all road users. The Police have an important task to record all crash data. Engineers use the crash data to look for patterns of crashes which can be treated with carefully considered crash countermeasures.

Read the Police crash data thoroughly and arrange it in a way that can assist with the next step – the diagnosis of the crashes.

Because some blackspots do not have enough Police crash records (or in some cases there may be no recorded data), the next thing to do is to speak with local people who live or work around the blackspot in order to develop your own picture of crash patterns at the location. Locals often know a lot about crashes at the site, although they may exaggerate (or forget) some details.

However, they can often give a good idea about whether the crashes happen in the morning, or the evening, or the night. They may recall if crashes happen during wet times, or whether the crashes involve vehicles from one particular direction. All these details are invaluable to an engineer, especially if official crash data is lacking

It doesn't matter where the data about the crashes comes from, it is all data and it can all be used to help with the diagnosis of the crash problem. It may not be perfect, and you should certainly be careful with some of the information from local people. But with some time and with some thought, it is possible to establish a reasonable set of data about the crash history at the blackspot.

3. Diagnose the crash problem

Take all the crash data and begin to transform it into clear easy to read information. This is where you and your colleagues (the blackspot investigation team) need to be like a doctor. A blackspot can be viewed as a "sick" location on the road network – at least in a road safety sense. As a doctor your job is to examine the patient and to prescribe the correct medicine. To do this you make use of a range of tools available and you investigate the pattern of crashes at the blackspot (your "patient").

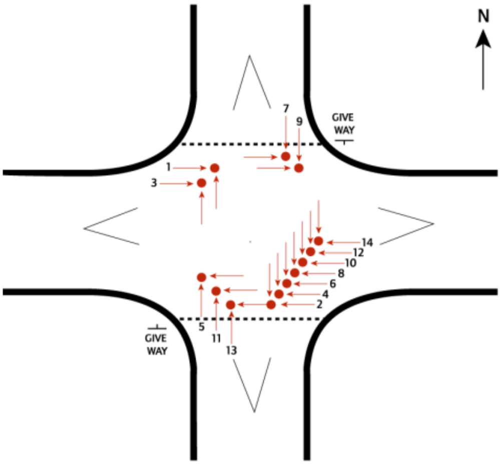
When a person is sick they go to a doctor and they tell the doctor their symptoms. It may be a sore throat, a severe pain in the abdomen, a broken arm, or an unknown serious and debilitating sickness. The doctor examines the patient, asks them questions, checks their pulse, maybe their breathing, gradually dismissing some possibilities and eventually diagnosing the cause of the problem.

It is only when the cause of the health problem is diagnosed that the doctor will prescribe something (medicine, an operation, a bandage, rest, a referral to a specialist) to help the patient to recover. If you are a patient you do not want your doctor to wrongly prescribe something for you. You want to get better – and quickly.

A road safety engineer does the same for the "sick" locations (blackspots) on the road network. Road safety engineers should firstly find out what the problem is. This can be a challenge – unlike a human patient, blackspots cannot speak! But by inspecting the site, by examining the crash data and by inspecting the conditions at the site, a road safety engineer can make a clear determination about what the likely source of the crash problem is. This means assessing what role the road environment may be playing in the crash pattern at the blackspot.

4. Draw a crash diagram

A crash diagram is a sketch of the blackspot that shows the direction that the vehicles (or pedestrians) were travelling at the time of the crash. The crash diagram is used to look for patterns in the direction of travel of the vehicles involved in the crashes.



A Crash Diagram showing right angle crashes at a cross road intersection

In this crash diagram (above) there is a clear pattern of right angle crashes – with the largest group happening in the south east corner of the intersection.
A crash diagram does not give any guidance with other patterns – such as the time of the crashes, or the weather conditions, or the people involved in the crashes, or any other patterns. For those, we use a crash factor grid.

5. Prepare a crash factor grid

A crash factor grid is a table that summarises the known facts about each crash. Each column in the grid (below) represents one crash.

The rows represent factors such as time of day, day of week, weather, vehicle type, crash type. It is limited only by the amount of crash data available.

Crash factor grids are prepared quickly on a computer, using software such as Microsoft Excel. When the grid is filled it may then be manipulated to establish if there are other patterns (such as crashes on dry roads at night, or motorcyclists from the north colliding with vehicles from the east during day time, or many other combinations) that warrant special investigation.

Crash Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Day of month	13/7	04/9	19/12	08/6	03/7	07/11	30/12	27/2	03/5	24/7	18/4	21/5	14/6	20/8
Day of week	sat	wed	thu	sun	thu	fri	tue	fri	sun	fri	sun	fri	mon	fri
Time of day	1700	1855	1530	1900	1345	2145	1900	1220	1800	2000	1845	1610	1735	1855
Severity	3	3	2	3	2	1	3	3	1	2	3	2	2	3
Light condition														
Road condition	W	W	D	D	D	D	D	D	D	D	D	D	W	D
Vehicle 1	car	m/c	car	car	car	car	car	car	car	m/c	car	car	van	car
Vehicle 2	m/c	handcart	truck	m/c	car	car	car	truck	car	m/c	car	car	m/c	car
Vehicle 3					car			car			car			
Direction 1	N	S	N	S	N	S	S	S	S	S	N	S	N	S
Direction 2 (&3)	E	W	E	W	W,E	W	E	W,N	E	W	W,E	W	W	W
Other						unlicensed driver			speeding				heavy rain	

A Crash Factor Grid

In this example (which is for the same blackspot as the crash diagram above) there is a pattern of evening/night time crashes. These crashes tend to have occurred on dry roads.

6. Inspect the site – day and night

Armed with the information gained from the crash diagram and the crash factor grid, your investigation team then travels to the site and inspects it at the times of day/night the crashes have been reported. If the main crash pattern is a night time pattern you should inspect the site at night. If it's a weekend problem, inspect the site on a weekend.

You are not likely to witness a crash while on-site. However you will see the types of vehicles and road users, and the speed of the traffic.

