RoSPA
The Royal Society for the Prevention of Accidents

Road Safety Engineering Manual

4 Investigating and defining accident problems

This chapter gives a comprehensive guide to the investigation of road accidents and how to define accident problems on the road network.

The accident investigation process is based on the following philosophy:

- High numbers of accidents of a similar type can indicate a problem related to the road
- Accidents of this type will continue to occur unless the problem is treated
- Making changes to the road environment can change driver behaviour and reduce road accidents

The methodology for studying high risk locations is described in detail in this chapter:

- Identify the accident problem locations – see section 4.1
- Rank the locations into priority order – see section 4.1
- Analyse the accident and other data at individual locations – see section 4.2
- Carry out a site visit – see section 4.3
- Define the accident problems – see section 4.4

4.1 Selecting and prioritising locations for investigation

There are four main approaches to accident investigation that illustrate the different ways in which an authority can classify and then tackle its road accident problems. These are:

- **Single site** – a discrete location such as a junction or short length of road
- **Mass action** – a collection of different locations exhibiting similar problems
- **Route action** – a whole route or section of that route with a higher than expected number of accidents
- **Area-wide action** – a whole area with a higher than expected number of accidents

Each approach has a different emphasis and is likely to produce a variation in the type of accident problem going forward for treatment.

For example the single site approach is likely to identify a series of individual junctions, probably involving injuries to occupants of conflicting motor vehicles. On the other hand, the area-wide action approach is likely to identify vulnerable road users such as child pedestrians and cyclists, who may not be targeted for priority action through any of the other approaches.

Each highway authority should review its strategy with respect to these approaches, with a view to using their resources in the most effective way. Section 7.11 looks at the subject of Road Safety Plans.

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4.1.1 Investigation levels

A highway authority will generally have a record of all the injury accidents in their area, or on the network they manage, and this should be stored on a computerised database of some form.

It is possible that some organisations (for example Highways Agency agents) with responsibility for road safety on part of a network may not have a fully computerised accident database. If the database is manually recorded then a visual inspection will have to be undertaken to identify locations falling into the categories listed in 4.1 above. If the information is stored on a computer database then a variety of standard interrogation reports can be set up to search through the database to identify sites falling into these categories. Because of the way in which some of the data is stored and due to coding errors, there can be difficulties in retrieving information accurately. The various search mechanisms may not therefore reveal all of the sites falling into each category or all of the accidents at the sites identified.

Geographic Information Systems (GIS) are becoming increasingly commonplace, offering more reliable identification of sites. They also make it possible to cross-reference this information to other highway data such as road condition surveys identifying levels of skid resistance, and traffic flow/speed information.

The first stage of the investigation process is to study the accident data in a logical manner in order to select problem locations for further in-depth investigation.

It is important to try to define an investigation level, that is, the number of accidents at which further investigation is carried out. An investigation level should be set against three factors:

- **The number and/or type of accidents** – for example, all injury accidents, or injury accidents involving skidding on wet roads, or injury accidents involving pedestrians
- **A length or area of highway** – for example, accidents per km of route, or accidents per square km of area, or a junction (normally including a short distance – usually around 20-50m – on the arms either side
- **A time period** – usually three or five years

An investigation level is therefore a predefined number of accidents at a discrete location, or per unit length or area, occurring within a fixed time period above which a more detailed investigation should take place. The investigation level can be set to provide selections of single sites, groups of sites, routes and areas containing accident numbers capable of being studied and treated in an annual programme or over a longer period. The investigation level should be set in relation to the overall accident problem throughout a highway authority area, and in relation to the resources available to tackle the problem.

An example of a reaction level for single sites would be 9 or more injury accidents at and within 100 metres of a junction within a three year time period.

It is important to be able to identify accident problem sites as efficiently and precisely as possible. However, it must be borne in mind that the objective of any selection process must be to produce sites with 'treatable' accident problems.

