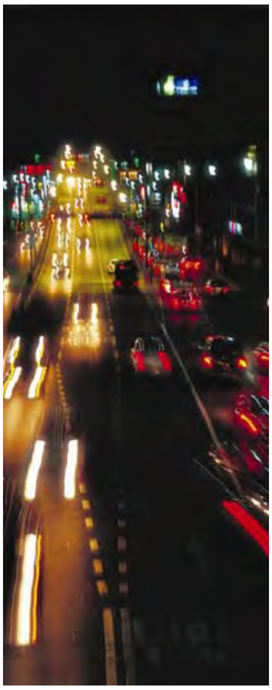

INCA User Manual

Version 4.1

July 2009 (Reissued September 2012)

Department for Transport

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From Thursday 13th September 2012, the responsibility for the maintenance, support, and sale of INCA on behalf of the Department for Transport has transferred from Mott MacDonald to Atkins Limited. For all enquires, please contact Atkins via email on INCA@atkinsglobal.com in the first instance or by telephone on +44 (0)1372 756272

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INCIDENT COST BENEFIT ASSESSMENT (INCA) SOFTWARE (Version 4.1)

User Manual

Issue and Revision Record

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D	July 09	M Wisten	A Gordon	C White	Issue

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1 Introduction

1.1 Overview

INCA (INcident Cost-benefit Assessment) is an Excel-based spreadsheet application for calculating incident-related delays and travel time variability costs, and for quantifying the benefits that may arise from remedial measures to reduce their impact. It has been developed for the Department for Transport for economic appraisal of the impact of incidents on inter-urban grade-separated high standard dual carriageways and motorways.

The current version of INCA is Version 4.1 and includes calculation of day-to-day variability (DTDV) as well as incident-related variability. The DTDV functions have been estimated for motorways and dual carriageways with grade-separated junctions only. The spreadsheet is currently not suitable for other types of dual carriageways or single carriageway roads.

This user manual is intended for hands-on users of INCA and those interested in the technical detail. A broader overview of INCA can be found in the separate document called 'INCA: A guide for project managers'. We recommend that users read the Project Manager's Guide first before using this manual.

The current version of INCA has been developed for motorways and dual carriageways. However, incident parameters and other INCA parameters have not been fully developed for non-motorway roads therefore the current version of INCA should not be used for assessing these schemes until the relevant parameters become available.

1.2 Contacts

Contacts for support on the application of INCA are:

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1.3 Structure of the manual

The rest of this user manual is structured as follows:

Chapter 2 deals with computer system requirements and provides installation information for the INCA spreadsheet.

Chapter 3 gives an overview of the INCA methodology and applications.

Chapter 4 describes the overall structure of the INCA spreadsheet and how inputs are captured in INCA.

Chapter 5 describes the worksheets that capture data and network information in INCA:

- The primary input sheet (PIS), which is described further in Chapter 6
- The secondary input sheet (SIS) which is described further in Chapter 7
- Trip matrix and value of time input sheet is described further in Chapter 8
- The speed flow and day-to-day variability worksheet is described in Chapter 9

Chapter 10 describes the outputs for one forecast year. These are then consolidated in the main worksheet, which is described in Chapter 11.

Advice on constructing INCA networks is described in Chapter 12.

The INCA installation comes with an example application that is described in Appendix A. Appendix B describes the calculations for incident delay and travel time variability. Default values for incident parameters are contained in Appendix C.

2 INCA Software

2.1 Installation

The INCA installation file is supplied via the INCA website www.dft-inca.org.uk. Usernames and passwords are supplied by INCA support. The software appears on the site as INCA 4.1.exe. This file should be saved to the hard disk and run to install the INCA spreadsheet. The default installation directory is C:\INCA\.

An example INCA network is also installed together with the INCA spreadsheets and can be found in a subdirectory called ‘Example’.

The INCA User Manual and the INCA Project Manager’s Guide will be placed in a ‘manuals’ subdirectory together with software release notes. All documentation is in pdf format which can be read using Adobe Reader (available free from www.adobe.com/reader).

The INCA website also provides other relevant information such as how to purchase INCA.

2.2 System Requirements

To run INCA we recommend the following as a minimum specification;

- Windows XP or Vista operating system.
- A licensed copy of Microsoft Excel 2003 or later
- 256Mb RAM
- 20Mb free hard disk space (for installation)

The macro security in Excel should be set to *Medium* in order to allow all functions of the INCA spreadsheet (from the Excel menu choose Tools->Macro->Security). When INCA is opened the user will see a security warning saying that it contains macros. The user should choose the Enable Macros option otherwise INCA will not work properly.

2.3 Caution

As INCA is an Excel spreadsheet, the user should be aware of potential Excel-specific problems when editing data. The user is advised to avoid dragging data between cells as it can corrupt cell references in the INCA calculations. Copying and pasting of data should be OK.

3 Overview of the methodology and applications for INCA

3.1 Introduction

INCA makes use of a database of the frequency at which twelve types of road incident occur, their build-up durations, and the number of lanes each incident type affects on average in order to calculate incident-related delay and travel time variability (TTV). The latter is represented as variations about expected journey times, and is a function of other values calculated in INCA that include the probability of a journey encountering an incident; the average delay per vehicle affected; and the variance of the delay per vehicle affected.

3.2 Incident delay calculation

INCA incident delay methodology is based on deterministic queuing theory which means that the maximum delay for an incident occurs to a vehicle that passes the incident location when the incident is just cleared from the motorway/carriageway, and that the average delay for vehicles passing the incident location is half the maximum delay. This assumes that demand is constant during the incident.

However, flows vary by time-of-day and day-of-week. As incident delay is a function of flow it is necessary to estimate delays for the different flow conditions. To achieve this condition, flows are classified into flow groups, and the delays arising from typical incidents are calculated for each of these flow groups. INCA models four flow groups, consistent with COBA10 flow groups. The current version of COBA (COBA11) uses 10 flow groups, see Chapter 7 of Part 4 of the COBA Manual.

To calculate the delays caused by an incident, it is assumed in INCA that:

(a) The demand flow is constant for the whole of the build-up and queue decline periods;

(b) The incident delays are measured relative to the time at which a vehicle would have passed the incident location;

(c) The modelled incident delay per vehicle should not exceed some locally determined maximum.

(d) Incidents have no effect beyond the end of the link.

These assumptions are likely to have more effect for incidents which cause long delays. To limit the effect of assumption (a), demand flow is split into flow groups as already indicated. Where they represent relatively short time periods, longer incidents could spill over into an adjacent flow group.

Fortunately, for all but the busiest flow groups, spill-over effects between flow groups are likely to have no net effect on the likelihood of any individual vehicle within each flow group being affected by an incident. INCA does not implement a proper spill-over mechanism. To compensate for this all link flows are capped at 95% of capacity to ensure that queues do not grow indefinitely.

Incident delay in INCA is calculated according to the relationships given in Appendix B. The calculation is over all links, all flow groups, and all incident types. The difference between DM and DS gives the value of the delay benefits from the scheme. This is converted to monetary values by application of values of time.

3.3 The effect of diversion

The delays which occur on road sections are dependent on the proportion of traffic diverting to avoid the incident, which in turn is dependent upon the overall duration of the incident, the length of the backed up queue and the availability of alternative routes and reliable information. Thus the total level of this diversion will depend on:

(a) The availability and attractiveness of alternative routes;

(b) The flow on the main carriageway and the proportion of capacity reduction;

(c) The duration of the incident; and

(d) The average or maximum delay per vehicle caused by the incident.

The diversion mechanism in INCA is that recommended in TRL (2004). The diversion proportion relationship in given in Appendix B and has been developed from observed data.

The traffic diverting is capped at 90% of excess demand (i.e. the difference between flow and incident-reduced capacity).

Very few drivers will divert until the queue has reached a suitable junction. Therefore, the diversion rate is likely to build up gradually as queues lengthen and subsequently be limited by the capacity of any available diversion route for that or earlier diversion opportunities. The TRL formula increases the diversion proportions for longer queues and is intended to represent the net effect of all the diversion opportunities. It is assumed that diverted traffic experiences the same delay as the traffic that remains on the main carriageway in INCA.

The user can specify the maximum diversion proportion. The default is 1.0, to represent the condition where 100% of traffic will divert if required.

3.4 Travel time variability

3.4.1 Overview

Travel time variability, in this document, refers to the sum of incident-related variability and day-to-day variability (DTDV). Journey times of individual vehicles and drivers fluctuate around an average journey time for a particular time period. Such fluctuations arise from two primary sources:

1. Variations in journey time between different time periods and days, caused by different traffic conditions, known and anticipated factors such as long term road-works; and

2. Variations of travel time at a specific time of day caused by unexpected traffic congestion and unforeseen incidents which reduce capacity, such as unexpected worsening weather conditions, accidents and breakdowns.

Variations in travel time under (1) are predictable and feed into transport benefit assessment frameworks such as COBA and TUBA. Variations in travel time as classified under (2) are unpredictable for individual journeys, although their mean and distributions can be predicted. They are not measured in COBA or TUBA economic evaluation, and are the subject of the INCA appraisal.

If a journey departing at a particular time and day is considered as having a mean journey time, then its variability is represented by a distribution of times about the mean; this distribution can be characterised by one or more parameters. As discussed in WebTAG 3.5.7 'The Reliability Sub-Objective' (DfT (2008)), the preferred measure of variability is the standard deviation of travel times around this mean.

3.4.2 Travel time variability calculation

The calculation of travel time variability at journey level involves all variability components affecting a journey. These are:

- Incident variability on all links
- Day-to-day variability on all links, i.e. variability not caused by incidents but by fluctuations in demand, weather, etc.

For each incident type the real-life build-up periods and numbers of lanes closed are distributed around the mean values. In order to calculate TTV, the standard deviation of travel time for whole journeys is established by:

(a) Calculating the variance of travel time for a typical single incident of each type for each individual link for each flow group; and multiplying this by the appropriate probability

(b) Calculating the variance caused by day to day variability for each link and flow group, as a function of average travel time

(c) Calculating from (a) and (b) the variance, and hence the standard deviation, of travel times for all routes through the network (as defined by the user).

Variances may be summed over a series of links and incident types, assuming the probability of incidents on one link/type is independent of the probability on other links/types. Standard deviations may not be summed in that way.

It is important that the route standard deviation calculated by INCA represents the whole journey, and not just that part of it passing through the scheme. This is achieved in INCA by modelling feeder links which represent that part of the journey not taking place on scheme links. Further advice on feeder links can be found in Section 12.