You will also be able to observe some of the main traffic conflicts at the blackspot.

You should look with fresh eyes at the road environment. Ask questions – is there something that may be misleading some road users at this site? Are buses obscuring visibility at the intersection? Do pedestrians have somewhere safe to wait? Is the intersection conspicuous to all road users? Is the curve well delineated, or might some drivers/riders be surprised by its sharpness.

Engineers talk with locals at a blackspot to gather additional information about the crashes. They are wearing reflective safety vests – an important safety measure while you are on-site.

If the main crash pattern is a night time pattern you should inspect the site at night. If the crash problem is a weekend problem, inspect the site on a weekend.

Inspecting the site is essential to see local traffic conditions and all other factors specific to the blackspot.

7. Develop countermeasures

You should now try to address the dominant crash pattern(s) using the lowest cost countermeasure that is likely to be effective. This is where your skills as a road safety engineer are put to best use. Judgement, logic and clear thinking are important skills that need to be applied at this time.

Definitely avoid countermeasures that are not aimed at the target crashes. Avoid expensive and complicated countermeasures. Do not simply install a “Crash Zone” warning sign or a “Go Slow” sign in the hope that these *may* overcome the problem.

Stay focussed on the main crash pattern(s) and stay focussed on countermeasures that will cost-effectively address these.

8. Prepare the design

Based on the package of countermeasures that are developed by your road safety engineering team, prepare a draft design for the suggested countermeasure(s). Ensure that the design does not deviate from the intended package of countermeasures developed by the crash investigation team.

9. Calculate the benefits and costs

When the design is complete, calculate the cost of your proposed countermeasures. The PWP&IWTD has costs for the most common treatments – signs, shoulder sealing, delineation, channelisation, lighting and so on. Use those figures to work out the total *cost* of your proposed package of countermeasures. From the draft design of the countermeasure(s), estimate the likely cost (INR C) of the works.

Next calculate the expected *benefits* (in INR) of your countermeasures. To do this you need to know the cost of a casualty crash and also the likely percentage reduction in crashes that your countermeasures will lead to.

- To obtain an agreed cost for a casualty crash in Karnataka you need to seek advice from the Road Safety Cell of PWP&IWTD in Bangalore. They will have a current figure based on research from agencies such as World Health Organisation (WHO) that you can use.
- To obtain the likely percentage reduction in crashes due to a countermeasure requires a Crash Reduction Factor Table. Indian road safety professionals do not yet have enough experience with blackspot programs to be able to produce a Crash Reduction Table that is unique to this country. Some other countries do have such Tables, and one of these (from Australia) is provided below.

Crash Reduction Tables such as this will allow you to make an estimate of the likely percentage reduction in casualty crashes at your site that your recommended countermeasure(s) can achieve. It does not matter for now that this is from another country, it simply allows all engineers who are investigating blackspots to use the same set of CRF's and thus to achieve some consistency in BCR's across Karnataka. The allocation of State funds to treat blackspots should be based on common factors.

In time, it is expected that road safety engineers will evaluate the performance of various countermeasures and will develop a table of crash reduction factors specifically for Karnataka.

Treatments	Crash Reduction Factor	Treatment Life
INTERSECTIONS		
New roundabout	**85%**	20
Modify roundabout (approach deflection)	**55%**	20
New traffic signals	**45%**	20
Convert intersection signals to roundabout	**30%**	20
Staggered T junction	**70%**	20
Removal of Y-intersection	**85%**	20
Splitter islands/median, urban	**20%**	20
Splitter islands rural, low volume	**45%**	20
Line marking to improve intersection	**10%**	5
Improve sight distance (clear obstructions)	**50%**	20
Improve signage	**30%**	15
Rumble strips on approaches	**30%**	5
Install Stop signs	**30%**	15
Install signs	**30%**	15
Change to Stop signs	**5%**	15
SIGNS and DELINEATION		
Reflectorized guide posts	**30%**	**20**
Curve Warning signs - static	**20%**	**15**
Curve Warning signs - vehicle activated	**75%**	**15**
Install chevron signs (CAMS) - normal	**35%**	**15**
Install chevron signs (CAMS) - electronic	**50%**	**15**
Painted centrelines	**30%**	**5**
Tactile centrelines	**40%**	**5**
Painted edge lines	**25%**	**5**
Tactile edge lines	**35%**	**5**
Barrier lines	**30%**	**5**
Raised reflective pavement markers	**20%**	**5**
PAVEMENT WORKS		
Road reconstruction	**25%**	20
Duplication short length	**30%**	20
Install raised median	**30%**	20
Widen pavement	**10%**	20
Construct overtaking lane	**25%**	20
Add lane	**10%**	20
Widen road for Right Turn lane	**50%**	20
Widen road for Left Turn lane	**15%**	20
Lane widening - 0.3m	**5%**	20
Lane widening - 0.6m	**12%**	20
Widen shoulder not seal - 0.6m	**7%**	20
Widen shoulder not seal - 1m	**10%**	20
Widen shoulder and seal - 0.6m	**8%**	20
Widen shoulder and seal - 1m	**12%**	20

NOTE: The Crash Reduction Factor is the percentage reduction expected from the countermeasure. If more than one countermeasure is proposed for a site, use the largest crash reduction factor for your calculations.

With the cost of a casualty crash known, multiply the likely crash reductions by the crash costs to establish the likely benefits (INR) of the countermeasure(s). Dividing the benefits (INR B) by the costs (INR C) yields the Benefit-Cost Ratio (BCR).

The blackspots that have the highest BCR's are the ones that should be funded first – spending public funds to reduce crashes at these blackspots will return the greatest benefits to the community.

10. Write your blackspot report

Gather all the information together and write your crash investigation report that is to be sent to Head Office for approval of funding. Add photographs, all your diagnosis tools, and your draft designs.

Ensure that you explain the crash patterns that you found and the reason why you have selected the countermeasures. Take particular care in presenting the BCR – ensure that the benefits claimed are in accord with the agreed CRF table, and that the cost of your proposed works is reasonable.

