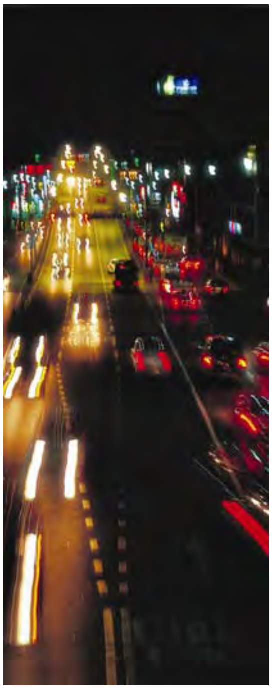

INCA – A Guide for Project Managers

Version 4.1

July 2009 (Reissued September 2012)
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INCA:
A Guide for
Project Managers

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Chapters and Appendices

1 Introduction

This note is a high level guide to INCA. It is intended to be read by anyone who requires a broad understanding of what INCA can be used for and how it works. Hands-on users of INCA and those who are interested in the fine detail of the calculations should also read the INCA user manual (Mott MacDonald, 2009).

'Reliable journeys' is one of three key objectives of the Highways Agency as well as being a central theme of the Eddington Report. Reliability is one of the sub-objectives within the 'Economy' section of a NATA appraisal.

In modelling, the term 'reliability' is often replaced by 'travel time variability' or 'journey time variability', with these two phrases used interchangeably. They refer to unpredictable variations in journey time, i.e. excluding predictable variations such as those associated with travelling at different times of day or different days of the week. Travel time variability on roads can be divided into two types: that due to incidents, and that due to more minor random variations in flow and capacity (referred to as day to day variability (DTDV)).

INCA (INcident Cost-benefit Assessment) is a spreadsheet application that can be used for estimating incident-related variability and DTDV on major inter-urban roads. It is used to compare variability and incident delay effects between do-minimum (DM) and do-something (DS) schemes[1]. The changes in delays and variability are monetised and discounted over a 60 year appraisal period to give the reliability benefits of the intervention. These benefits contribute to the total Present Value Benefits (PVB).

Some typical applications of INCA are discussed in Section 3. The current release of INCA is only suitable for use on motorways and grade-separated dual carriageways. Research has been carried out to investigate extending it to inter-urban single carriageways, but this work has not yet been implemented. Also, INCA is not suitable for urban roads, for which separate guidance exists in WebTAG Unit 3.5.7: The Reliability Sub-Objective (DfT, 2009b).

The rest of this note is set out as follows:

Section 2 explains what is meant by journey time variability and how it is measured and valued.

Section 3 discusses some typical applications of INCA.

Section 4 gives an overview of the data requirements for running INCA.

Section 5 sets out the sequence of calculations performed.

Section 6 talks about interpreting INCA outputs.

Section 7 explains some of the limitations of INCA.

[1] Also referred to as the 'without intervention' and 'with intervention' cases.

2 What is journey time variability?

The definition of journey time variability is provided in WebTAG Unit 3.5.7: The Reliability Sub-Objective (DfT, 2009b). To summarise, it represents **unpredictable** variation in journey times, i.e. it excludes predictable variations such as those associated with different times of day, days of the week, or times of the year.

On motorways and trunk roads variability can be split into two components: incident-related variability and day to day variability (DTDV). Each of these is discussed in the following sections.

2.1 Variability due to incidents

In INCA an incident is defined as any event that causes a temporary blockage of the main carriageway and therefore a reduction in capacity. INCA considers 12 different types of incident such as accidents, emergency roadworks and vehicle breakdowns. In many cases the reduction in capacity will lead to queuing which would not otherwise have occurred. INCA explicitly considers two aspects of this queuing:

- The time spent queuing
- The effect of the queue on journey time variability

Further details of how INCA calculates these effects can be found in Section 5.