To calculate total cost TTV (in time units) the standard deviations for each route are multiplied by the route flow. The route flow is one of the user-defined inputs to INCA. It will be reduced for any flow groups where link flows exceed 95% of capacity.

The difference between the TTV costs in the Do Minimum and the Do Something produces the TTV benefits. These are then monetised.

Further details of the TTV calculations can be found in **Appendix B.**

3.5 Applications of INCA

Typical schemes for which the INCA methodology is appropriate range from motorway traffic management measures to motorway widening schemes which change incident-related delays and travel time variability. These include:

(a) Measures to reduce the likelihood of incidents affecting a running carriageway, such as accident reduction measures or the provision of hard strips or extra vehicle refuge facilities adjacent to the running carriageway;

(b) Measures to reduce incident durations such as improved surveillance, information services, and dedicated recovery services;

(c) The widening of a running carriageway or reallocation of capacity on an existing road;

(d) New road schemes which change the capacity of existing highways;

(e) Hard-shoulder running schemes, i.e. Managed Motorway – Dynamic Hard Shoulder (MM-DHS) schemes.

INCA uses data on incidents on the motorway network. This type of data has not yet been compiled for all purpose inter-urban roads or urban roads. In principle, INCA can be applied to all purpose inter-urban roads, however this should not be done until relevant parameters become available.

The INCA methodology cannot be applied to urban roads as they have markedly different characteristics compared with dual carriageway inter-urban roads, in terms of incident impacts on the road itself, diversion behaviour and other secondary impacts. Methods for the assessment of variability on urban roads can be found in WebTAG Unit 3.5.7.

4 Structure of a Typical INCA Run

There are two stages to setting up a full INCA run:

(a) Setting up INCA for each forecast year. Each of these represents a complete calculation of INCA delay and TTV benefits for one year before any discounting is applied. In the INCA release, the filename for this spreadsheet is 'INCA 4.1 OneModelYear.xls', which should be copied and renamed accordingly for each application. A minimum of two forecast years, and a maximum of six, is required to be able to carry out a 30 or 60 year appraisal.

(b) Setting up the INCA Master Spreadsheet to allow 30 or 60 year appraisal. This pulls together all the single year INCA spreadsheets to produce complete results reported in 2002 base year values. In the release, the file is called 'INCA4.1.xls', which may be copied and renamed accordingly for each application.

The main INCA spreadsheet carries out economic appraisal to a specified horizon year using a method similar to that used in the TUBA software with the number of modelled years limited to a maximum of six appraisal years.

Data for the years between any two modelled years is linearly interpolated. Results for years before the first modelled year are extrapolated from the first two modelled years. Beyond the last modelled year data is extrapolated using a horizontal line. This is illustrated in Figure 4.1 which shows a case with only two modelled years.

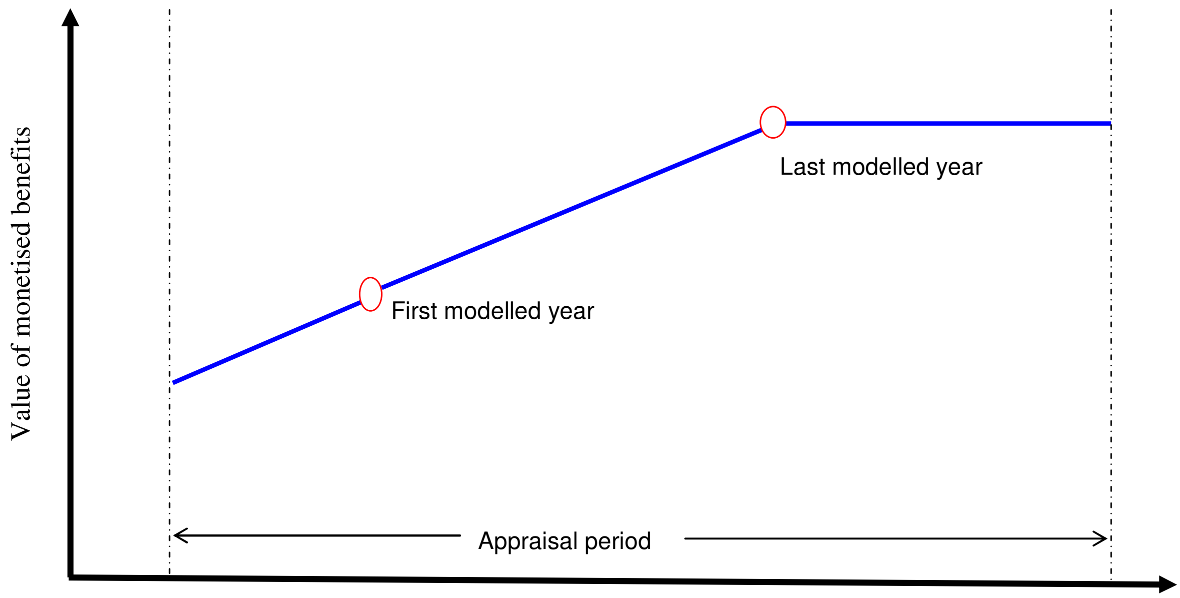

Figure 4.1. Interpolation and extrapolation with two modelled years.

The INCA process is summarized below.

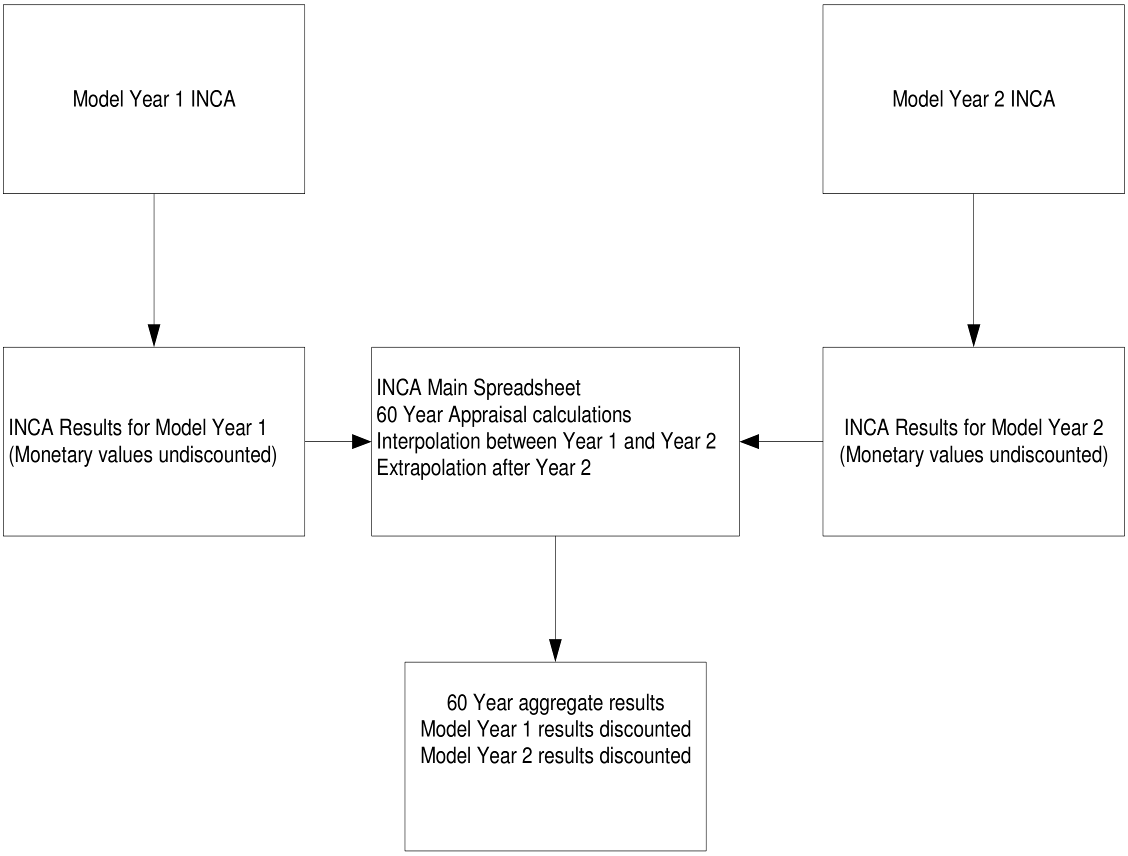

Figure 4.2: INCA Setup for a typical 60 year appraisal with two modelled years

5 INCA Model Year Spreadsheets

The single year spreadsheet captures all scheme and network data via a set of four key worksheets. The INCA structure including inputs and outputs is summarised Figure 5.1 below and is discussed in more detail in the sections that follow.

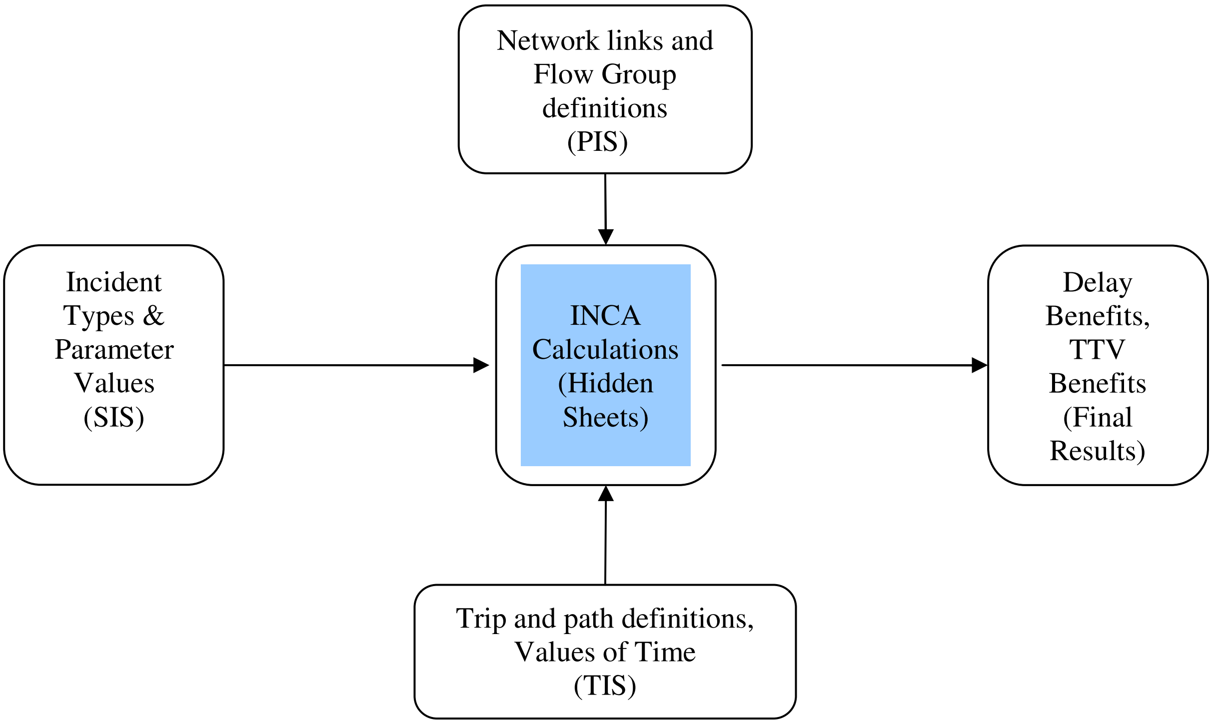

Figure 5.1: INCA Spreadsheet Structure

The INCA single year appraisal has four key input worksheets that feed into hidden worksheets that carry out calculations that make up the INCA spreadsheet program. The four input worksheets are:

i) The Primary Input Sheet (PIS)

ii) The Secondary Input Sheet (SIS)

iii) Trip Matrix and Value-of-Time Input Sheet

iv) Speed Flow and Day-to-day Variability Sheet (DTDV).