Your report (especially the BCR for your package of countermeasures) will be compared with similar reports for other blackspots from around the State. The investigations that have produced the highest BCR's are the ones that will receive funding first.

11. Send to Head Office for a decision about funding

Funding of blackspots under the state wide blackspot program is a responsibility of staff in Head Office. They are responsible for seeing that for the highest ranked sites should normally be provided first – and then successively down through the list until all funds are expended.

When funding approval is given you will be responsible for the detailed design of your blackspot countermeasure(s). When the design is completed remember to have it road safety audited.

Monitor the performance of the new site immediately after it becomes operational, and for as long as you feel it to be necessary. This may be for several months at some sites.

Evaluate the treatment later (a three year follow-up is usually optimum) as part of a program-wide evaluation. The information from such evaluations will help Karnataka to establish, and then to refine, its own table of crash reduction factors.

PART C - SOME BLACKSPOT EXAMPLES

1. Effective countermeasures for intersection crashes

Reducing intersection crashes should be one of your highest priorities as a road safety engineer for a number of reasons. Firstly, they comprise a substantial proportion of the overall crash problem, both in rural and metropolitan areas.

Secondly, crashes tend to concentrate at intersections because of the high levels of conflict, compared with non-intersection locations. This means that implementing cost-effective countermeasures through changes to the road environment is easier and more likely to be successful at intersections.

Thirdly, intersection crashes tend to be severe because of the speed differentials in right angle and right turn against crashes. And finally, there is a range of traffic control devices for intersections which, when correctly applied, are highly cost-effective in reducing the number and/or severity of intersection crashes.

Cross Traffic Crashes

Crashes which take place at crossroads can usually be described as either overshoot or restart crashes. This is an important difference to establish with cross-traffic crashes at your blackspot, as the countermeasure for the two types of crash are quite different.

Overshoot crashes are where the driver of the vehicle on the "minor" road is unaware of the intersection and drives through it or at least into it without slowing. If this happens at the time a second vehicle is driving through the intersection on the intersecting road, a right angle crash will occur. If a driver drives through an intersection without knowing it is there, and no crash eventuates, he/she may forever remain ignorant of his/her potentially tragic mistake.

The most appropriate countermeasure for overshoot crashes is to improve the conspicuity of the intersection. This may be achieved by:

- improving the Approach Sight Distance (ASD)
- repainting centre lines and holding lines

- advanced warning signs
- advanced direction signs
- installing intersection lighting (if crashes have happened at night)
- duplicating the Stop/Give Way sign
- installing a splitter island on the minor approach
- installing a roundabout or traffic signals
- trimming obstructing foliage.

Re-start crashes occur when a driver has slowed or even stopped at the intersection, but has then selected an inadequate gap in traffic on the intersecting road. Crash investigators need to ask why the driver would select such an inadequate gap – are sightlines obstructed, are major road speeds excessive, or are major road volumes so high that entering drivers feel pressured to take smaller gaps than they should.

Developing appropriate countermeasures for re-start crashes is often more difficult and more expensive than for overshoot crash problems. The most common countermeasures are:

- improving the Safe Stopping Sight Distance (SSID)
- improving sight lines by trimming foliage (but this requires on-going maintenance).
- relocating bus stops and prohibiting parking to open sight lines.
- installing a roundabout or traffic signals.
- reducing operating speeds on the major road (noting the need for on-going enforcement).

When entering traffic volumes start to approach 10,000 vehicles/day measures which actively assist in gap selection, such as roundabouts or traffic signals, are the most suitable treatment to consider.

Right turn Against Crashes

Right-turn-against crashes are a major problem at signalised intersections. Efforts to reduce the incidence and severity of right-turn-against crashes mainly involve the use of turn phases for the relevant movements. Only fully controlled right-turn phases (3-aspect arrow displays) have proven to be effective in reducing this crash type.

Right-turn-against crashes can also be reduced through the installation of a roundabout, or by improvements in sight distance to oncoming traffic, through the removal of obstructions and/or the provision of separate right turning lanes. This latter layout has the added advantages of reducing pressure applied by following drivers, who may otherwise be delayed by the right turner. They also reduce the potential for rear-end collisions.

Pedestrian Crashes

Pedestrian crashes involving pedestrians walking along a road can be reduced by sealing shoulders (rural) or by constructing footpaths (urban). Sealing bus stops and providing a shelter can encourage buses to stop off the road and pedestrians to wait for them.

Pedestrian crashes involving pedestrians crossing the road will not be solved by the installation of Zebra crossings until strong and efficient enforcement takes effect. Pedestrian operated traffic signals can be effective, but only if power supply can be guaranteed and good maintenance is possible.

The best remaining option is a pedestrian refuge that gives pedestrians a safe place to store as they select a gap in the second direction of traffic.

A substantial proportion of pedestrian casualty crashes occur at intersections, where pedestrians emerge from side roads to cross busy main roads. If the intersection has traffic signals, pedestrians can be assisted in several ways. The most frequent pedestrian crash type at signalised intersections involves conflict with left or right-turning vehicles. The presence of conflicting pedestrians complicates the driving task, especially the attention-sharing component in an already demanding traffic environment.

At non-signalised intersections, geometric improvements such as central approach islands or kerb outstands, which either reduce the width of road to be crossed or which make the pedestrian more visible, can prove successful.

Rear-end Crashes

Rear end crashes can occur anywhere on the road network, but are more likely at median openings and at intersections.

If the rear end crashes happen at an opening in a median, see if you can provide a sheltered turn lane into which the slowing vehicles can move, away from the through traffic. If the median is too narrow, explore options to try to provide a partially sheltered lane, to try to assist motorcyclists and smaller vehicles.

Also, make the median opening much more conspicuous. Place advanced warning signs at least 50-100m in advance of the opening, matched by a series of three lane direction arrows. A street light near the opening can be useful for night time problems.