2.2 Day to day variability

DTDV can be summarised as all journey time variability that is not caused by incidents. It is typically the result of unpredictable day to day variations in traffic flow (as opposed to the predictable variations such as the difference between weekdays and weekends), or random fluctuations in capacity such as those caused by the weather.

INCA includes methods for estimating DTDV as a function of flow and travel time. These are discussed in Section 5.

2.3 Measuring and valuing variability

Many different measures of variability have been proposed in the literature. WebTAG recommends the use of the standard deviation of travel time. The standard deviation is a measure of how travel times are distributed around the average, with increasing standard deviation associated with increasing variability.

For the purposes of appraisal it is necessary to apply a monetary value to the standard deviation of travel time. Using the so-called reliability ratio it is possible to relate the value of one minute of standard deviation to one minute of average travel time (where the latter is defined by the values of time given in WebTAG Unit 3.5.6 Values of Time and Operating Costs). For car travel the reliability ratio is 0.8, meaning that one minute of standard deviation has the same value as 0.8 minutes of average travel time.

Sometimes variance is mentioned rather than the standard deviation. The variance is the square of the standard deviation.

3 Typical INCA applications

INCA can be used for any scheme that will reduce the impact of incidents on journey time variability, or affects day to day (non-incident) variability. Such schemes tend to fall into three categories. The first consists of those schemes that affect the characteristics of incidents, typically by reducing the number of incidents, or reducing the time taken to deal with an incident. Examples include MIDAS (Motorway Incident Detection And Signalling), which will reduce the number of accidents[2], and CCTV, which will reduce the duration of incidents by enabling them to be identified sooner.

The second category includes those schemes which make the road better able to cope with incidents. This almost always means an increase in capacity, such as that associated with motorway widening. Increasing capacity means that more capacity is available during the incident and a smaller queue builds up. When the blockage is removed from the carriageway the extra capacity means that the queue clears more quickly.

The third category of scheme is where day to day variability is reduced, most notably on controlled motorways where variable mandatory speed limits are used.

Some schemes will include elements of more than one category. For example, Dynamic Hard Shoulder running (DHS) will include increased monitoring to reduce incidents and improve response times, the option of using the hard shoulder increases capacity, and the use of variable speed limits improves day to day variability.

Detailed guidance on the use of INCA for DHS can be found in the user manual.

4 Data requirements for running INCA

INCA is a network-based model with the capability to represent schemes using up to a maximum of 63 links. Up to 63 routes can be defined for each test.

4.1 Link data

4.1.1 Network vs feeder links

Links in INCA may be either ‘feeder’ or ‘network’ links. Feeder links perform a similar role to zone connectors in traffic assignment models – they do not correspond directly to real physical links but are a more abstract representation of the part of the journey that does not take place on the main network. Data requirements for both link types are the same, though it is expected that for feeder links the same data will apply to the DM and DS scenarios.

[2] MIDAS includes induction loops in the carriageway which are used to detect queuing. These loops are then linked to variable message signs which warn drivers of the queue. This leads to a reduction in secondary accidents where a vehicle collides with the back of a queue.

The non-linearities in the variability calculations (see Section 5 for details) mean that the level of variability on the feeder links can have a significant effect on the benefits calculated by INCA. The characteristics of the feeder links, particularly the length (which is a key determinant of variability), therefore need to be coded in accordance with the good practice set out in the User Manual. The significance of the feeder links is discussed further in Section 7.4.

Network links are usually those links which are being modified as part of the scheme. However, it is also possible for them to represent links that may be only indirectly affected. For example they may be parallel to the scheme and benefit from reduced traffic and hence less variability when the scheme is implemented.

4.1.2 Link characteristics and flow data

This is fairly standard data that needs to be defined for all links: length, two-way AADT, percentage of heavy vehicles, number of lanes and capacity. This data can usually be obtained from an existing model[3]. Otherwise it is available from various Highways Agency databases (such as TRADS for flow data).