The following sections explain how the selection (or ranking) process can be applied to each of the four approaches to accident reduction.

4.1.2 Single sites

Single sites are individual locations considered to be hazardous due to the total number of accidents recorded within a specific, recent period of time.

The location at which the accidents occur might be a confined area (up to 400 metres in diameter), or a short length of route (around 300 to 500 metres long). However, most single sites are described within the defined limits of individual junctions.

Single site accident location near a school.

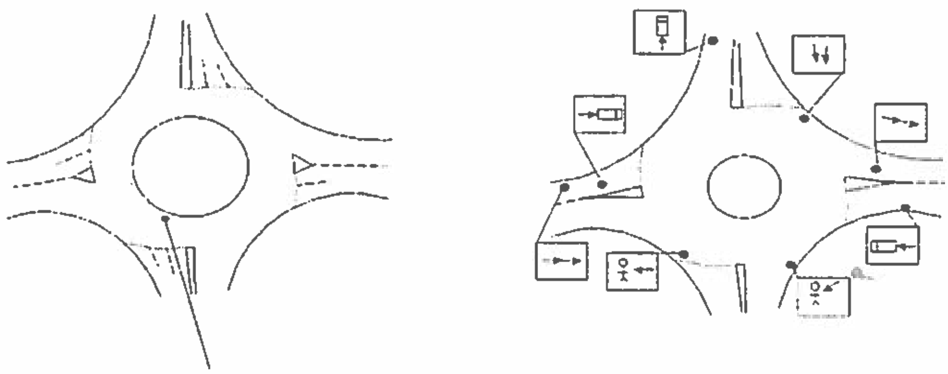
The time period chosen for analysis of single sites is usually three or five years and should comprise full 12 month periods, though not necessarily calendar years. The time period chosen is a compromise between statistical and practical factors. For example, a five year period gives a better basis for statistical examination, in that some of the effects of random fluctuations in accident numbers are removed. However, finding out if the site has been treated in any way over that period of time, or if traffic patterns have changed significantly, can prove difficult. It is important in terms of understanding potential cause and effect within the accident distribution to determine any such changes.

4.1.2.1 Accident totals

The simplest way of ranking single sites is to list them in descending order of accident total with the site at the top of the list having the highest number of accidents for a three or five year period. Most accident systems will produce lists of sites ranked in this way, for junctions, lengths of road, or grid referenced cells.

In order to identify 'treatable' accident problem sites it will be necessary to carry out further analysis at individual sites from the list. A high accident number does not necessarily imply a treatable problem – it may simply be a function of the size and type of the junction or of the traffic flow. In Figure 4.1, the first roundabout has a total of nine loss of control collisions on the northbound approach, seven in the dark and seven on a wet road surface – a potentially 'treatable' problem. The second roundabout has eight accidents – with no discernible 'treatable' pattern.

Figure 4.1: Roundabouts with treatable and non-treatable accident patterns



Dark/ light	dark	dark	dark	dark	dark	dark		dark
Weather	wet	wet	wet	wet	wet	wet	wet	Ice
Accident Type								

Dark/ light		dark			dark		dark	
Weather	wet				wet			wet
Accident Type								

A listing of accident totals needs to be updated at regular intervals. It should indicate improving or worsening situations and point to the most effective use of resources. This should be reviewed annually. It is possible to indicate rising and falling trends on this type of list and get monthly monitoring updates on these sites as an early warning mechanism of developing problems.

This is the simplest ranking method and provides a very useful and powerful tool in the subsequent decision making process.