If an intersection displays a history of such crashes you should look at the approach and try to determine if the Stop/Give Way signs are conspicuous in adequate distance. Are drivers/riders reacting too late, and creating a rear end problem. Do your best to make all approaching drivers/riders aware of the presence of the intersection; install an additional advance warning or advanced direction sign approximately 50m in advance of the intersection.

2. Effective countermeasures for mid-block crashes

Crashes that occur between intersections are called mid-block crashes. The block may be 100m long (particularly in urban areas) or several kilometres long (particularly in rural areas). Typical mid-block crashes include single vehicle run-off-road crashes, head-on crashes, side swipe crashes, rear end crashes and pedestrian crashes.

To counter single vehicle run-off-road crashes, adopt the five step roadside hazard management strategy:

- Do all you can to keep the vehicles on the road – seal shoulders, install edge lines and centre lines, install plastic (forgiving) guide posts, and delineate curves.
- Remove the hazard – remove any fixed object larger than 100mm diameter that is within the clear zone.
- Relocate the hazard – if it is not practical to remove the hazard, try to relocate it further from the road.
- Alter the hazard – if it cannot be relocated, alter it (by softening side slopes, or weakening sign posts).
- Finally – when all the options have been exhausted, consider the installation of properly designed crash barrier.

More details about this roadside hazard management strategy are contained in pages 29 and 30 of the road safety audit field guide

To counter head-on or side swipe crashes, look closely at the geometry of the road. Is a crest limiting forward sight distance? Is vegetation on the inside of horizontal curves blocking sight lines?

Then look at the line marking and signage. Are lines clear and well maintained? Are shoulders sealed to provide a recovery area for drivers/riders confronted by on-coming vehicles?

To counter mid-block pedestrian crashes, many of which are likely to involve pedestrians who are walking along the road, provide sealed shoulder at least 1m wide (preferably 1.5m wide) with strong edge lines. Use warning signs where appropriate and consider street lighting if the crashes occur mainly at night.

Low cost improvements to the road and the roadside can do a lot to reduce the frequency and the severity of crashes on the roads of Karnataka.

3. Blackspot case studies from Karnataka

The following case studies summarise the result of four blackspot investigations on state highways in Karnataka. They have been selected to showcase some of the most commonly found road safety issues on the roads of Karnataka, and which can be readily reduced through good road safety engineering.

BLACKSPOT REPORT ONE

Y- Junction of two Highways

1. The location

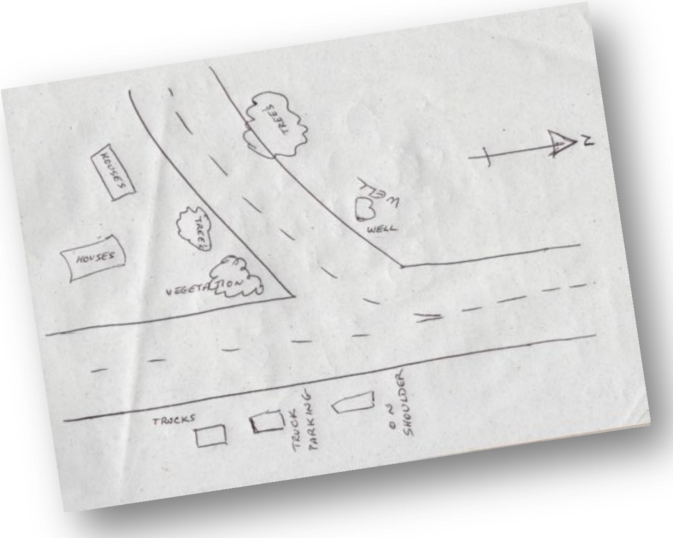
This blackspot is a busy Y- junction of two State Highways in central Karnataka. It is in a rural area but many houses and small buildings have been built nearby in the past few years. The area is quite flat.

Both highways are two lane, two way roads with 7m wide pavements. One highway is a straight road at the Y junction with 1m wide unsealed shoulders. The other also has unsealed shoulders but it merges with the first highway in a sweeping curve. There are some drop-offs from the pavement to the unsealed shoulder (up to 100mm) along both roads. The line marking is well worn; there is a “No Overtaking” sign on the northern approach but no other warning signs for the junction. Only one advanced direction sign exists (this is on the western approach) and it incorrectly shows the directions through the junction. There is no lighting. Free travel speeds are generally in the range 60-80km/h.

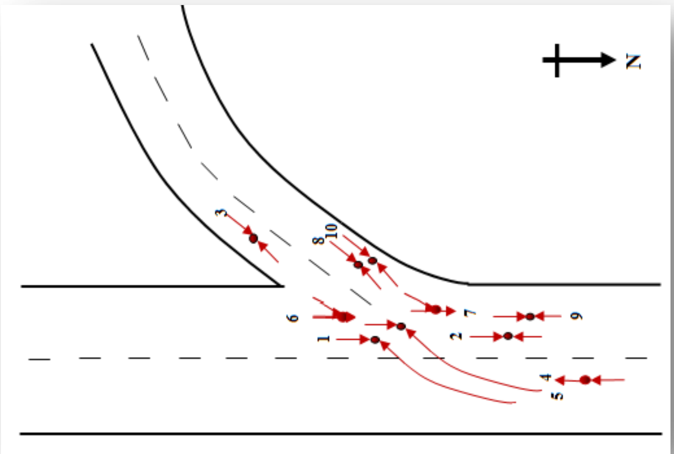
2. The crash problem

Based on information from local Traffic Police officers there is an average of at least one casualty crash per month. The Police reports show five fatal crashes and three serious casualty crashes in the past year. There have been many slight casualty crashes according to locals, but the Police do not have any details of those. These reported crashes are:

- Head-on crashes - trucks/ buses from the south colliding with motorcycles from the north.
- Right turn against crashes – vehicles turning right at the Y-junction (from the north) colliding with through traffic from the south at the junction.
- 70% of the crashes occur at night time.