An induced traffic multiplier can be specified for each link, indicating that DS flows are higher than DM. This may be a result of wider area re-assignment or variable demand effects. Use of this feature usually depends on being able to obtain the value of the multiplier from existing models. Induced traffic is not usually applied to feeder links.

4.1.3 Incident data

For each link and scenario (DM or DS) INCA requires a range of data for each of its 12 incident types. This includes characteristics such as the incident rate, the duration of the incident and the average number of lanes blocked. A set of values for different road types are available from TRL (2004)[4]. In many INCA applications these values can be applied. The exception will be those schemes which directly affect incidents, in which case the incident rate, duration and/or the number of lanes blocked will need to be changed accordingly for the DS scenario, for those links affected by the scheme.

4.2 Route flow data

INCA does not include any assignment procedure so the user has to specify which links are used for each route in the network. The user also has to specify the flow on each route.

If an existing traffic assignment model is available then this route data can be obtained by carrying out select link analyses on the network links.(If not then analysis of roadside interview or similar data will be required.)

Route flow data is required in addition to link flow data because variability benefits need to be calculated at the route level. This is explained further in Section 5.2.2.

[3] While AADTs are not normally a direct output of traffic models, they can normally be obtained by applying factors to the modelled periods flows. These factors are usually calculated from long term count data from sites in the study area.

[4] These values are based on incident data collected from the West Midlands motorway network between December 2002 and November 2003.

4.3 Other data

INCA also requires a variety of other data, including values of time and flow group definitions. Standard values are applied for both of these.

The principle of flow groups follows that used in COBA10. Like COBA10, INCA uses just 4 flow groups, compared with the 8 or 10 in COBA11 (DfT, 2006).

Flow groups are used to group different hours in the year according to the level of flow. For example, INCA flow group 4 represents the 500 busiest hours in the year. Flow group multipliers are used to convert from AADTs to hourly flows in each flow group. INCA comes with a default set of multipliers, which can be overwritten if required.

Using flow groups allows INCA to take account of the variation of flow levels throughout the year, without the need to explicitly represent different time periods, days and seasons.

5 An overview of the INCA calculations

5.1 Link-based calculations

INCA starts with a sequence of calculations for each combination of scenario (DM/DS), link, incident type and flow group. These are summarised in Figure 5.1, which is followed by a brief text description of the process. The detailed formulae for all the calculations can be found in the user manual.