Figure 4.2: List of sites ranked by accident total ***(Source – WMJDT)***

WEST MIDLANDS METROPOLITAN DISTRICT COUNCILS   RUNA2 - TRAFFIC ACCIDENT ENQUIRY SYSTEM

	JUNCTION NUMB			TOT ACCS	FAT	SER	SLI	% PED	% CHLP	% PCYC	% P2W	% SVMP	% DARK	% WET
1	179	A0034/B4515 PARK LANE	BM	12	0	3	9	0.0-	0.0	0.0	8.3	0.0	25.0	25.0
2	72	A0038/A4040 OAK TREE LN	BM	12	0	1	11	8.3	0.0	0.0	8.3	0.0	50.0	41.7
3	6	A0041/A45 COVENTRY RD	BM	11	0	1	10	0.0	0.0	0.0	0.0	0.0	18.2	45.5
4	112	A5127/B4531 STATION RD	BM	9	0	0	9	0.0	0.0	0.0	0.0	0.0	44.4	33.3
5	110	A0456/A4123 WHAMPTON RD	BM	8	0	2	6	0.0	0.0	0.0	0.0	0.0	37.5	50.0
6	301	A0435 MOSELEY R/BRIGHTN	BM	8	0	2	6	0.0	0.0	0.0	25.0	0.0	50.0	25.0
7	2042	A0454/A4148 PLECK R	WL	7	0	1	6	0.0	0.0	0.0	14.3	0.0	42.9	42.9
8	595	B4129 NORFLK R/AUGUSTUS	BM	7	0	0	7	0.0	0.0	0.0	0.0	0.0	14.3	0.0
9	1565	A4123 WHAMP R/NEWBURY L	SA	7	0	0	7	0.0	0.0	0.0	0.0	0.0	42.9	57.1
10	34	A0441/B4127 EDGBASTON R	BM	6	1	1	4	0.0	0.0	0.0	0.0	0.0	33.3	33.3
11	119	A0038/A4540 LEE BNK MWY	BM	6	1	0	5	0.0	0.0	0.0	16.7	0.0	66.7	33.3
12	1508	A0457/B4135 ROLFE ST	SA	6	0	2	4	0.0	0.0	0.0	0.0	0.0	0.0	50.0
13	281	A0041 WARWCK R/KNIGHTS	BM	6	0	1	5	0.0	0.0	0.0	16.7	0.0	50.0	66.7
14	311	A4540/B0000 GT LISTER S	BM	6	0	1	5	0.0	0.0	0.0	0.0	0.0	33.3	50.0
15	1562	A4123 WHAMP R/POUND R	SA	6	0	1	5	0.0	0.0	0.0	16.7	0.0	50.0	16.7
16	1571	A0041 HILL TOP/NEW ST	SA	6	0	1	5	0.0	0.0	0.0	16.7	0.0	50.0	33.3
17	2212	A0041 CMPTN RD/CHAPEL A	WV	6	0	1	5	0.0	0.0	0.0	16.7	0.0	50.0	33.3
18	2219	A0449 PENN R/ROOKERY LN	WV	6	0	1	5	0.0	0.0	0.0	16.7	0.0	83.3+	50.0
19	399	A4540/B4127 WHEELEYS LN	BM	6	0	0	6	0.0	0.0	0.0	16.7	0.0	16.7	33.3
20	2262	A4123/A4039 PARKFLD RD	WV	6	0	0	6	0.0	0.0	0.0	16.7	0.0	50.0	33.3