Sketch of blackspot



A collision diagram for the junction, showing a clear pattern of head-on and "right turn against crashes

Crash Number	1	2	3	4	5	6	7	8	9	10
Day of month	03/04	11/05	20/05	05/07	24/07	08/08	15/09	13/10	17/10	28/11
Day of week	Sun	Sat	Mon	Wed	Sat	Tue	Thur	Sun	Thue	Sat
Time of day	1500	1800	2000	0100	1000	2100	2130	2200	2320	1930
Severity	2	1	1	3	1	2	2	1	1	3
Light condition										
Road condition	D	W	D	D	D	W	D	D	D	D
vehicle 1	Truck	Truck	Bus	Truck	Car	Truck	Car	M/C	Car	Bus
vehicle 2	Bus	M/C	M/C	Truck	Truck	Car	M/C	M/C	Car	Car
vehicle 3										
Direction 1	NB	WB	NB	SB	NB	NB	NB	WB	SB	WB
Direction 2 (&3)	WB	NB	WB	NB	NB	NB	NB	NB	SB	NB
Other				Driver Asleep				Drunk & Driving		

SB- Southbound, NB-Northbound, WB-Westbound

Crash factor grid

3 Recommended countermeasures in priority order.

Aim to improve driver/rider awareness of the Y junction, and clarify who is to give way. Eventually, convert this to a T junction.

Short term

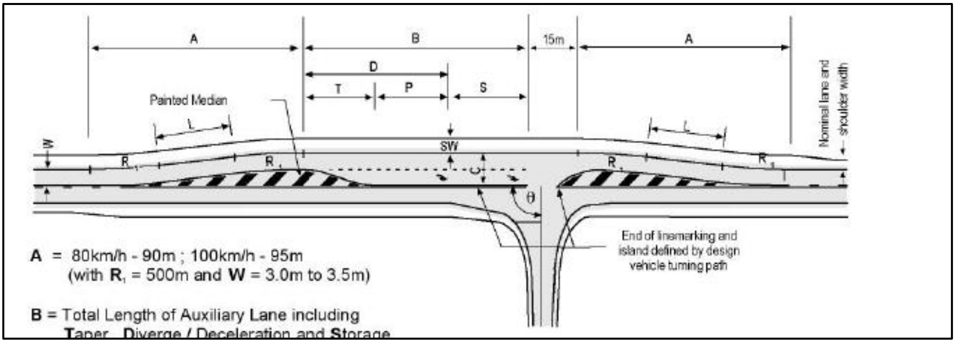
- Install new reflective advanced direction signs approximately 100m from the junction on all three approaches.
- In particular, ensure the new advanced direction sign on the western approach clearly shows the correct directions at the intersection.
- Install a Give Way sign and markings on SH 25.
- Renew all line markings on both highways.
- Cut back vegetation along the western side of the intersection to increase sight lines.
- Install new reflective junction warning signs on each approach.
- Install two new street lights at the junction.
- Remove the “Accident Zone Go Slow” signs and other unnecessary signs at the junction.

Long term

- Square up the intersection to make a T junction (see diagram)
- Seal shoulders along both highways.

The Y junction blackspot has worn centre line marking on the straight road only. There is a "No Overtaking" sign on the northern approach but no other effective signs. The lighting does not work. Vegetation restricts sight lines across the intersection.

The second highway is also flat but it has a significant horizontal curve just before the junction. It has no line marking and no signage to warn drivers/riders of the junction ahead, expect for one advanced direction sign that has some misleading direction arrows on it.



The Y junction should be redesigned and programmed to be replaced by a T junction (similar to this) at an early time.

BLACKSPOT REPORT TWO

A series of curves near a bridge

1 The location

This blacklength is on a two lane, two way highway with a number of horizontal curves either side of a 50m long concrete bridge. The highway is quite flat as it passes through this rural area; it is heavily used by trucks, and the pavement is in poor condition. There are large drop-offs from the road pavement to the unsealed shoulders. Free travel speeds of small vehicles are 60-80km/h when traffic conditions permit, while trucks travel at 50-70km/h.

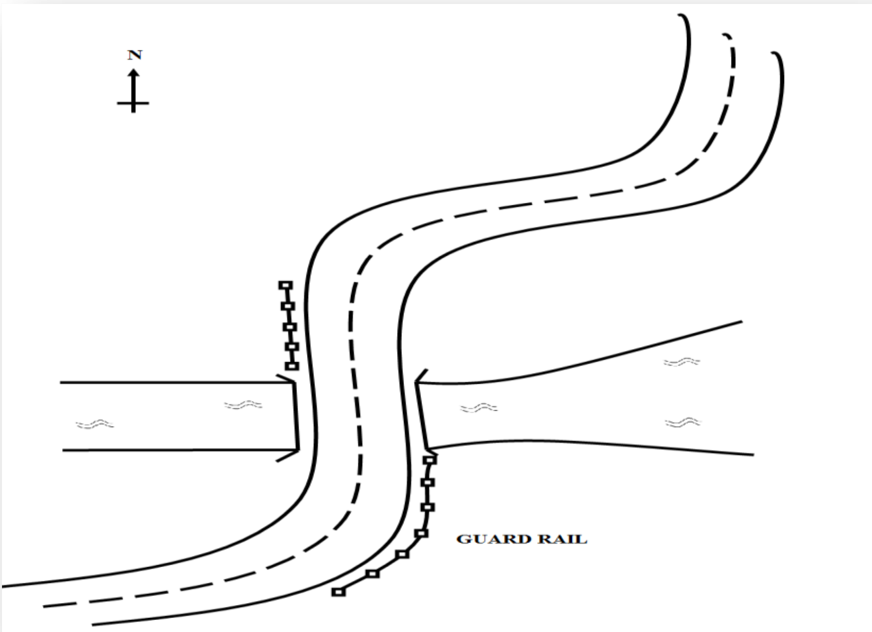
The crashes occur at a number of locations through these curves and at the bridge. The barrier on each side of the bridge has been struck several times. One crash appears to have involved a vehicle "pocketing" into the bridge abutment because the barrier is not joined strongly to it. The two curves either side of the bridge have radii of about 75m and sight distance through both of them to the bridge is poor because of overgrown vegetation. The line marking is worn out and a number of guide posts are missing from each curve.