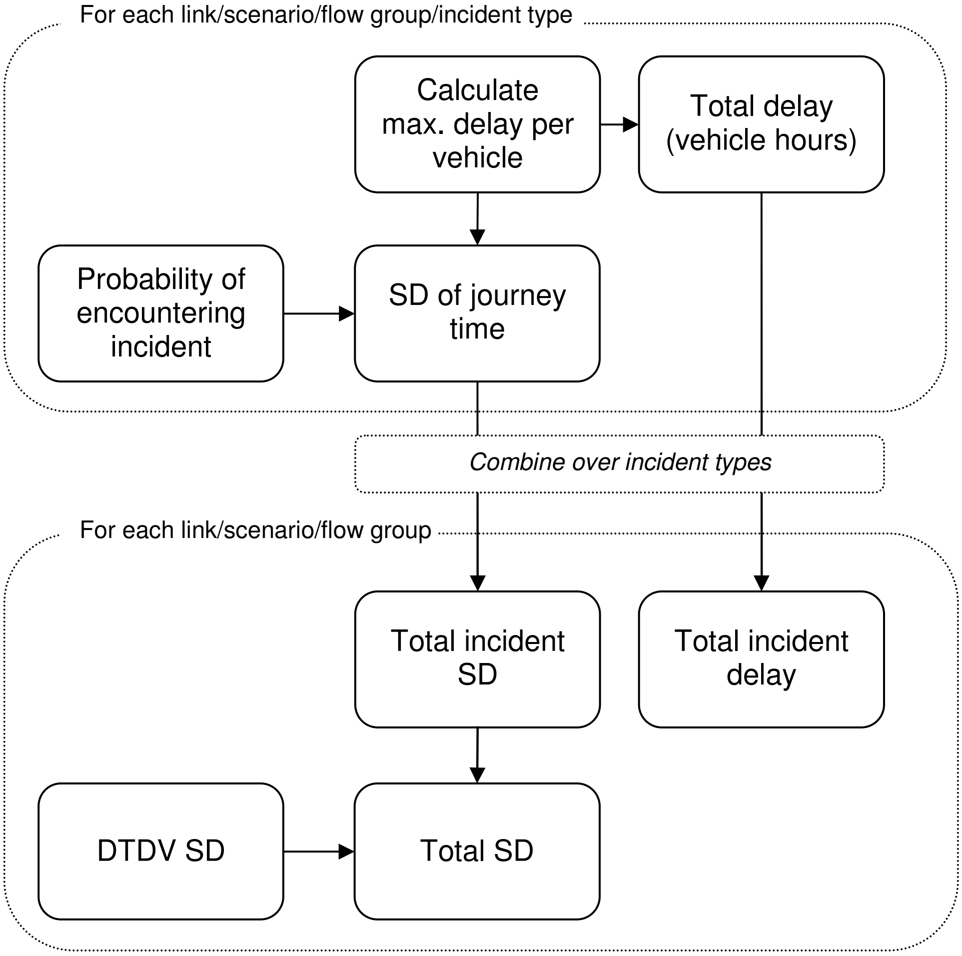

Figure 5.1. Overview of link-based calculations in INCA (SD=standard deviation; DTDV=day to day variability).

5.1.1 Incident delays

Initially INCA considers each combination of link, scenario, flow group and incident type in turn. Using standard deterministic queuing formulae[5] it calculates various delay measures for each incident. These include the maximum delay per vehicle and the total delay in vehicle hours.

[5] Deterministic queuing is that which only occurs when capacity is exceeded. For example, if the capacity is 1800 vehicles per hour and the flow is 2000 vehicles per hour, then after an hour the queue will have increased by 200 vehicles. In the case of INCA 'vertical queuing' is also assumed, i.e. the physical extent of the queue (which may then affect upstream junctions) is not taken into account.

The flow used in these calculations is the AADT, multiplied by the relevant flow group multiplier[6]. For the DS scenario any generated traffic specified by the user is included. This flow may be reduced to account for diversion when an incident occurs and some of the traffic that would normally use that road diverts to alternative routes. The level of diversion increases according to the maximum expected delay, using the method recommended in TRL (2004).

INCA assumes that the diverting traffic experiences the same delay as non-diverting traffic.

5.1.2 Incident variability

The effect of each incident on the standard deviation (SD) of journey time mostly depends on the maximum delay per vehicle, and the probability of any given vehicle encountering an incident. This probability depends on the number of incidents that occur in a year (calculated from the AADT and the incident rate) and the average duration of each incident.

5.1.3 Combining over incident types

The total incident delay (in vehicle hours) is multiplied by the number of incidents per year and summed over all incident types to give the total annual delay for each link, scenario and flow group.

Obtaining the standard deviation over all incident types is more complicated. It is not possible to simply sum the standard deviations. Instead they first have to be squared to obtain the variance. These variances are then summed over incident types to get the total incident variance[7]. The square root of this is taken to obtain the total incident standard deviation (by link, scenario and flow group).

5.1.4 Day to day variability

Models have been calibrated for INCA which give the standard deviation for journey times as a function of the mean journey time for a variety of road types, including 3 and 4 lane 'normal' motorways (D3M and D4M), 3 and 4 lane controlled motorways, roads with MM-DHS and two lane dual carriageways with grade-separated junctions (Mott MacDonald, 2008a, 2008b). The mean journey time is estimated using COBA speed-flow curves.

5.1.5 Total link variability

Once the DTDV SD has been calculated it is combined with the incident SD to obtain the total SD for each link, flow group and scenario (by taking the square root of the sum of the two variances).