The four worksheets are described in more detail in the sections that follow.

6 Primary Input Sheet (PIS)

The PIS worksheet contains definitions and values for some global INCA parameters and network link definitions and link parameters. The PIS worksheet also has definitions of flow groups (in the COBA sense) that are used in the INCA appraisal. The user provides the following information as input:

- Global parameters (modelled year, current year of data, traffic growth from base year, maximum diversion proportion, average delay threshold, threshold factor, One/Two way indicator). These parameters are explained further below.
- Link data (type, length, number of lanes, lane capacity and observed flows, road types)
- Flow group definitions

A number of these parameters can change between the Do Minimum (DM) and the Do Something (DS). For motorway widening schemes, for example, the number of lanes in the DM and DS will be different for the relevant links. The type of road may also change between the DM and DS.

The Primary Input Sheet (PIS) shown in Figure 6.2 is the first of four worksheets that form the INCA input. In order to illustrate the required inputs to the PIS we consider the simple example shown in Figure 6.1 represents a motorway widening scheme between Junction 2 and Junction 3.

The DM has 3-lanes for this section of the motorway while the DS has 4-lanes. Together with this, the road types are changed from D3M (in the DM) to D4M (in the DS) so that the correct day-to-day variability relationships are applied for the DM and DS respectively. In this simplified example, trips do not extend far beyond the motorway network section (Junction 1 to Junction 4); all feeder links therefore have short distances.

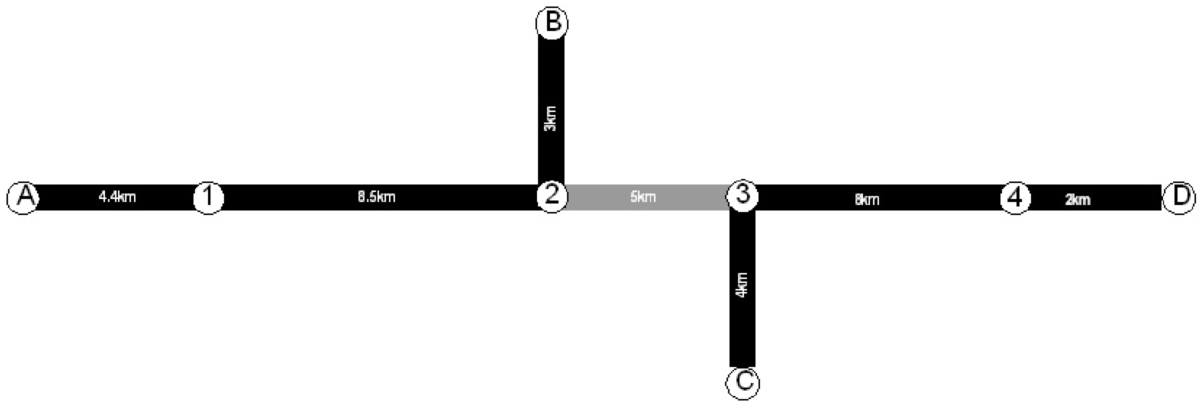

Figure 6.1: Motorway Section Modelled

PRIMARY INPUTS

Scenario Name: INCA version 4.1 Example 2010

Parameters

Maximum Diversion Proportion	Directions for Calculation of Benefits	Average Delay Threshold (Min)	Threshold Factor	Base Year of Data	Traffic Growth Factor from Base Year to Model Year	Accident Rate Decline Factor from Base Year	Heavy Vehicle PCU Factor
1.0	2	30.00	0	2007	1.03	0.00	2.5

Base Year Traffic and Network Data

Link Between Junctions	Link Type (Network=1; Feeder=0)	Length (kms)	Two-way Base Year AADT (Veh/day)	Percentage of Heavy Veh during Flow Groups 1-3	Percentage of Heavy Veh during Flow Group 4	Number of Lanes per Direction		Proportion of Traffic Generated	Capacity per Lane (PCUs/Hr)	Road type	
						Do Minimum	Do Something			Do Minimum	Do Something
A-1	0	4.4	90000	11.0%	9.0%	3	3	0.00	2300	D3M	D3M
1-2	1	8.5	90000	9.0%	9.0%	3	3	0.00	2300	D3M	D3M
B-2	0	3.0	70000	10.0%	9.0%	3	3	0.00	2300	D3M	D3M
2--3	1	4.0	100000	11.0%	10.0%	3	4	0.00	2300	D3M	D4M
C-3	0	4.0	80000	9.0%	9.0%	3	3	0.00	2300	D3M	D3M
3-4	1	8.0	80000	9.0%	9.0%	3	3	0.00	2300	D3M	D3M
4-D	0	2.0	80000	10.0%	9.0%	3	3	0.00	2300	D3M	D3M

Flow Group Definition

Flow Group	Hours per Annum	Factor Hr/AADT	Flow Group Specific Generated Traffic Multipier	Difference from Defaults Hours p.a.	Factor
1	5000	0.0180	1.00	0	0.00
2	2500	0.0639	1.00	0	0.00
3	760	0.0848	1.00	0	0.00
4	500	0.1016	1.00	0	0.00
Annual Totals H	**8760**				
Total Days	**365.00**				

NB - Annual hours should add up to 8760 and annual days to 365 unless this is a partial run which is dealing only with some of the 4 flow groups.

Figure 6.2: Primary Input Sheet

6.1 Parameters and header section

The parameters and header section of the INCA Input primary Sheet contains a number of parameters required that adjust specified flow group values and flows to the correct levels for a specified year of appraisal. The following summarises the entries:

- **Scenario Name.** This is self-explanatory and identifies a particular run/setup of INCA. The forecast year is given after the scenario description.

- **Maximum diversion proportion.** This has a default value of 1 and represents the maximum proportion of traffic that may divert away from the scheme following an incident.

- **Directions for calculation of benefits.** This specifies whether benefits should be calculated for one direction or for both directions. One-way benefits are half of the two-way benefits.

- **Average Delay Threshold and Threshold Factor.** The average delay threshold and threshold factor are used to dampen extreme calculations in delay calculations. The proportion of delay above the defined threshold is multiplied by the threshold factor. For example, if the threshold factor is set to zero then delay per vehicle is restricted to the defined delay threshold. We recommend that the default values are not changed.

- **Base Year.** This is the year to which the input flow data relate, i.e. the values in the PIS are for this year. Factors (discussed below) are used to derive future year values.

- **Traffic Growth factor.** Determines traffic growth from the base year to the forecast year. The growth factor is applied to all the flow groups uniformly. The forecast year is given after the scenario description.

- **Accident Decline Factor.** Determines the reduction in accident occurrence since the input year based on observed trends, i.e. 0.10 = 10% reduction since base year. This factor should be calculated for the relevant road type using the information in Chapter 4 of Part 2 of the COBA manual, DfT (2006).

- **Heavy Vehicle PCU Factor.** This is the conversion factor from HGVs to PCUs that is used in the calculations, which is set at 2.5 by default. This can be changed to reflect the type of heavy traffic prevalent in the network being modelled.

6.2 Base year traffic and network data

Link definitions and characteristics together with associated base year traffic flows are specified in the Base Year traffic and network data section of the PIS.

There are two main types of links that are defined in INCA – feeder links and network links. Each INCA network currently can have a maximum of 63 links defined.

Feeder links represent composite links (in length or capacity) which lead to the main network. Network links refer to all real links in the network not identified as feeder links. Network links and feeder links are treated the same way for purposes of calculating delays and travel time variability.

However, feeder links need to be assigned sensible link lengths and, to ensure that they do not distort scheme benefits, to represent whole journey lengths. Induced traffic should not normally be included for feeder links. The guidance in Section 12 describes in more detail how feeder links should be modelled.

The following data is specified in the network definition section of the INCA Primary Input Sheet:

- **Link Between Junctions.** This is simply a description of each link in the network indicating the nodes it connects together.

- **Link Type.** The network is defined as a series of links whose connectivity is further defined in the Trip Matrix Input Sheet (TIS). Link type “1” is used for network links and “0” for feeder links.

  INCA allows up to 63 links to be specified. Where less than 63 links are required to specify a network, the excess links should carry a description with no further data specified.

- **Length**. Length of link in kilometres from one junction to the next. The distance is measured from mid-point of the junction to mid-point of the next junction.

- **Base Year AADT 2-Way**. Annual Average Daily Traffic flow (two-way) for the link.

- **Percentage of heavy traffic** for flow groups 1-3 (see below for definition of flow groups).

- **Percentage of heavy traffic** for flow group 4, the busiest flow group.

- **Number of Lanes per Direction.** The number of running lanes is specified for the Do Minimum and the Do Something.

- **Proportion of traffic generated.** This can be used if it is expected that the scheme increases traffic in the Do Something situation (either through re-assignment or induced traffic). The value specifies the proportion of extra traffic using the link (i.e. 0.1 = 10% generated traffic and -0.1 = 10% suppressed traffic). Inputs should be based on a traffic model.

- **Capacity per Lane**. This is specified in PCUs/hr.

- **DM and DS Road Types.** The available road types are defined in the 'SpeedFlow and DTDV' worksheet described in detail below. A drop down box allows the choice of road type to be made.

  The chosen road type determines the DTDV relationship to be used for the link in the calculation of day-to-day travel time variability. It has no effect on incident delays or incident-related variability.

6.3 Flow Group Definition table

The concept of flow groups in INCA originates from COBA and is based on accounting for a year of 8760 hours and 365 days and Annual Average Daily Traffic (AADT) flows. For details of how to calculate flow group values please consult Chapter 7 of Part 4 of the COBA Manual http://www.dft.gov.uk/pgr/economics/software/coba11usermanual/, DfT (2006). INCA uses four flow groups corresponding to earlier versions of COBA.