2 The crash problem

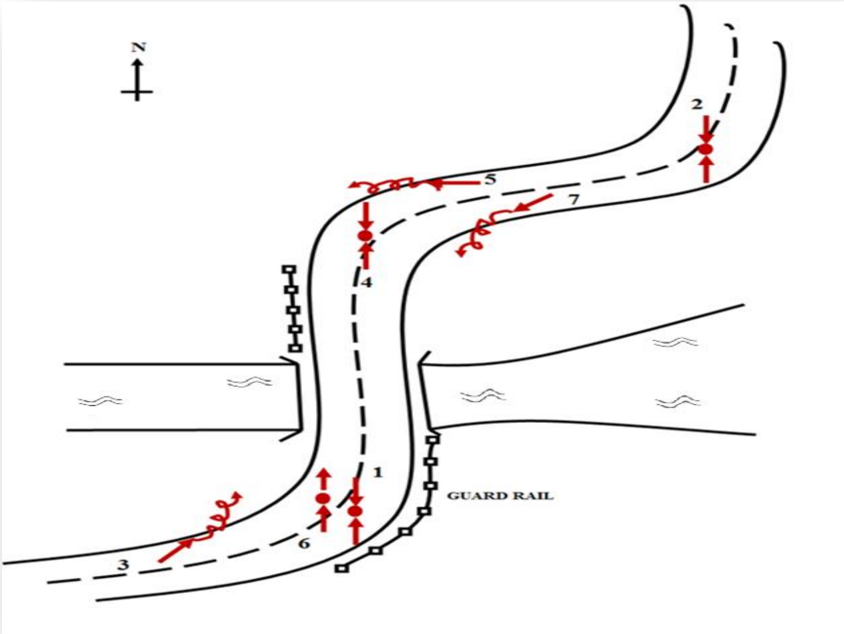
At least seven crashes are known to have occurred on these curves in the past 18 months. Based on local knowledge and Police inputs it appears that the main crash types are:

- Head-on crashes between trucks/ buses with small vehicles (especially motorcyclists). These happen during the day, at dusk but mainly at night time.
- Run-off-road single vehicle crashes at night, usually involving cars or buses.

It is concluded that drivers are not aware of the curves due to a lack of delineation. Some drivers react too late and they end up on the wrong side of the highway. On-coming motorcyclists have no space to avoid a collision.



Sketch of blackspot



Collision diagram

Crash Number	1	2	3	4	5	6	7
Day of month	01/10	10/11	12/03	08/04	05/08	01/06	07/07
Day of week	Wed	Wed	Fri	Sat	Mon	Wed	Sun
Time of day	0015	2000	2330	1445	0230	1030	0100
Severity	1	1	2	2	1	2	3
Light condition							
Road condition	W	W	D	D	W	D	D
vehicle 1	Truck	Bus	Car	Car	Bus	Bus	Car
vehicle 2	LCV	M/C	-	M/C	-	M/C	-
vehicle 3							
Direction 1	SB	SB	NB	SB	SB	NB	SB
Direction 2 (&3)	NB	NB		NB		NB	
Other							Driver Asleep
SB- Southbound, NB-Northbound, WB-Westbound							

Crash factor grid

3 Recommended countermeasures in priority order.

Aim to make the curves more conspicuous, and to create a recovery area for errant vehicles.

- Open sight lines on the inside of each curve by cutting back the vegetation.
- Install a series of chevron alignment markers (CAM's) around the outside of each curve – to face drivers/riders from both directions
- Place curve warning signs 50m in advance of the tangent point of each curve.
- Build up the unsealed shoulder around the outside of each bend.
- Seal the shoulders on both sides of the highway for a length of at least 200m either side of each curve.
- Install a solid centre line through the curves, over the bridge and for at least 50m on each approach to define the centre of the road and to prohibit overtaking here.
- Use edge lines to guide drivers.
- Replace all damaged crash barrier. Ensure it is connected strongly to the bridge abutments, with reduced post spacings over the last 10m. Ensure reflectors are placed on the barrier.
- Install "Width Markers" at the bridge abutments to aid conspicuity of the travel path across the narrow bridge.
- Post speed limit signs along the highway (possibly 60km/h but to be agreed with Traffic Police). Ensure that drivers/riders are given a clear message about their maximum permissible speed.

The first curve is a left handed curve that has no delineation. If a driver on this approach enters the curve too fast they can swing wide and, if another vehicle is travelling in the opposite direction, there is a real risk of a head-on or side-swipe collision. If the on-coming vehicle is a motorcyclist they will have no recovery area due to the drop off onto the unsealed shoulder.

The highway lacks basic traffic management devices – the centre line is worn, the sight lines across the bend are restricted by the vegetation, and there is no delineation.