Z TEST CONTROL TABLE is W 2 NETWORK,TRAF SIGNAL JUNCS

- denotes signif less at 1 %   + denotes signif more at 1 %

4.1.2.2 Accident rates

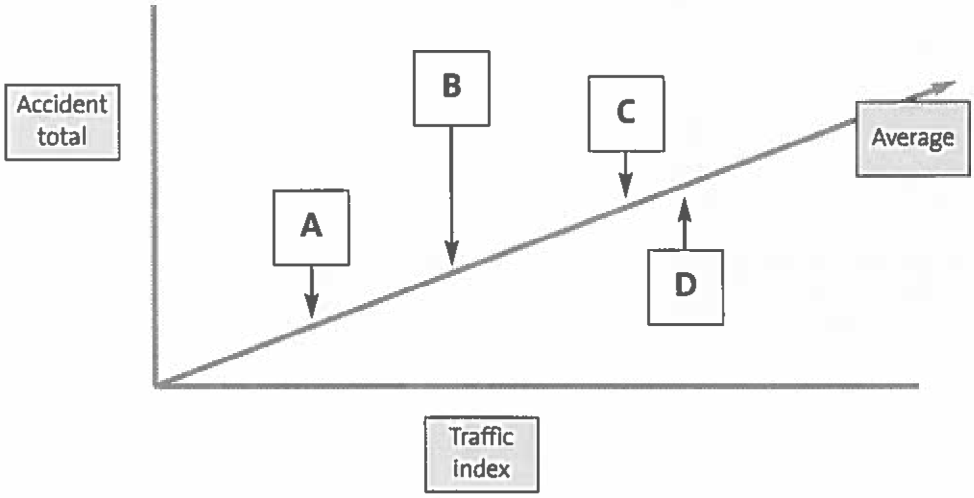
Some local authorities have developed methods for ranking sites based on accident rates, whereby the accident total is divided by a measure of traffic flow, for example, accidents per million vehicle kilometres. In this type of ranking system the traffic flow acts as an index of exposure for accidents, since it is assumed that accidents are related to the number of vehicles passing through the site.

Whilst accidents generally increase with an increase in traffic flow, it is difficult to define the precise relationship between accidents and flow at any site. The relationship varies according to accident type, time of day, type of road and junction layout etc. Traffic flow is one of a series of variables contributing to accident occurrence. As with accident total, accident rate listings do not necessarily generate treatable sites, and often generate sites with low accident numbers and low traffic flows.

A refinement of the accident rate listing method is the 'Potential for Accident Reduction' (PAR) (20). This method involves a series of lists that compare accident rates at individual sites with an average for that type of site. The worst sites are those that have an accident rate furthest from the average. They have the greatest potential for accident reduction if their accident rates were reduced to average levels.

In Figure 4.3, site B has the greatest potential for treatment as its accident rate is furthest from the average.

Figure 4.3: Example of PAR



It would be possible to use the PAR method to generate lists for roundabouts, signals, priority junctions and so on.

Accident rate listings provide a means of exposure for crude accident totals. However, they do not necessarily improve on the potential for treatment at the listed sites.

4.1.2.3 Severity ratio

The ratio between fatal/serious and total injury accidents at a site can be used as a means of weighting those sites with a higher severity ratio further up in the priority list for investigation. Once again this may not be a guide to treatability but can allow investigators to tackle more 'serious' problems first. It is up to individual highway authorities to decide whether or not this is appropriate to their road safety strategy, but the new national targets do emphasise the need to reduce fatal and serious casualties as a priority.

4.1.2.4 Fatal accidents

Sites where fatal accidents have been recorded should be routinely checked in order to establish whether any individual fatal accident forms part of a pattern of accidents at the site. However, efforts should not solely be concentrated on sites with single fatal accidents.

4.1.2.5 Accidents involving vulnerable road users

In order to target part of the casualty reduction effort towards locations with poor vulnerable road user safety, it may be necessary to weight sites with high proportions of pedestrian, child pedestrian, or cycle accidents. This may help to compensate for under-reporting within these casualty groups. This approach will have greater credibility if the highway authority has carried out research to establish the levels of under-reporting within the vulnerable road user groups.

4.1.3 Mass action

The mass action approach to accident reduction is where the accident data for the whole or a selected part of a highway authority area is searched to identify the locations of accidents having factors for which there is a well-tried accident reduction remedy. Examples of some suitable factors and remedies are:

- **Darkness accidents** – improving street lighting, road surface, or signs and markings
- **Skidding on a wet road surface** – improving road surface, or drainage

A poorly constructed drop-kerb crossing point leads to localised flooding.