In this table the Factor hr/AADT is applied to the AADT to calculate the hourly flow in the relevant flow group. The flow group specifications and a network-wide Flow Group Specific Generated Traffic Multiplier work together with link specific values of the proportion of generated/induced traffic specified in the Base Year Traffic and Network data section.

The flow-group specific multiplier is multiplied by the link-specific proportion of traffic induced (or generated). A value of 0 implies ***no*** induced traffic in ***any*** flow group, regardless of the proportion of traffic induced specified. The default value of 1 implies full application of the link specific values in the affected flow group(s).

This table also calculates the difference of specified group flow values from default COBA flow group definitions as a check.

The user may change these values to reflect local conditions for the network being modelled.

7 Secondary Input Sheet (SIS)

The Secondary Input Sheet is used to specify detailed incident-related inputs for all of INCA's twelve incident types for the Do Minimum and Do Something. Where a carriageway blockage reduces the road capacity below the demand flow, queuing and delays will occur. This generates travel time variability.

If the number of incidents or the severity of delays caused can be reduced, economic benefits arise from a reduction in delay due to incidents; and a reduction in TTV caused by incidents. Delays due to incidents during roadworks are included in QUADRO, but are not otherwise included in current highway evaluation, such as COBA or TUBA. Thus in most cases, any economic benefits arising from reduced incident delay need to be calculated together with TTV benefits using INCA.

7.1 Incident Types

INCA calculates costs and benefits based on the twelve categories of incident types recommended by TRL (2004). Each of the twelve categories of incidents has different rates of occurrence, lane blockage effects and different build-up durations on the motorways that were studied (M40, M42, M6 and M5). These incident types are:

1. Single Lane Accident - An accident which blocks only one lane of the running carriageway. Generally, these have medium average build up durations and a low carriageway blockage effect.
2. Multi-Lane Accident - An accident that blocks more than one lane of the running carriageway for part of its duration. These are relatively infrequent. They have relatively long average build up durations and a medium carriageway blockage effect.
3. Non-HGV Breakdown - These are incidents where a vehicle (not HGV) suffers a mechanical or other failure and obstructs the running carriageway.
4. HGV Breakdown – As above but for HGVs.
5. Minor Debris - These are incidents where the running carriageway is obstructed by debris generally from vehicles, for example, tarpaulins, ropes and tyres. These incidents have the shortest build up durations and a relatively low carriageway obstruction effect.
6. Non-HGV fire - Vehicle fires are among the least frequent incidents, but have very long build up durations and the highest carriageway obstruction effect.
7. HGV Fire.
8. Load Shedding. Shedding of a goods vehicle's load.
9. Spillage. Spillage on the running carriageway mainly of chemical or fuel products.
10. Single Lane Emergency Roadworks.
11. Multi-lane Emergency Roadworks.
12. Animal Incident.

7.2 Incident parameters (Tables 2.01-2.24)

SECONDARY INPUT FOR INCA

Mott MacDonald

Incident Definition Parameters

NB Default Values are for D3/D4 Motorways with a Hard Shoulder

Equalise_DM_and_DS_Parameters

Table 2.01 Do Minimum - Single Lane Accident incident

Parameter	Default Values	A-1	1-2	B-2	2--3	C-3	3-4	4-D	Not used	Not used	Not used	Not used	Not used	Diff from Default
		Local Values by Link												
Incident Rate - per Million Vehicle Kms	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.00
Mean Incident (Buildup) Duration - Mins	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	0.00
RMS Duration Weighting	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.00
Weighted Incident Duration - Mins	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**0.00**
Variance Weighting	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.00
Average Lanes Blocked	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	0.00
Buildup Lane Capacity Factor	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.00
Maximum Diversion Proportion	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00

Table 2.13 Do Something - Single Lane Accident incident

Parameter	Default Values	A-1	1-2	B-2	2--3	C-3	3-4	4-D	Not used	Not used	Not used	Not used	Not used	Diff from Default
		Local Values by Link												
Incident Rate - per Million Vehicle Kms	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.0000
Mean Incident Duration - Mins	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	0.0000
RMS Duration Weighting	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.0000
Weighted Incident Duration - Mins	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**24.35**	**0.0000**
Variance Weighting	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.0000
Average Lanes Blocked	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	0.0000
Buildup Lane Capacity Factor	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.0000
Maximum Diversion Proportion	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.0000

Figure 7.1: Incident Type Parameters for DM and DS for a single incident type.

As shown in Figure 7.1, for each incident type **and** for each link in the network, the SIS holds values for a number of parameters. These values may be default values for each incident, may be based on observations, or be adjusted to allow for the effects of the scheme. The default values of these parameters have been obtained from TRL (2004).

Table B.1 to Table B.4 in Appendix C give the default parameters for the Do Minimum and Do Something which include the following:

- **Incident Rate.** This is the rate of incident occurrence expressed as *the number of incidents per million vehicle kilometres*.
- **Mean Incident (Build-up) Duration (B).** This is expressed in *minutes* and represents the average duration of an incident for a particular incident class. This is the time between the occurrence of an incident of a particular category, and the time when all obstructions are removed.
- **RMS Duration Weighting.** A weighting applied so that average delay of an incident is closer to the average delay from all incidents in the class.
- **Weighted Incident Duration (Mins)**. Calculated from the mean incident duration and the duration weighting.
- **Variance Weighting.** This is a weighting that takes into account the distribution of the durations within an incident class. Usually these are kept at default values and constant between do-minimum and scheme. This is applied after the duration weighting.
- **Average Lanes Blocked.** Number of lanes blocked taken as an average during the incident. The number of lanes (NLANE) is defined in the Primary Input Sheet.

- **Build-up Lane Capacity Factor, (BLCF).** This is the factor specifying what proportion of the normal lane capacity is available during the build-up phase of the queue during an incident. This reflects the fact that even when a lane is fully open, it will not usually be operating at full capacity during the incident.

- **Maximum Diversion Proportion.** This is the maximum proportion of traffic diverting during an incident. The same value is used in the DS and DM. INCA replaces the default value specified above with a calculated value in calculation of incident delays and TTV.

In order to set the Do Something scenario to be identical to the Do Minimum scenario values the user can press the "Equalise DM and DS Parameters" button. DM values are copied to the DS tables. The default setup uses the same parameters for DM and DS.

The default values represent parameters for standard Dual 3 motorways. The user must ensure that the correct values are input in the Do-Minimum and Do-Something cells to represent their particular scheme. Changing road types in the primary input sheet does not automatically change incident parameters in the secondary input sheet.

8 Trip Matrix and Value of Time Input Sheet

INCA requires that base year trips for each route are specified. The Trip Matrix Sheet (TIS) contains descriptions of flow movements on the network; and a definition of how these flows traverse the network. These values are based on the Do Minimum traffic flows and must be consistent with the values specified in the Primary Input Sheet. The user must specify:

- Trips for each route
- Links making up each route

This worksheet also contains Values of Time, and vehicle and trip purpose proportions that are used in quantifying the monetary value of delay and travel time variability benefits. These may be edited by the INCA user.

TRIP MATRIX AND ROUTE SPECIFICATION

Mott MacDonald

Table 3.1 Movement Flows

		Movement Name																
	Total	A-B	A-C	A-D	BC	BD	CD	-	-	-	-	-	-	-	-	-	-	-
Flow (Veh/day)	160000	30,000	30,000	30,000	20,000	20,000	30,000											

Table 3.2 Links Traversed by Movement

		Movement as named above																
Links in Network	Total	A-B	A-C	A-D	BC	BD	CD	-	-	-	-	-	-	-	-	-	-	IMPLIED LINK FLOWS
A-1	3	1	1	1														90,000
1-2	3	1	1	1														90,000
B-2	3	1			1	1												70,000
2--3	4		1	1	1	1												100,000
C-3	3		1		1		1											80,000
3-4	3			1		1	1											80,000
4-D	3			1		1	1											80,000
Not used	-																	-
Not used	-																	-
Not used	-																	-
Not used	-																	-
Not used	-																	-

Links Traversed are indicated by 1

VALUES OF TIME

Table 3.3 Vehicle and Trip Purpose Proportions

Heavy Vehicles split

OGV	PSV	Total
84.85%	15.15%	**100.00%**

Light Vehicles split

Car	LGV	Total
88.54%	11.46%	**100.00%**

Car Work Time Proportions

Flow Group	1	2	3	4
Work Time %age	10.70%	16.70%	15.70%	14.10%

Source: COBA (2002 version) Car Work Time Proportions (Part 2 Table 1/4)

Table 3.4 Values of Time

	Delay		TTV	
Type of Vehicle	Pence/Hr	Pence/Min	Pence/Hr	Pence/Min
Working Car	3018	**50.30**	2414	40.23
Non-Working Car	574	**9.57**	459	7.65
Average LGV	1163	**19.38**	930	15.50
OGV	1018	**16.97**	1222	20.37
PSV	7162	**119.37**	5730	95.50

Default Values in 2002 Prices

Figure 8.1: Trip Matrix and Value-of-Time Input Sheet (Tables 3.1 – 3.4)

8.1 Movement Flows (Table 3.1) and Links Traversed (Table 3.2)

Route flows are specified in **Table 3.1** of the worksheet. Flows should be defined as two-way AADTs.

The list of links used by each movement is detailed in INCA **Table 3.3** with the links traversed by the movement coded as '1' and the remaining left blank. A maximum of 63 movements or routes may be specified per run. The link flows implied by the movement definitions are shown in Table 3.2. These should be consistent with AADTs defined in INCA Table 1.2 so that the travel time variability calculation is not distorted.

TTV benefits will be calculated for the movements specified in this table only, whereas delay benefits will be calculated for all links defined in the PIS.

Note: A specific example for coding a Managed Motorway Dynamic Hardshoulder Running scheme (MM-DHS) is suggested in Appendix A.

8.2 Vehicle and Trip Purpose Proportions

Vehicle and trip purpose proportions are specified in Table 3.4 of the worksheet.

8.3 Values of Time

The **values of time** are specified in Table 3.5 of the worksheet and are also given in Table B.4 of Appendix C. The default values are taken from WebTag Unit 3.5.6 (February 2007)

The default values of travel time delay and standard deviation are set out in the table below. The TTV values are based on the WebTAG recommended reliability ratio of 0.8 for cars. The same value is assumed to apply to LGVs and PSVs and a value of 1.2 is used for OGVs. This is further discussed in DfT (2008).