Blackspot Report Three

Blacklength on a highway curve on the outskirts of a town

1 The location

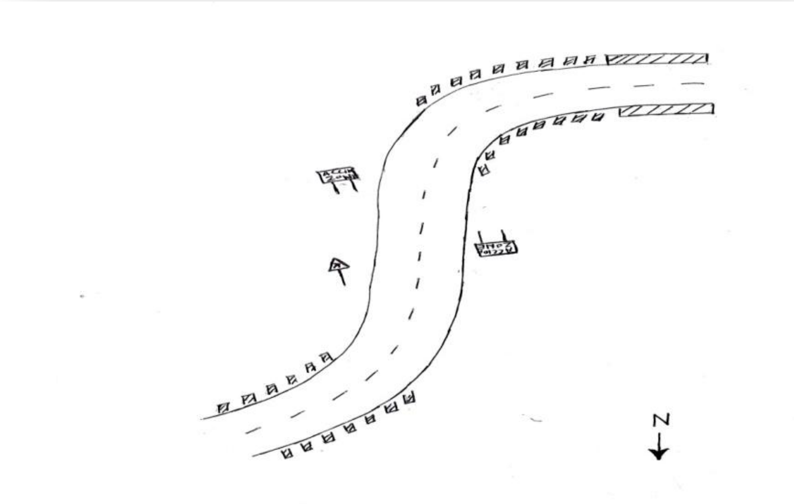
The blacklength is on the outskirts of a large town and is about 400m long. It commences with a pair of gentle reverse curves leading into a large sweeping right hand curve. The highway then straightens as it passes over a long bridge. The highway is a two lane, two way road, and is quite flat. The line markings are worn and many of the concrete guide posts along the outside of the large right hand curve have been knocked/damaged/lost. The shoulders are not sealed. A “Right Curve” warning sign is the only warning sign in this blacklength. There are a number of business signs along the highway advertising services. They can distract drivers/riders and are unnecessary. There is no street lighting; a steep slope up to 3m high exists around the curves. Local transportation is mainly by auto rickshaws which stop on the carriageway to pick up and set down passengers. Several collisions have involved pedestrians crossing the highway at one such stop.

2 The crash problem

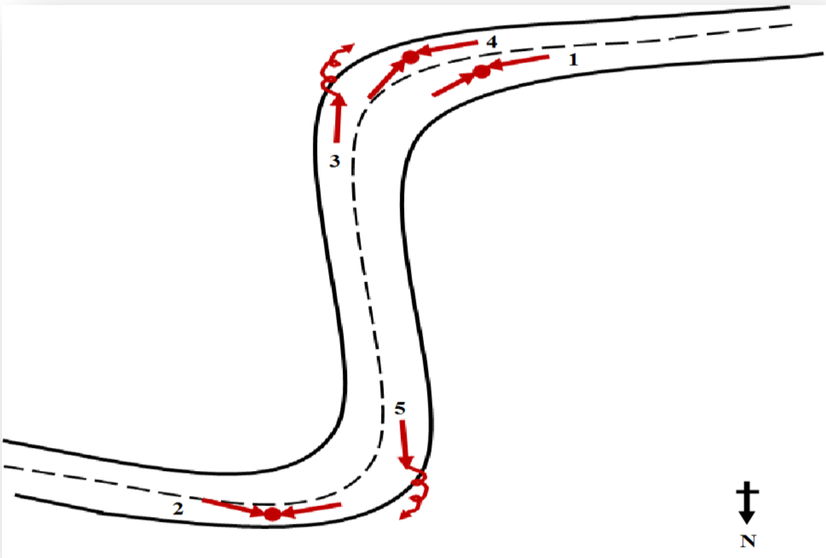
The Police have supplied details of 5 crashes that they have attended in the past 18 months. However, local people said that more than 12 crashes have occurred over a period of 18 months. Based on local knowledge and Police inputs, these crashes comprise:

- Head-on crashes between trucks/buses with small vehicles (especially motorcycles) on the curve mainly due to overtaking.
- Run-off-road crashes on the sweeping right hand curve.
- Pedestrians struck by motorcycles and buses while getting on and off the auto rickshaws.

According to local residents, about 75% of crashes involving trucks occur during night. They also say that some vehicles in the right hand lane have travelled directly into on-coming traffic.



Sketch of blackspot



Collision diagram

Crash Number	1	2	3	4	5
Day of month	06/02	03/04	01/06	12/08	22/12
Day of week	Sat	Fri	Mon	Wed	Tue
Time of day	1400	2200	2350	2045	0300
Severity	1	2	3	3	1
Light condition					
Road condition	W	D	D	W	D
vehicle 1	Bus	Truck	Truck	Bus	Truck
vehicle 2	M/C	LCV		M/C	
vehicle 3					
Direction 1	NB	SB	SB	SB	NB
Direction 2 (&3)	SB	NB		NB	
Other			Drunk & Driving		
SB- Southbound, NB-Northbound, WB-Westbound					

Crash factor grid

3 Recommended countermeasures in priority order.

Aim to make the curve more conspicuous, and to create a recovery area for vehicles. Assist pedestrians to cross from the bus stop

- Install a solid centre line as a no-overtaking line along the full length of the curve. Install edge lines as well.
- Install 12 Chevron Alignment Markers (CAM's) around the outside of the left hand curve and 8 chevrons along the outside of the right hand curve.
- Install "Curve" advanced warning signs on both approaches of the highway to the major curve.
- Replace damaged concrete guide posts with plastic lightweight guide posts along both sides of highway through this blacklength.
- Seal the shoulders (at least 1.5m wide) and keep them clean by sweeping them regularly.
- Install duplicate "Pedestrian" warnings signs approximately 50m north and south of the auto rickshaw stop.

This blacklength is on a reverse curve. The line markings are worn out, and only one right hand curve warning sign is present on the second curve. Lots of unnecessary sign boards exist; they may distract drivers/riders and they do not serve a useful road safety purpose.

Many of the concrete guide posts along the curve have been damaged.There is drop off of approximately 3 metres behind these posts that is a roadside hazard. The remaining guide posts are not reflective, and there are no edge lines or chevron alignment markers to delineate the curve.