- **Failure to comply with stop or give way signs and markings** – improving junction conspicuity
- **Conflict between opposing flows and/or turning movements at signal controlled junctions** – providing separate right turn facilities
- **Nose-to-tail collisions with vehicles turning from a major road** – local widening or improved signing or road surface
- **Excessive speed approaching large roundabouts** – introducing yellow bar markings
- **Single vehicle accidents especially on sharp bends** – leading to improved signing and delineation

A selection of several sites should be made from those having the highest number of accidents involving a particular factor.

The proportion of accidents of that particular type must be checked against other similar sites to ensure that the chosen factor really is the one with which the road user failed to cope, and for which there is a treatment.

For example, in a search for sites involving accidents occurring in darkness, two sites each had 12 darkness accidents. At one site the 12 darkness accidents occurred in a total of 35 accidents. At the other site the 12 darkness accidents occurred out of a total of 16 accidents. Obviously darkness is a more dominant factor in accidents at the second site. The justification of any action to treat darkness accidents at the first site should be carefully assessed since the rate of accident occurrence may not be unusual. Comparison of similar sites using statistical tests is discussed in more detail later in this chapter.

4.1.3.1 Road users

Ranking or plotting accidents by different classes of road user can produce results of great value in considering work priorities, especially for staff involved in road safety education, training and publicity (ETP) initiatives.

Cycle accident locations can be identified and ranked and the information then used to determine the need for special cycle facilities. Similarly with child cycle accidents, listings can indicate not only problem locations, but also where cycle training should be concentrated thereby helping to ensure that ETP resources are used effectively.

Analysis of pedestrian problem sites could assist policies for the provision and phased implementation of pedestrian crossing facilities. It would also indicate if age is a relevant factor, and help to establish where ETP initiatives for the young or elderly should be concentrated.

Other road users meriting this approach include motorcyclists and commercial vehicle drivers.

A priority ranking system that lists accidents or casualties against a number of characteristics such as time, location, number and age can provide valuable information to ensure that resources are directed to the situations most deserving of attention. Another method of locating accidents suitable for mass action treatment is by means of computer-generated plots covering the whole area under study.

4.1.4 Route action

With the route action approach, the distribution of accidents on routes of a particular road class is determined in order to identify those sections of road that have more accidents than expected for that type of road and level of traffic usage. The search process generally uses a highway unit of anything up to 25-30km in length within a time period of three or five calendar years.

Example of a route studied in Gloucester as part of SaferCity project.

Lengths of road can be ranked in descending order of number of accidents, number of accidents per kilometre or accidents per million vehicle kilometres.

It is important to consider whether or not to treat junctions in the overall analysis for a length of road, since junctions may have already been identified through one of the methods referred to above, and double counting of accident locations should be avoided.

Ranking can be carried out using accident rates as opposed to accident numbers. However, traffic flow is only one of a series of variables contributing towards accident occurrence so it may be unwise to use accident rate as the main ranking criterion, since the highest-ranked sites then tend to be those with low flows but with only one or two accidents. The rate can be useful in conjunction with other criteria such as an examination of statistically significant accident factors, to rank sites for priority treatment.

Take, for example, a single carriageway rural route 7.2km in length with 39 accidents in a three year period. The annual average daily traffic flow for that route is 11,500 vehicles.

The annual accident rate can be calculated as follows:

$$\frac{\text{Number of accidents} \times 10^6}{\text{Number of days in period} \times \text{traffic flow} \times \text{length of route}}$$

$$= \frac{39 \times 10^6}{[3 \times 365 \times 11500 \times 7.2]}$$

= 0.43 accidents per million vehicle kilometres

= 43 accidents per 100 million vehicle kilometres.

This figure can then be compared with a national or local average.

The values obtained by this calculation can relate either to lengths of road between junctions or lengths including junctions.