5.2 Benefit calculations

Figure 5.2 shows how the link-based data are then used in the estimation of benefits. The following sections describe this process in a bit more detail.

[6] The flow group multiplier is used to convert the AADT to the hourly flow in each flow group. Default values are supplied with INCA, which can be replaced by the user's own values.

[7] This assumes that the various incident types are independent of each other.

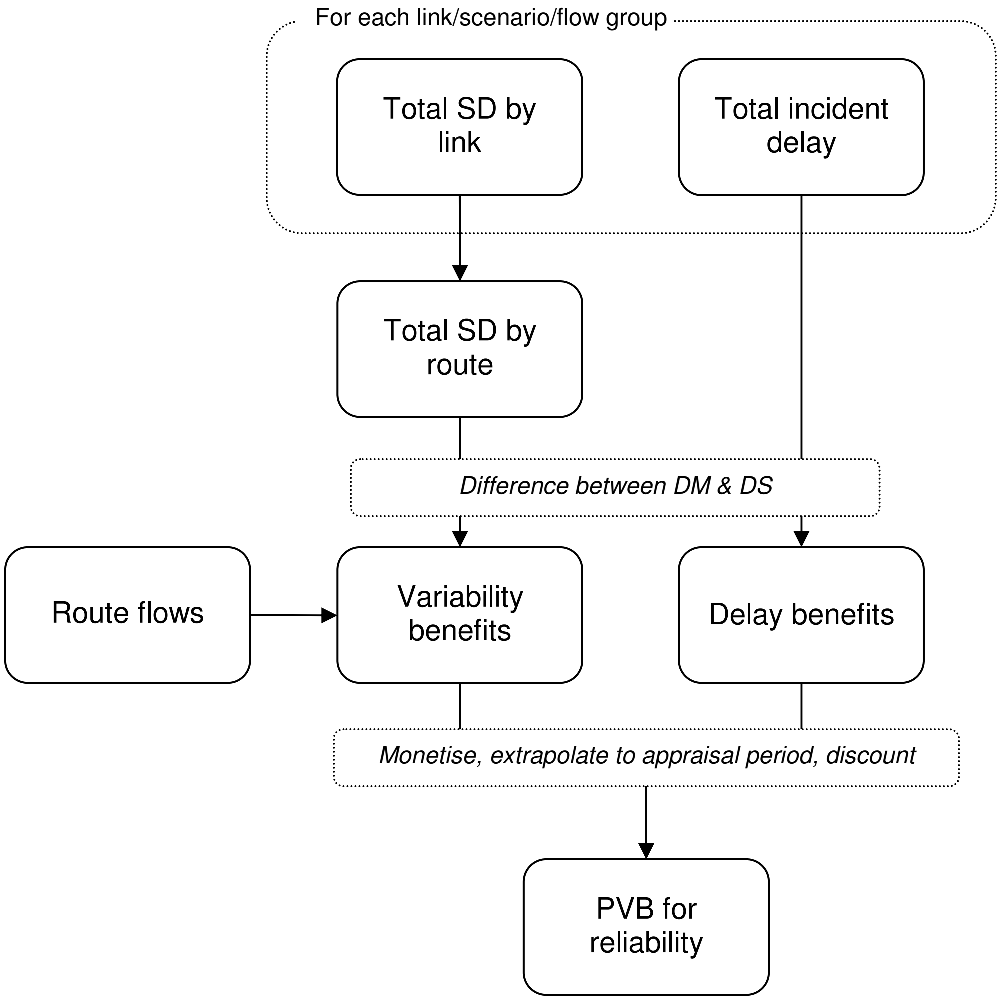

Figure 5.2. Calculation of benefits from link-based data.

5.2.1 Incident delay benefits

The incident delay benefits are the reduction in delays between the DM and DS. This can be done by link, incident type and flow group.