9 SpeedFlow and DTDV Sheet

This worksheet is used to define the speed flow curve and DTDV parameters for each road type that are used for calculating day-to-day travel time variability. For most INCA applications there should be no need to edit this sheet.

SPEED FLOW AND DTDV DEFINITIONS

		Road Type									
		D4M	D3M	D3M-ATM with 50mph	D4CM	D3CM	D2APMS	D3M-ATM with 60mph			
Speed Flow Definitions											
Free flow speed (lights) (km/h) (VL0)		118	118	118	118	118	108	118			
Breakpoint 1	Flow (total vehs/hr) (Q1)	4800	3600	3600	4800	3600	2160	3600			
	Speed (km/h) (V1)	110.8	110.8	110.8	110.8	110.8	101.52	110.8			
Breakpoint 2	Flow (total vehs/hr) (Q2)	12776	9582	4500	12776	9582	5586	9582			
	Speed (km/h) (V2)	45	45	100.9	45	45	45	45			
Breakpoint 3	Flow (total vehs/hr) (Q3)			4500.1				4500.1			
	Speed (km/h) (V3)			81.1				81.1			
Breakpoint 4	Flow (total vehs/hr) (Q4)			6419				6419			
	Speed (km/h) (V4)			79.3				79.3			
Breakpoint 5	Flow (total vehs/hr) (Q5)			8000				8000			
	Speed (km/h) (V5)			77.8				77.8			
Minimum speed (km/h)		45	45	45	45	45	45	45			
Maximum speed heavies (km/h)		93	93	93	93	93	86	93			
DTDV Definitions											
Coefficient a		-48.498	-58.682	-89.070	68.455	54.046	31.179	-89.070			
Coefficient b		1.738	2.201	5.934	-5.524	-4.048	-1.990	5.934			
Coefficient c		-8.739E-03	-1.446E-02	-1.343E-01	1.381E-01	9.362E-02	3.715E-02	-1.343E-01			
Coefficient d		9.411E-06	3.638E-05	1.101E-03	-9.909E-04	-5.976E-04	-1.312E-04	1.101E-03			
Do not exceed DTDV for road type				D3M				D3M			

Figure 9.1: Speed Flow and DTDV Sheet

9.1 Speed Flow Curve

The shape of the speed-flow curves is fully compatible with COBA speed-flow curves, and with the MM-DHS speed-flow curves developed by the Highways Agency. They take the form shown in Figure 9.2:

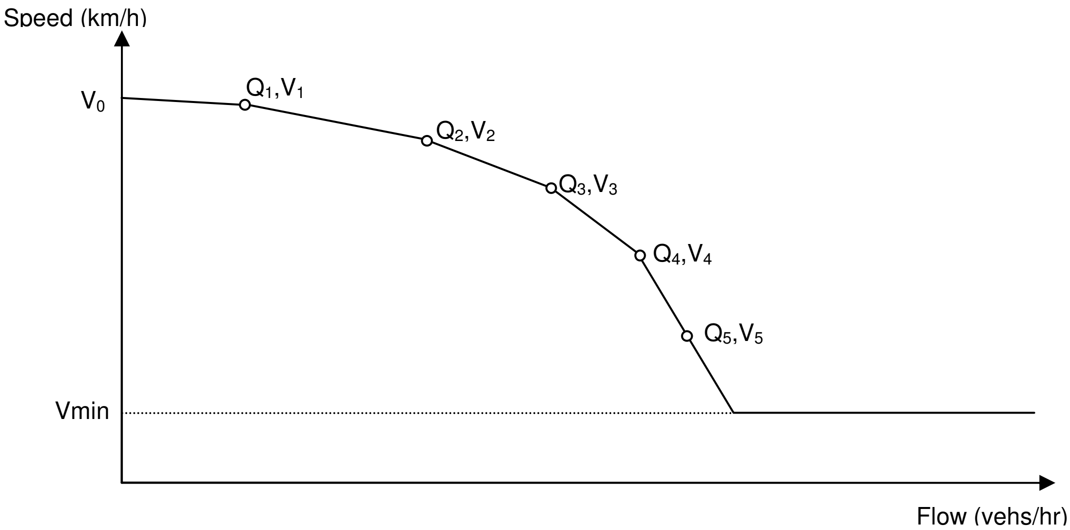

Figure 9.2: Example speed-flow curve used by INCA

The curve is piece-wise linear, with up to five breakpoints. Beyond the last breakpoint the speed flow curve is extrapolated from the last and penultimate breakpoints until it reaches the minimum allowed speed. The same speed-flow curve applies to all vehicles on the link. However, a maximum allowed speed for heavy vehicles is defined. If the speed calculated using the curve exceeds this value, then the heavy vehicle speed is set to the maximum allowed.

The following data must be defined for each road type:

- Road type name
- Free flow speed for light vehicles in km/h (V_0)
- First breakpoint: flow in vehs/hr and speed in km/h (Q_1,V_1)
- Minimum speed in km/h (V_{min})
- Maximum speed for heavy vehicles in km/h
- Optionally, up to four additional breakpoints may be defined [(Q_2,V_2) to (Q_5,V_5)]

Note that flows in this worksheet are defined as vehs/hr and *not* vehs/lane/hr. They are one-way flows.

Default curves are provided for D4M (four lane motorways), D3M (three-lane motorways), D2APMS (dual all purpose roads with marginal strips) and D3M with MM-DHS (50 mph hard-shoulder running; data for 60 mph running is not yet available). The first three are based on COBA curves with zero hilliness and bendiness. The parameters will need to be adjusted if either of these is significant. The 'D3M with MM-DHS' curve is based on the 'Scenario 2' curve provided by the Highways Agency which corresponds to hard shoulder running with a 50mph speed limit. The curve follows the standard D3M COBA curve then switches to the new MM-DHS curve at a flow of 4500 vehs/hr.

In the absence of data for 60mph hard-shoulder running, it is recommended that the 50mph parameters are used when modelling hard-shoulder running.

The parameters for the default curves are:

Table 9.1: Default speed-flow curves in INCA

		D4M*	**D3M***	**D2APMS**	**D3M with MM-DHS (50mph)**	**D3M with MM-DHS (60mph)**
Free flow speed (lights) (km/h) (VL0)		118	118	108	118	118
Breakpoint 1	Flow (total vehs/hr) (Q1)	4800	3600	2160	3600	3600
	Speed (km/h) (V1)	110.8	110.8	101.52	110.8	110.8
Breakpoint 2	Flow (total vehs/hr) (Q2)	12776	9582	5586	4500	4500
	Speed (km/h) (V2)	45	45	45	100.9	100.9

		D4M*	D3M*	D2APMS	D3M with MM-DHS (50mph)	D3M with MM-DHS (60mph)
Breakpoint 3	Flow (total vehs/hr) (Q3)				4500.1	6213
	Speed (km/h) (V3)				81.1	94
Breakpoint 4	Flow (total vehs/hr) (Q4)				6419	7430
	Speed (km/h) (V4)				79.3	89.1
Breakpoint 5	Flow (total vehs/hr) (Q5)				8000	12776
	Speed (km/h) (V5)				77.8	45
Minimum speed (km/h)		45	45	45	45	45
Maximum speed heavies (km/h)		93	93	86	93	93

*The standard D4M and D3M speed-flow curves are also assumed to apply to D4CM and D3CM respectively (three and four lane controlled motorways).

Certain rules apply to the definition of breakpoints for speed flow curves:

- At least one breakpoint must be defined
- For each breakpoint speed and flow must both be defined, or both left blank
- The flow at each breakpoint must be greater than that at the previous breakpoint
- The speed at each breakpoint must be less than or equal to that at the previous breakpoint

INCA will check that all these rules have been followed and will report an error if they have not.

Note that the speed flow curve is used only in the calculation of journey time per km for input to the DTDV function. It has no other uses; in particular, it is not used to calculate benefits due to changes in average travel times.

9.2 Day-to-day variability

The DTDV coefficients are used in a function of the following form:

Standard deviation of journey time (in seconds per km)= $a + bx + cx^2 + dx^3$

where x is the mean journey time per km, as calculated from the speed-flow curve.

Default values for the coefficients are provided for D4M, D3M, D3M with MM-DHS (50mph), D3CM, D4CM and D2APMS. The coefficients are from Mott MacDonald (2008a, 2008b). Although the parameters for these road types are fixed, the user may define additional/modified curves, up to a limit of 10 in total.

Table 9.2: Default DTDV coefficients in INCA

	D4M	**D3M**	**D3M with MM-DHS (50mph)**	**D4CM**	**D3CM**	**D2APMS**
a coefficient	-48.498	-58.682	-89.070	68.455	54.046	31.179
b coefficient	1.738	2.201	5.934	-5.524	-4.048	-1.990
c coefficient	-0.0087	-0.0145	-0.1343	0.1381	0.0936	0.0372
d coefficient	0.0000	0.0000	0.0011	-0.0010	-0.0006	-0.0001

DTDV coefficients for D3M with MM-DHS (60mph) are the same as those given for MM-DHS (50mph).

These DTDV curves were estimated from observed data and are only really valid over the range of journey times for which there were observations. These ranges are as follows:

- D3M: journey times up to 130 sec/km (=28 km/h)
- D4M: journey times up to 130 sec/km (=28 km/h)
- D3M with ATM: journey times up to 60 sec/km (=60 km/h)
- D4CM: journey times up to 80 sec/km (=45km/hh)
- D3CM: journey times up to 80 sec/km (=45km/hh)
- D2APMS: journey times up to 80 sec/km (=45km/h)

The default speed-flow curves all have a minimum speed of 45km/h, or 80 seconds per km. This means that they will always return journey times within the observed range for D3M, D4M, D4CM, D3CM and D2APMS. However, a little more care is needed in the application of the D3M with MM-DHS (50mph) DTDV curve. There are two key features of the way the DTDV curves are implemented in INCA, which minimise the risks from applying them outside the observed range.

The first is a consequence of the cubic function used. This means that the curves can be hump-shaped – variability increases with journey time, reaches a maximum value, then decreases. This decrease tends to happen beyond the observed range of the data. As a safeguard, the calculated variability in this 'decreasing' region is replaced with the maximum value. This is shown in Figure 9.3. The dotted line shows the standard deviation in the decreasing region, as calculated by the cubic function. The solid line shows the standard deviation that is actually used in INCA.