Some highway authorities routinely investigate all accidents on entire lengths of routes (for example all A and B class roads). The investigation programme is managed by undertaking a portion of the defined route network each year. Hence investigations can be carried out as part of a three year cycle. This method of operating has the advantage that it can be tied into cyclical road condition surveys such as skidding resistance measurement, and ensure timely use of valuable information.

4.1.5 Area-wide action

The area-wide approach looks at the distribution of accidents throughout the whole, or a selected part of an area, for a specific period of time. Generally, only urban areas (i.e. those containing roads subject to a 30 or 40 mph speed limit) are considered. The time period can be three or five years and the accident parameter can be total accidents, accidents per unit area or accidents per unit of population.

Speed cushion used in a residential area to reduce speed related accidents.

The boundaries of an area may be determined initially by routes or links forming the major road network, by parish or ward boundaries, or by other features such as railway lines, canals or rivers. Care should be taken to avoid setting arbitrary boundaries through the centre of residential areas.

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The area-wide approach is very important in identifying accident patterns involving vulnerable road users in urban areas. Accidents involving child pedestrians and cyclists do not tend to cluster at easily treatable single site locations, and solutions to these problems often involve the introduction of a series of measures across the area. Most area-wide action plans aim to reduce vehicle speeds and remove or mitigate the effects of through traffic by the introduction of traffic calming and traffic management measures.

Increasingly, highway authorities are looking to promote cycling and walking as safer modes of transport, and these techniques are becoming part of the 'Safer Routes to School' initiatives being promoted by the DTLR.

It is important to locate and identify those areas where vulnerable road users are most at risk, both in terms of total numbers, and relative to population figures. Vulnerable road users are normally defined as pedestrians, especially children and the elderly, the mobility or visually impaired, pedal cyclists, equestrians and (in some circumstances) riders of powered two-wheeled vehicles.

Initially, total accident and casualty numbers should be used to rank a number of areas. The areas listed should concentrate on the local distributor network and residential access roads.

The list of areas for investigation can be derived in different ways depending on the database system. GIS can be very useful for this, producing a series of plots for different users overlaid on the road system. In the absence of such a system, a series of overlay graph plots should be produced identifying all accidents on local distributor and access roads over a three or five year period. The plots could then be overlaid on base plans for the area.

A count can then be made using the plot of the total number of accidents within each area, and a list of the totals produced for further investigation.

Further overlays showing accident and casualty totals for the following vulnerable road user categories could also be derived:

- All pedestrian casualties
- Child pedestrians (under 16), as shown in Figure 4.4

Figure 4.4: A plot of child pedestrian accidents *(Source – Sandwell MBC)*

- Elderly pedestrians (over 60);
- All pedal cycle casualties
- Child pedal cyclists (under 16)
- Powered two wheeler riders
- Equestrians

The number of each type of vulnerable road user accident in each area is then determined. It is important to ensure that no significant clusters lie outside the areas already identified from the general accident plot.

A more detailed analysis can then be undertaken that includes a comparison with population details. For this to be achieved, estimates are needed for each of the areas in terms of total population, population under 16, and population over 60.

It is then possible to produce a number of alternative priority lists, including those generated by accident or casualty numbers, and those generated by casualty rates per head of population. A final priority listing for the areas should relate to priorities set out in the local highway authority's Road Safety Plan or Local Transport Plan.

4.2 Statistical analysis of accidents

Before the details of individual accidents are examined at a site, or throughout an area, it is important to carry out some level of statistical analysis. The following sections aim to introduce simple, well-tried statistical techniques that will help to identify accident problems and to establish whether these problems have any 'statistical significance'.

In order to give a first impression of problems at a particular site, route or area it is useful to compare percentages of accident types with those experienced nationally. If the percentage at the site is less than the national percentage then there is generally no need to carry out more complex statistical tests. These percentages can be calculated from Road Accidents Great Britain. Some useful percentages are shown in the table below.