5.2.2 Variability benefits

The variability benefit calculation is more complicated than the delay benefit. This is because, unlike journey times, it is not possible to simply sum the standard deviation over all the constituent links to obtain the route standard deviation. This is referred to as non-linearity. Route-based and link-based calculations therefore give different answers. In INCA the route-based calculation is used, as recommended in WebTAG.

The standard deviation for each route is calculated by taking the square root of the sum of the variances of all the links that make up the route. This implicitly assumes that the journey times on each link are independent, which may not be the case in reality. This is discussed further in Section 7.3.

For each route the difference in standard deviation between the DM and DS is multiplied by the route flow to obtain the benefit. This is done for each flow group.

5.3 Monetisation of benefits

Delay and variability benefits are monetised using the standard or user-input values of time and the reliability ratio, as discussed in Section 2.3.

5.4 Interpolation and extrapolation, discounting

A different INCA spreadsheet is required for each modelled year. As with standard transport models it is usual to model the scheme opening year, and 15 years later. A separate spreadsheet is used to take the results from up to six model years and interpolated/extrapolated to cover the whole appraisal period (usually 60 years, but may be 30 years for technology schemes). Growth in the value of time and discounting are also applied to obtain the Present Value Benefits (PVB) for the reliability impacts of the scheme.

6 Interpreting INCA outputs

6.1 Breakdown of benefits by source

The INCA spreadsheet for a single modelled year gives a fairly detailed breakdown of benefits by flow group and type of benefit (delay and variability). There is also a breakdown by type of incident (for delays) and by type of incident and DTDV for variability. Some care is needed in interpreting the latter. Because of the non-linearities in the calculations, in most cases it is not possible to unambiguously split the total variability benefits between each incident type and DTDV. The results presented use a crude approximation to give some idea of the importance of each. However, this is known to given anomalous results in some cases, i.e. some individual elements may be of the wrong sign or magnitude. If this happens then the total reliability benefit can still be used.

6.2 The effect of induced traffic

If there is induced traffic on a link (i.e. there is more traffic in the DS than DM) then, other things being equal, delays and variability will be higher in the DS. This may offset any positive effects of the scheme, leading to overall negative reliability benefits.

Induced traffic in INCA may be a result of re-assignment from a wider area, or other demand responses such as a change of mode or destination. In the first case INCA will not include the variability benefits resulting from reduced traffic elsewhere in the network.

7 Limitations of INCA

7.1 Number of links

As mentioned earlier INCA is currently limited to a total of 63 links, including both network and feeder links. This sometimes requires the INCA network to be a simplified and aggregated representation of reality. The effects of this can be limited by following the good practice advice in the INCA User Manual.

7.2 Validation of incident-related variability

The calculation of incident-related variability in INCA has been built up from first principles. It has not been validated against any observations of the actual variability caused by incidents. (This does not mean that the user himself/herself has to validate an INCA spreadsheet, other than verifying that all the input data are correct.)

7.3 Independence of link journey times

When calculating the standard deviation for the whole route INCA assumes that the journey times for the constituent links are independent, e.g. the time on one link being higher than average does not affect whether the time on another link is higher or lower than average. If in reality they are positively correlated then INCA will be underestimating the route standard deviation. On the other hand if they are negatively correlated INCA will be overestimating it.

On the whole we would expect link times to be positively correlated, i.e. when they are higher than average on one link they will be higher than average on adjacent links as well. This means that INCA will usually give a conservative estimate of the true variability benefits.

7.4 Effect of feeder links

Suppose a scheme reduces the variability on a single link in the motorway network. Because of the non-linearity in the route variability calculation, the variability benefit to a short distance trip passing through that link will be higher than that to a long distance trip. The difference in benefit could be as much as a factor of 3 or 4. The reasons for this are discussed below.