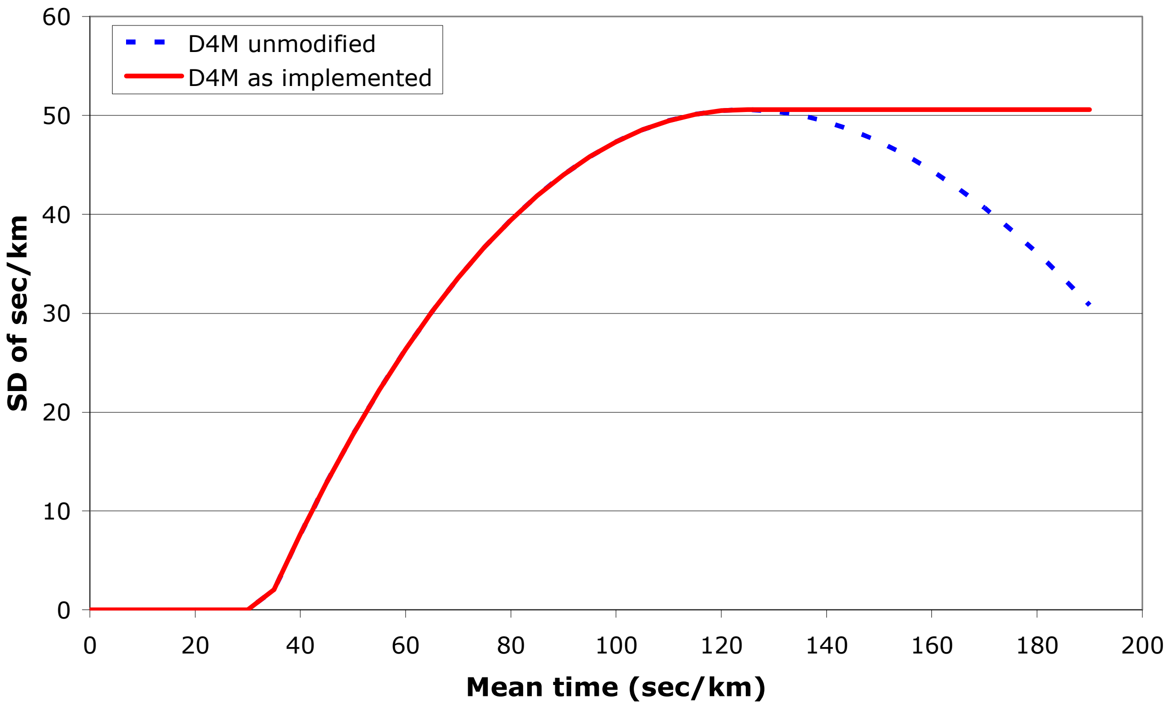

Figure 9.3: Preventing decreasing variability in INCA.

The second key feature also relates to the use of the curves beyond the observed range. It is possible to define a 'capping' road type. For example, in the default curves, 'D4CM' is defined as the capping road type for 'D3M with MM-DHS (50mph). This means that if the variability calculated for D3M with MM-DHS (50mph) exceeds that for D4CM then the value for D4CM is used instead. This is shown in Figure 9.4.

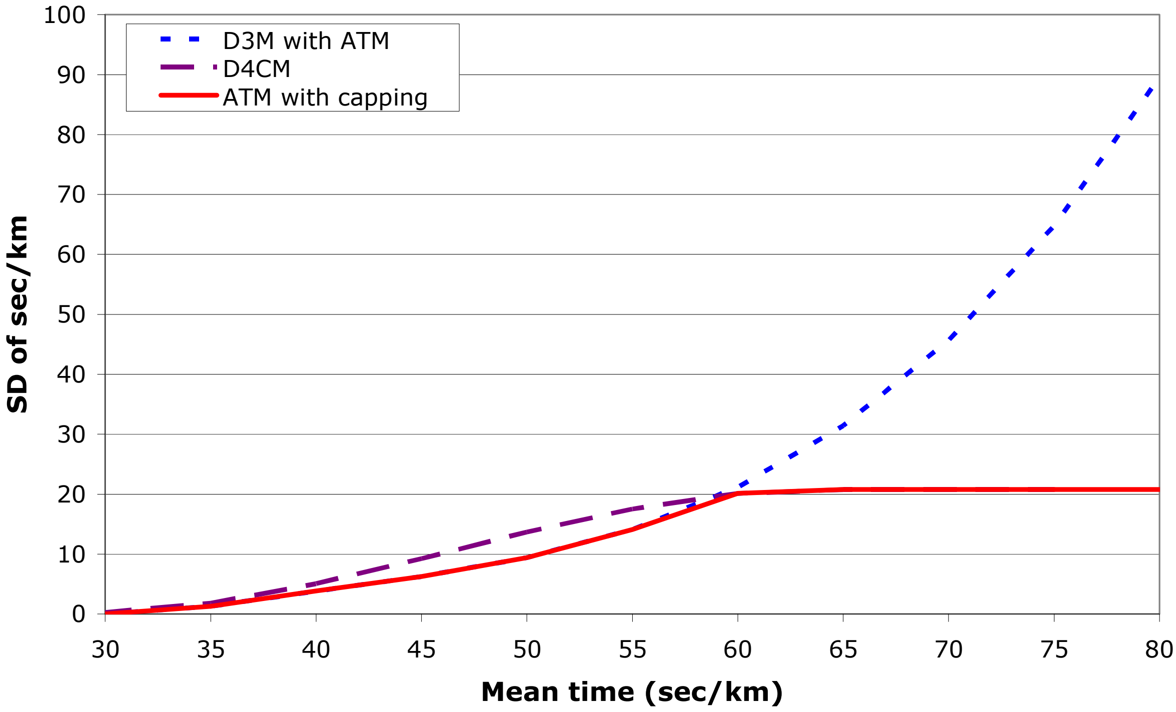

Figure 9.4: Application of DTDV capping in INCA.

10 Results from one model year

The outputs from the INCA appraisal for (each model year) are consolidated in the 'Final Results' worksheet of the single model year appraisal INCA (see Figure 10.1 below). These include:

- Benefits by flow group
- Benefits by incident type
- Delays by incident type

The summary table within the 'Final Results' worksheet provides

1. Total annual TTV benefits
2. Total annual delay benefits
3. Total annual benefits = (1) + (2)

Limitations of INCA are highlighted in the Project manager's guide (Mott Macdonald, 2009). Interpretation of results should bear these in mind. Some care is needed in interpreting the breakdown between incident variability and DTDV benefits. 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 give anomalous results in some cases, but even then the total reliability benefit can still be used.

All monetary values in the results worksheet are presented without application of discounting or value of time growth. This is carried out in the "Main" spreadsheet that calculates benefits over a 60 year period.

'Report 1' contains a summary of the scenario while **'Report 2'** contains a summary of benefits (delay and TTV) by flow group and source. In congested situations it is usual to obtain most benefits from flow group 4, although in this flow group the impact of delay threshold parameters may dampen the figures most.

'Report 3' contains the incident delays and travel time variability reports, identifying benefits by incident type.

The main variability benefits reported in the Model Year Results sheet includes DTDV benefits, unless otherwise stated in the table header. INCA Table 5.2 includes the approximate proportion of total variability benefits attributable to DTDV.

As with the proportioning of TTV benefits between different types of incident, this is only a crude approximation. It is not possible to precisely separate out the TTV benefits from different sources due to the non-linear nature of the TTV calculation. The user must be aware of this.

The calculation of travel time variability and delay benefits in INCA, which produce these outputs listed above, is described in the sections that follow.

INCA Version 4.1 RESULTS

Mott MacDonald

(Monetary values are in 2002 prices and values. These are not discounted and Value of Time growth has not been applied)

Total Annual Benefit	£0
Total Annual TTV Benefit	£0
Total Annual Delay Benefit	£0

Report 1 Run Scenario Definition

Maximum Diversion for Incidents	Base Year	Average Delay Threshold - Min	Threshold Factor	Growth Factor	Directions	Total Number of Links	Number of Network Links	Number of Movements	Accident Decline Factor
Scenario Name and Modelled Year		INCA version 4.0 Model	2010						
1.0	2007	30	0	1.03	2	7	3	6	0

Report 2 Summary of Benefits

Table 5.1 Benefits by Flow Group

Benefit Type	Flow Group 1	2	3	4	Total
Total Incident Delay Benefit	£0	£0	£0	£0	£0
Total TTV Benefit	£0	£0	£0	£0	£0
Sum Total Benefit	£0	£0	£0	£0	£0
Percentage of Benefit from TTV	0.00%	0.00%	0.00%	0.00%	0.00%
TTV Cost Remaining	£0	£4,604,196	£3,273,394	£3,798,786	£11,676,376

Table 5.2 Benefits by Source

Source	Delay Benefits		TTV Benefits		Total Benefits	
	Annual Benefit	%Total	Annual Benefit	%Total	Annual Benefit	%Total
Single Lane Accident	£0	0.0%	£0	0.0%	£0	0.0%
Multi Lane Accident	£0	0.0%	£0	0.0%	£0	0.0%
Non-HGV Breakdown	£0	0.0%	£0	0.0%	£0	0.0%
HGV breakdown	£0	0.0%	£0	0.0%	£0	0.0%
Minor Debris	£0	0.0%	£0	0.0%	£0	0.0%
Non-HGV fire	£0	0.0%	£0	0.0%	£0	0.0%
HGV fire	£0	0.0%	£0	0.0%	£0	0.0%
Load shedding	£0	0.0%	£0	0.0%	£0	0.0%
Spillage	£0	0.0%	£0	0.0%	£0	0.0%
Single Lane emergency roadworks	£0	0.0%	£0	0.0%	£0	0.0%
Multi Lane emergency roadworks	£0	0.0%	£0	0.0%	£0	0.0%
Animal	£0	0.0%	£0	0.0%	£0	0.0%
Day to day variability	N/A	N/A	£0	0.0%	£0	0.0%
TOTAL	£0	0.0%	£0	0.0%	£0	0.0%

NB. TTV Benefit attribution is approximate being based on the TTV variance change for all links

Report 3 Incident Delay and TTV Reports

Table 5.3 Delays by Incident Type Averaged Over All Links

Scenario	Do Minimum		Do Something		Δ Change DS-DM		Scheme Effect Flag
Incident Type	Avg Delay per Vehicle Delayed (Min)	Total Annual Delay (Min)	Avg Delay per Vehicle Delayed (Min)	Total Annual Delay (Min)	Avg Delay per Vehicle Delayed (Min)	Total Annual Delay (Min)	
Single Lane Accident	3.08	183,505	3.08	183,505	0.00	0	✖
Multi Lane Accident	17.29	877,318	17.29	877,318	0.00	0	✖
Non-HGV Breakdown	2.63	120,196	2.63	120,196	0.00	0	✖
HGV breakdown	4.11	705,682	4.11	705,682	0.00	0	✖
Minor Debris	3.47	402,393	3.47	402,393	0.00	0	✖
Non-HGV fire	4.93	35,703	4.93	35,703	0.00	0	✖
HGV fire	8.99	227,449	8.99	227,449	0.00	0	✖
Load shedding	2.48	2,627	2.48	2,627	0.00	0	✖
Spillage	5.82	12,861	5.82	12,861	0.00	0	✖
Single Lane emergency roadworks	4.08	626,789	4.08	626,789	0.00	0	✖
Multi Lane emergency roadworks	7.74	104,361	7.74	104,361	0.00	0	✖
Animal	6.04	19,296	6.04	19,296	0.00	0	✖
Total	70.66	3,318,180	70.66	3,318,180	0.00	0	