Accident type	Built-up roads	Non built-up roads
Wet road	31%	39%
Dark	26%	25%
Pedestrian	22%	2%
Single vehicle (non pedestrian)	31%	29%

Averages or norms are often used to help establish the significance of accident parameters, for example, whether or not the proportion of dark accidents on a particular section of a route is significantly high and therefore worth investigating.

Statistical tests are used to establish the significance of the difference between the norm and a site or route value, and to determine whether this difference is due to random fluctuation, or a real problem associated with the site or route. The tests are also used to examine the probability of certain events occurring.

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The statistical analysis techniques frequently used in accident investigation are:

- Norms and standard deviation calculations
- The Poisson test
- The Chi Squared test
- The *k* test

These techniques and the interpretation of their results are explained below.

4.2.1 Averages or norms and the standard deviation

Accident analysis work often involves comparisons between different sets of statistics, in order to define problems. It is important to know whether the level of accidents is higher than expected, for example whether the proportion of wet road accidents at a site is worse than average.

When considering the occurrence of accidents over a period of time, for example on a particular route, the route can be divided into sections of equal length and the number of accidents in each section recorded. The average is found by dividing the total number of accidents by the number of sections in the route. This form of average is known as the 'arithmetic mean' or the 'norm'.

However, the norm as a single value is insufficient as a means of describing the occurrence of accidents on that route as it shows neither how accidents are dispersed along the route nor the extent to which large groups of accidents are occurring at a few locations. The most suitable measure for determining the dispersion of accidents per section compared with the norm is the 'standard deviation'.

The standard deviation can be calculated once the norm has been calculated.

For example, to calculate the norm and standard deviation for accidents along a route:

If x = number of accidents within a route section.
n = number of equal length sections comprising the route.
A = the sum of all the x values = $\sum x$ = total accidents on the route.

Then
the norm = A /n
and the standard deviation,
S = the square root of [$(\sum x^2 - n\{A/n\}^2) / (n-1)$].

The coefficient of variation must be calculated to understand whether or not this figure is significant and whether further investigation of sections of the route is necessary. It is calculated as follows:

The coefficient of variation $C_V = S / (A / n)$

When the coefficient of variation, C_V is greater than 1.0, the standard deviation, *S*, is considered to be 'very substantial' and therefore significant.

Example

A section of road is divided into 10 sections of equal length and the number of accidents within each section is noted:

Section	Accidents	Section	Accidents
1	8	6	14
2	4	7	6
3	5	8	7
4	11	9	4
5	3	10	5

Therefore, using the above notation:

x = 8,4,5,11,3,14,6,7,4,5

n = 10

and

$A = \sum x = 8 + 4 + 5 + 11 + 3 + 14 + 6 + 7 + 4 + 5 = 67$

Norm = A / n

= 67/10

= 6.7

Standard deviation, S = square root of [$(\sum x^2 - n\{A/n\}^2) / (n\text{-}1)$].

where

$\sum x^2 = 64 + 16 + 25 + 121 + 9 + 196 + 36 + 49 + 16 + 25 = 557$

so

S = square root of $\left[\dfrac{557 - 10 \times 6.7^2}{9}\right]$

= 3.47

Cv = 3.47 / 6.7 = 0.52

As Cv is less than 1.0, the standard deviation is not very substantial. However, those sections where the number of accidents is greater than or equal to the norm plus the standard deviation, that is those sections with more than 10.17 accidents, warrant detailed investigation. This is sections 4 and 6 on this route.

4.2.2 The Poisson test

Often a site is identified where accident numbers have increased in recent times. The Poisson test can be used to determine whether the recent increase is likely to persist or whether the increase was due to random fluctuation and therefore the number of accidents at the site will return to previous levels. The Poisson test is used to calculate the probability of a particular number of accidents occurring at a location in a given year when the long-term average for that location is known.

Example

Suppose the accident figures for a given site were as follows:

Year	1	2	3	4	5
Accidents	3	1	3	2	6