This means that the characteristics of feeder links, and the level of variability assumed for them, can have a large influence on the total variability benefits. This is true even if the feeder links don't change between the DM and DS. This is illustrated by the following graph. In this example the standard deviation (SD) on the scheme link reduces from 100 seconds to 80 seconds between the DM and DS, i.e. a reduction of 20 seconds. However, the reduction in the *route* SD also depends on the variability on the feeder link. If this is zero then the route SD reduces by 20 seconds, but as the variability on the feeder link increases the difference between DM and DS variability gets smaller.

The graph shows how the benefit per trip (on the y-axis) decreases as the variability on the feeder link increases (shown on the x-axis). A short distance trip will tend to have a lower standard deviation on the feeder link compared to a long distance trip hence, according to the graph below, will receive a greater benefit from the same scheme.

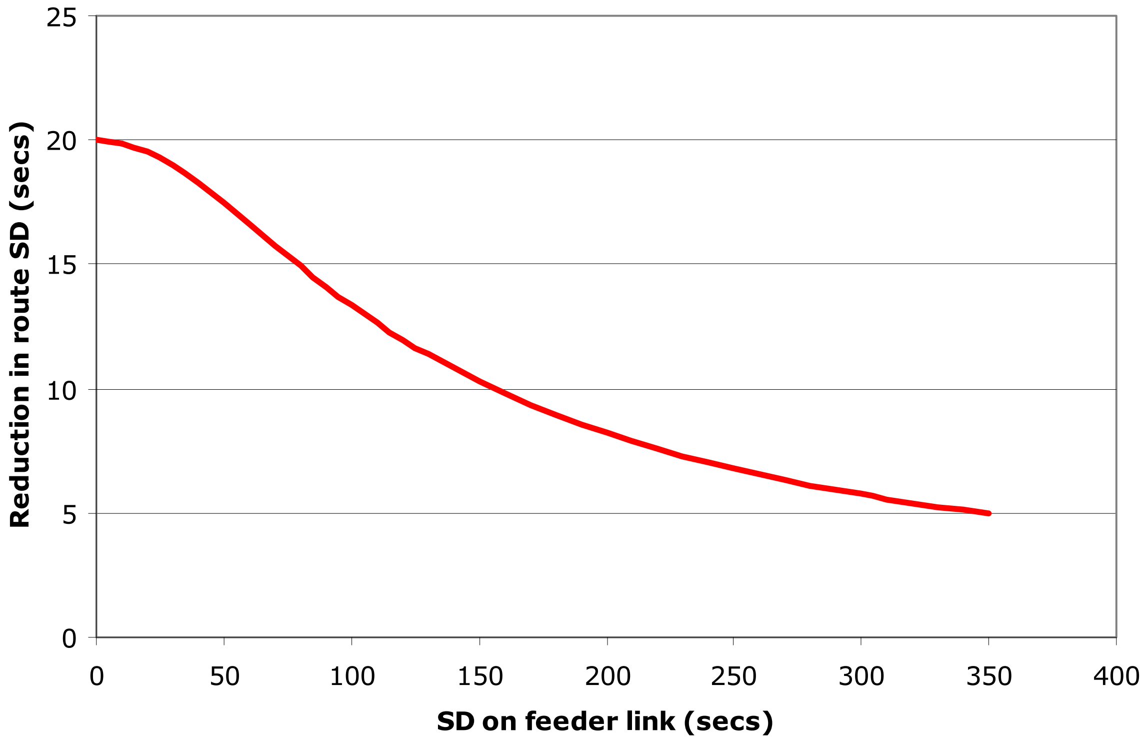

Figure 7.1. The effect of feeder links on variability benefits.

This means that the variability benefits are very sensitive to the characteristics of the feeder links, in terms of their flow, length and incident characteristics. The user manual provides advice on good practice in the use of feeder links, but even if this guidance is followed there will still be a degree of uncertainty associated with the variability benefits reported by INCA.

Feeder links do not have any effect on the delay benefit calculation, which can therefore be considered more robust.

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Acknowledgement

INCA is a development of the INCIBEN spreadsheet originally produced by John Fearon.