Blackspot Report Four
A pedestrian blackspot in a village on a Highway

1 The location

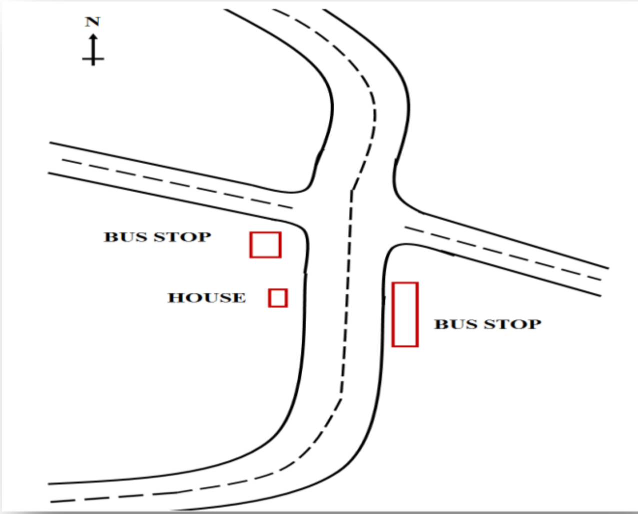
The highway has a sweeping left hand curve some 200m before passing through this small village. Buildings are close to the side of the highway, particularly at the village road that intersects with the highway at a small cross road in the middle of the village. Some 50m past the intersection the highway takes another slightly larger radius curve to the left.

The village serves a local farming area and the surrounding land is quite flat. The highway is also flat as it passes through the curves and the village. There are some warning signs on each approach to the village, and some old speed breakers have been recently removed from the highway on each approach to the village. However, the “Speed Breaker” warning signs are still in place. The highway through the village has no street lighting, no sealed shoulders and no sealed bus laybys. Villagers stand at or near the highway awaiting buses. Buses were observed stopping on the highway to pick up/set down passengers. While they do this they are at risk of rear end collisions, they block sight lines to/from the intersection and they cause highway traffic to overtake them, sometimes at speed.

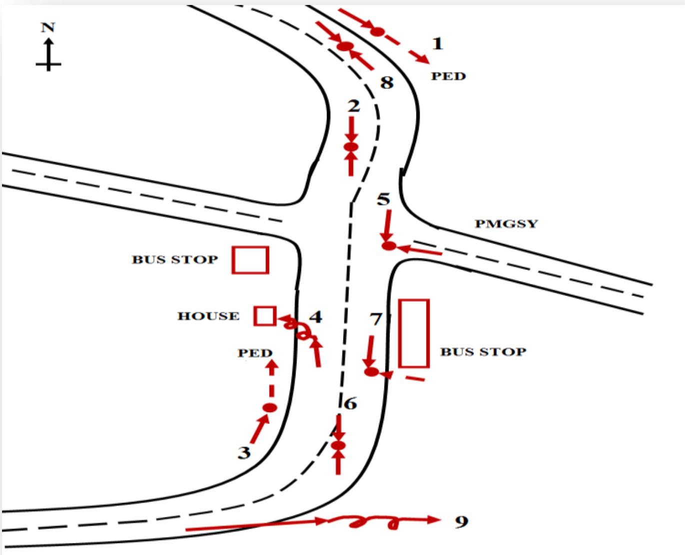
2 The crash problem

Based on local knowledge and Police inputs the main crash patterns comprise:

- Head-on crashes between trucks/buses with small vehicles (especially motorcycles).
- Right angle crashes at the cross road junction in the centre of the village. These mainly involve motorcyclists and animal drawn vehicles exiting the village road.
- Pedestrian crashes – crossing the highway, walking along it.
- Single vehicle run-off-road crashes at the curve on the entry to the village



Sketch of blackspot



Collision diagram

Crash Number	1	2	3	4	5	6	7	8	9
Day of month	06/01	26/01	08/02	15/03	08/04	15/05	19/06	22/06	17/08
Day of week	Sun	Tue	Fri	Thur	Sat	Wed	Sun	Tue	Thur
Time of day	0300	2300	0900	1400	1730	0500	1100	1630	2230
Severity	1	3	1	3	1	1	2	2	3
Light condition									
Road condition	D	D	W	W	D	D	D	W	D
vehicle 1	Truck	Car	Truck	M/C	Bus	Truck	Bus	Car	Car
vehicle 2		Car			Oxen Cart	Truck		M/C	
vehicle 3									
Direction 1	SB	NB	NB	NB	SB	NB	SB	NB	NB
Direction 2 (&3)		SB			WB	SB		SB	
Other	Drunk & Driving		Loss og control						
SB- Southbound, NB-Northbound, WB-Westbound									

Crash factor grid

3 Recommended countermeasures in priority order.

Aim to make entering drivers/riders more aware of the need to reduce speed and to look for pedestrians and slow moving vehicles in the village. Assist pedestrians to walk along the highway and to wait in comfort at the bus stop

- Install “Gateway” signs on both sides of the highway on both approaches to the village. These large signs should have a Welcome to Upanayakanahalli” message and a 40km/h speed restriction sign on a bright yellow backing board. They should be placed on each side of the highway approximately 200m out from the village cross road junction.
- Discuss the speed limit with Traffic Police and seek their support for enforcement.
- Install new “Cross Road” warning signs 50m north and south of the village junction.
- Reinstate the centre line and paint edge lines along the highway.
- Install 6 chevron alignment markers (for each direction) around the outside of the curve before the village.
- Seal the shoulders at least 2m wide through the village to assist pedestrians and motorcyclists.
- Paint Stop lines across the side roads at the junction.

- Install at least one street light at the junction to highlight the junction after dark.
- Discuss with villagers and the bus operators the best locations for two sealed bus stopping areas in the village. Take care not to block sight lines at the village junction.

The curve before the entry to the village has no line marking and little delineation. It needs edge lines, a solid centre line, sealed shoulders, and chevron alignment markers.

The existing village signs should be replaced with Gateway signs on both sides of the highway to face drivers/riders entering the village. Each sign should combine a 40km/h speed limit with a Welcome sign on a yellow backing board. On the reverse should be a 60km/h speed sign and a message such as "Drive Safely".

The village road is used by many animal drawn vehicles and motorcyclists. If they select a wrong gap when crossing or entering the highway, a serious right angle collision can occur. If buses and trucks travel through the village at speeds above about 40km/h, the consequences of any crash will be quite severe.

Pedestrian wait on or beside the highway and when a bus stops it often blocks one lane of the highway. Because they stop near the village intersection, these stationary buses can also restrict sight lines to/from the intersection. This increases the risk of intersection crashes.