Table 5.4 TTV For A Route Traversing All Links (incident-related TTV only)

TTV Statistic	Flow Group 1	2	3	4
Do Minimum Variance - Mins	0.00	2.49	7.90	17.47
Do Minimum SD - Mins	0.00	1.58	2.81	4.18
Do Something Variance - Mins	0.00	2.49	7.90	17.47
Do Something SD - Mins	0.00	1.58	2.81	4.18
Variance Change DS-DM - Mins	0.00	0.00	0.00	0.00
SD Change DS-DM - Mins	0.00	0.00	0.00	0.00

Figure 10.1: Summary of Results

11 INCA Master Spreadsheet

A typical INCA run has two modelled years to allow a 30 or 60 year appraisal to be carried out in accordance with WebTag. The approach followed is similar to TUBA with a minimum of 2 years specified in the Main INCA Spreadsheet. A maximum of six forecast years (also called modelled years) can be defined.

Since some schemes (such as technology schemes) are assessed over 30 years, INCA allows the user to specify the length of the appraisal period in the Master Spreadsheet.

INCA Version 4.1

Mott MacDonald

INCA SCENARIO	INCA ATM Testing
APPRAISAL PEROID (Yrs)	30
CURRENT YEAR	2007

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Modelled Years		2010	2025				
Source Files	File Name and Folder	INCA_40_2010.xls	INCA_40_2025.xls				
	(Double Click to Change)	C:\INCA\	C:\INCA\				
	Clear						

Figure 11.1: Master Spreadsheet Model Year Specification

Results from the individual model year INCA spreadsheets are interpolated for the years in between and extrapolated for the years beyond the last forecast year to cover the specified appraisal period. The results for each year are then discounted and added together to provide results for the full appraisal period in 2002 prices, discounted to 2002. The INCA Master Spreadsheet also reports results for each forecast year in 2002 prices.

The following information is required in the INCA Master Spreadsheet:

- Scenario name
- Appraisal period (usually 60 years)
- Current year – this is the year when the appraisal is being carried out
- Modelled / forecast year spreadsheets (up to maximum of six)

From these inputs, the INCA Master Spreadsheet produces TOTAL BENEFITS which represent the sum of Delay Benefits and TTV Benefits for the specified INCA appraisal period. Results are also provided for each forecast year and broken down into different incident types where possible.

11.1 Results from 30 or 60 year appraisal

Table 11.1 shows results from the “Main” spreadsheet which performs the 30 or 60 year appraisal. This gives all the monetary values discounted and with growth in values of time applied. The table gives aggregate values as well as values for each of the forecast years.

Table 11.1: Total benefits over 60 years

Report 1 TOTAL BENEFITS	
	£
TOTAL BENEFITS	X+Y
Total TTV Benefit	X
Total Delay Benefit	Y

The TOTAL BENEFITS represents the sum of Delay Benefits and TTV Benefits for the INCA appraisal. This is the value that may be combined with other values, from TUBA for example, to obtain a Present Value of Benefits (PVB) that includes incident delay and TTV benefits. Incident delay time saving benefits have the same values of time (VOT) as other travel time savings and are discounted over the whole of the appraisal period – as in standard cost-benefit appraisal software such as COBA or TUBA. The value of time used in INCA is based on national values and may be supported by local working time and vehicle type proportions. Monetary benefits for each year in the appraisal period are discounted to 2002 in line with WebTag guidance.

INCA 4.1 FINAL SUMMARY RESULTS OVER APPRAISAL PERIOD

All entries are present values discounted to 2002, in 2002 prices

Report 1 TOTAL BENEFITS
All entries are present values discounted to 2002, in 2002 prices

	£
TOTAL BENEFITS	194,483,459
Total Incident and DTDV TTV Benefit	167,485,373
Total Delay Benefit	26,998,085

Report 2 SUMMARY OF BENEFITS

Table 2.1 Benefits by Flow Group
All entries are present values discounted to 2002, in 2002 prices

Benefit Type	Flow Group 1	2	3	4	Total
Total Incident Delay Benefit	0	4,565,054	8,552,385	13,880,646	26,998,085
Total Incident and Day-to-Day TTV Benefit	0	70,838,824	47,344,814	49,301,736	167,485,373
Sum Total Benefit	0	75,403,878	55,897,199	63,182,382	194,483,459
Percentage of Benefit from TTV	0%	94%	85%	78%	86%

Table 2.2 Benefits by Type
All entries are present values discounted to 2002, in 2002 prices

Type	Delay Benefits over Appraisal Period	%Total	TTV Benefits over Appraisal period	%Total	Total Benefits over Appraisal Period	%Total
Single Lane Accident	1,564,063	5.8%	3,154,647	1.9%	4,718,710	2.4%
Multi Lane Accident	6,179,660	22.9%	114,472,732	68.3%	120,652,391	62.0%
Non-HGV Breakdown	994,878	3.7%	1,617,445	1.0%	2,612,324	1.3%
HGV breakdown	6,074,756	22.5%	11,805,204	7.0%	17,879,960	9.2%
Minor Debris	3,231,415	12.0%	7,504,730	4.5%	10,736,146	5.5%
Non-HGV fire	296,618	1.1%	1,117,773	0.7%	1,414,390	0.7%
HGV fire	1,898,734	7.0%	9,021,161	5.4%	10,919,894	5.6%
Load shedding	21,900	0.1%	31,539	0.0%	53,439	0.0%
Spillage	106,211	0.4%	383,984	0.2%	490,196	0.3%
Single Lane emergency roadworks	5,701,228	21.1%	15,061,456	9.0%	20,762,684	10.7%
Multi Lane emergency roadworks	776,303	2.9%	4,734,052	2.8%	5,510,355	2.8%
Animal	152,320	0.6%	1,000,902	0.6%	1,153,222	0.6%
DTDV	N/A	N/A	-2,420,253	-1.4%	-2,420,253	-1.2%
Total	26,998,085	100.0%	167,485,373	100.0%	194,483,459	100.0%

NB. TTV Benefit attribution is based on the TTV variance change for all links

Report 3 - INCA BENEFITS FOR EACH MODELLED YEAR

All entries are present values discounted to 2002, in 2002 prices

		2010	2025	0	0	0	0
Total Benefits		5,248,201	3,971,158	0	0	0	0
Total Delay Benefits		728,552	551,274	0	0	0	0
Total TTV Benefits		4,519,648	3,419,884	0	0	0	0
Delay Benefits by Flow Group	Flow Group 1	0	0	0	0	0	0
	Flow Group 2	123,189	93,214	0	0	0	0
	Flow Group 3	230,789	174,631	0	0	0	0
	Flow Group 4	374,574	283,429	0	0	0	0
	TOTAL	728,552	551,274	0	0	0	0
TTV Benefits by Flow Group	Flow Group 1	0	0	0	0	0	0
	Flow Group 2	1,911,609	1,446,458	0	0	0	0
	Flow Group 3	1,277,615	966,734	0	0	0	0
	Flow Group 4	1,330,424	1,006,692	0	0	0	0
	TOTAL	4,519,648	3,419,884	0	0	0	0
Delay Benefits by Incident Type	Single Lane Accident	42,207	31,937	0	0	0	0
	Multi Lane Accident	166,760	126,182	0	0	0	0
	Non-HGV Breakdown	26,847	20,314	0	0	0	0
	HGV breakdown	163,929	124,040	0	0	0	0
	Minor Debris	87,201	65,982	0	0	0	0
	Non-HGV fire	8,004	6,057	0	0	0	0
	HGV fire	51,238	38,770	0	0	0	0
	Load shedding	591	447	0	0	0	0
	Spillage	2,866	2,169	0	0	0	0
	Single Lane emergency roadw	153,850	116,413	0	0	0	0
	Multi Lane emergency roadwo	20,949	15,851	0	0	0	0
	Animal	4,110	3,110	0	0	0	0

Figure 11.2: Results for a 60 year appraisal

12 Advice for implementing INCA in specific cases

Following discussions between the Department for Transport (ITEA), Highways Agency (TAME) and Mott MacDonald (the INCA developers), on the use of INCA software for MM-DHS (hard-shoulder running) and D4M schemes, the following methodology has been developed by TAME for the specification of the network structure and traffic flow inputs for all INCA appraisals.

Due to the non-linear nature of the variability calculation, the benefits to a journey passing through a scheme link will depend on the amount of variability on the non-scheme links as well. This is closely related to distance and shorter trips will tend to get more benefits than longer ones. To represent total journey lengths, therefore, two types of link are specified: feeder links and network links.

Feeder links allow the combination of several real-life links to approximate total journey lengths (for variability from incidents) / times (for DTDV) on the network, and hence total journey variances, which is then used in the calculation of benefits.

However, because INCA only allows the use of a maximum of 63 links, the specification of the network is critical to the derivation of monetary benefits. Below we identify the approach that should be used to distil an assignment model structure to a network compatible with INCA's limit of 63 links and 16 routes.

12.1 Network Structure

Given that overall journey properties are critical to the level of benefits derived from travel time variability reductions, journey times / distances should be disaggregated as far as possible. As many feeder links as possible should be used to model different journey lengths, while allowing sufficient network links to represent the scheme. A distribution of journey lengths should be derived using select link analysis in the traffic model to inform this disaggregation. Finer disaggregation should be used at shorter journey lengths, as this is when the sensitivity to journey lengths is greatest.

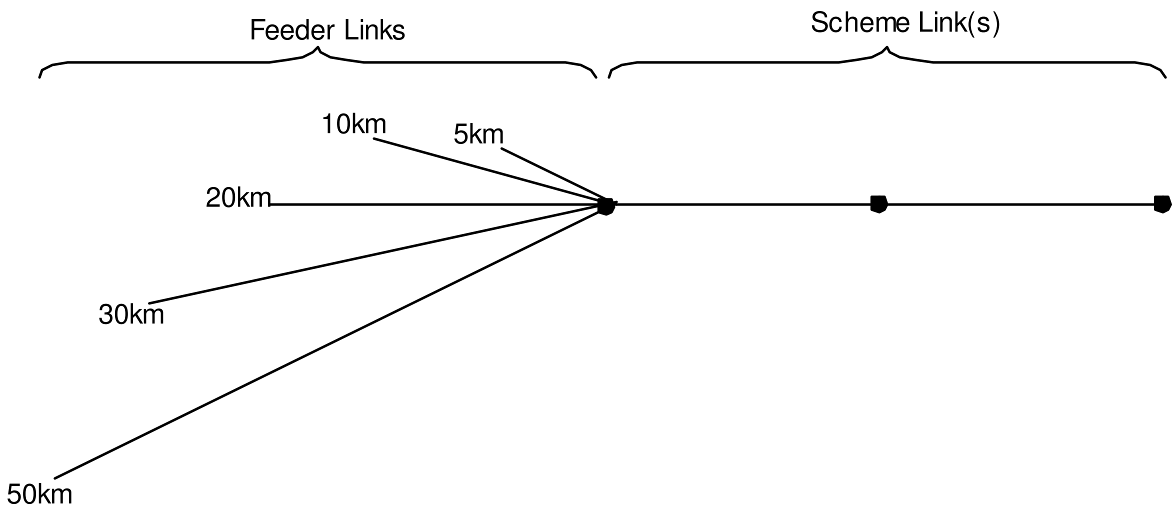

Figure 12.1: Proposed Network Structure in INCA

The Figure above illustrates an example network structure which may be used. Additional feeder links (to further disaggregate journey lengths / times) or scheme links (to allow for significant changes in flows / journey characteristics along the improved section) could be added as necessary. For sections of improvements above about 30km, more than one scheme link should be used for the INCA assessment.

One of the advantages of the INCA method is that its networks do not have to bear any resemblance to its real life counterpart. This network structure takes advantage of this flexibility. One feeder link can therefore be used to mimic journeys joining and leaving at any of the junctions along the route. This method maximises the level of journey time disaggregation that can be achieved through maximising the use of feeder links.

Note that there is no need to have feeder links at the beginning and end of each route in the INCA network. Each route needs to include only one feeder link, to capture all the variability on the non-scheme link part of the journey.

12.2 Link Flows

Traffic flows in INCA are specified in terms of AADT. Observed factors should be applied to convert hourly flows into AADT for the scheme link. The traffic flow on the scheme link(s) should be the distance-weighted average flow from the junction-to-junction links covered by the improvement.

Feeder links should include both the traffic flow that passes through the scheme link and non-scheme traffic, so that volume to capacity ratios (and consequently variability) on the feeder links are realistic. The main role of the feeder links is to make sure that the full variability of the journey on the non-scheme links is captured. If variability on the feeder links is underestimated, the variability benefits from the scheme itself would be overestimated.

Due to the difficulties in combining flows across different link types, it is not clear cut which are the best flows to use to make sure this calculation is accurate, but achieving congestion levels somewhere around the network average should be the aim. To ensure consistency between appraisals, we recommend using an AADT flow to achieve a ratio of flow to capacity (as defined in TD46/97)) of 0.60 for all flow groups. Scheme promoters can use different loadings if

(a) Based on their highway model, they believe that the number is markedly different in their study area and therefore using the default values would lead to incorrect results

(b) They are confident that the capacity constrained part of their model covers a wide enough area to be representative.

Where promoters have adopted their own values it should clearly stated how this has been calculated to allow a judgement to be made as to the appropriateness of the technique adopted.

Any changes in traffic flow between the Do-Minimum and Do-Something (input as proportion of traffic generated in INCA) caused by induced or reassigned traffic predicted in the traffic model should only be applied to the Scheme Link and no changes in flow should be applied to the Feeder Links.

The eventual specification of an INCA network is, as with all models, an issue of judgement, and will be based on the scheme and existing / potential traffic patterns. As INCA becomes more widely used, it is envisaged that this Guidance will develop to reflect users' experiences.

12.3 Effect of feeder links

It is also worth highlighting that the characteristics of feeder links, and the level of variability assumed for them, can have a large influence on the total variability benefits on the route. This is true even if the feeder links don't change between the DM and DS. This is illustrated by the graph in Figure 12.2 below. 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.

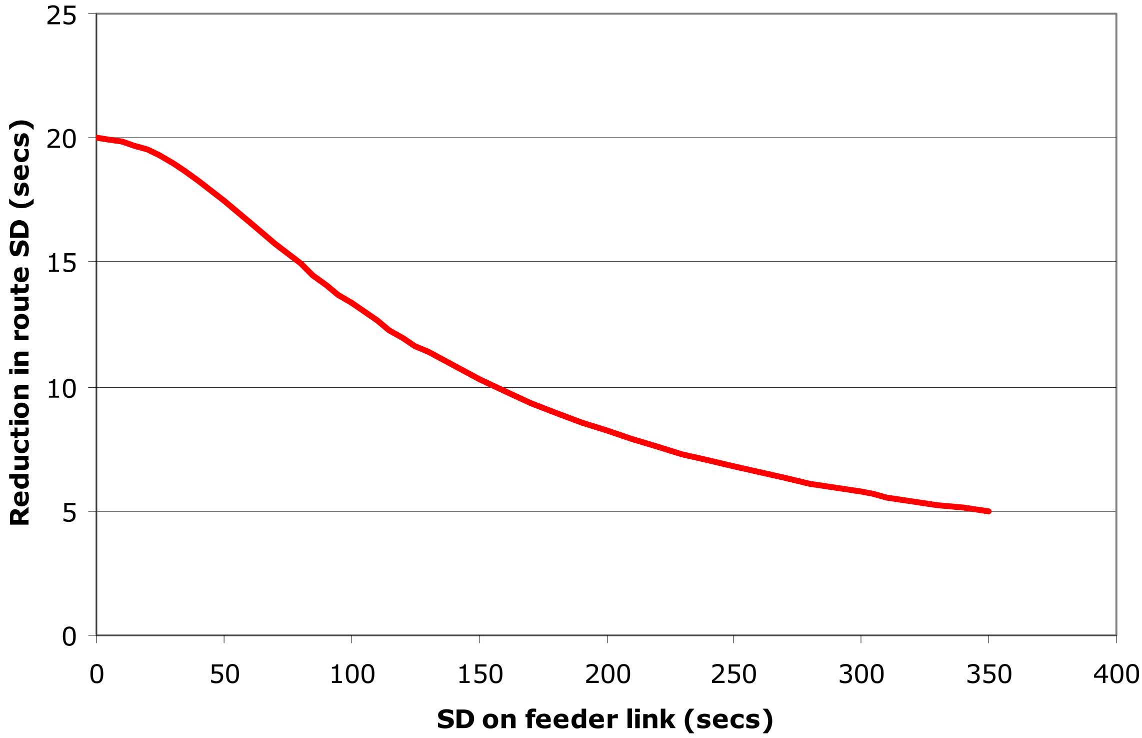

Figure 12.2. The effect of feeder link TTV on route TTV benefits.

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 network structure described above should therefore be considered in all cases. 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.

It is recommended that INCA models use a traffic loading of 60% for feeder links for both the DM and DS scenarios. Thus feeder links should generally be assigned 60% of the motorway scheme traffic flow level. This ensures that route TTV benefits are not unrealistically affected by traffic flows on individual feeder links.

The higher the feeder link loading the higher the variability on the feeder links. The variability on the scheme links then becomes less important over a full journey; this results in lower reported TTV benefits for the scheme. As feeder links have composite properties and may consist of traffic with less certain trip lengths, a loading of 60% is considered a realistic level that ensures that the overall feeder link flow impacts on scheme TTV benefits are not excessive.

13 Case Study: Application of INCA to a MM-DHS scheme

The INCA download comes with a default network which illustrates the reliability assessment required for introducing MM-DHS to an existing D3M motorway. Figure 13.1 illustrates the network structure used to assess the variability effects of the scheme. The scheme link represents a section of a motorway to be improved and has three lanes in each direction. It is expected that the assessment of similar schemes would follow this method.

In this example, the proposed scheme would introduce MM-DHS onto a 24km section of existing D3M. There are intermediate junctions along the scheme but flows and journey characteristics are sufficiently similar to allow aggregation of these real-life links into one scheme link. The increase in the number of links in the new version of INCA allows the modeller this additional level of disaggregation, if required.

Eight feeder links have been specified to model different journey lengths and times of vehicles using the scheme link. If more than one INCA scheme link is being used, an additional set of feeder links should be used. Due to the specification of the reliability calculation in INCA, feeder links do not need to represent real links but are coded to ensure realistic journey lengths and journey times are modelled. If significant levels of short trips are identified, the level of disaggregation shown below for shorter trip lengths should be increased.

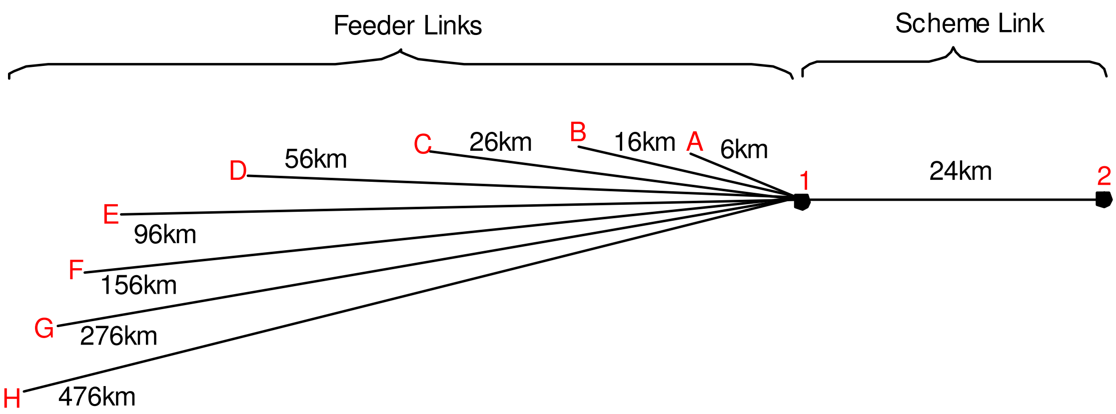

Figure 13.1: INCA Network Structure

13.1 Primary Input Sheet

(a) Scenario Parameters

The scenario parameters table in INCA is shown in Figure 13.2 below.

Scenario Name: **MM-DHS Scheme Example** 2011

Parameters

Maximum Diversion Proportion	Directions for Calculation of Benefits	Average Delay Threshold (Min)	Threshold Factor	Base Year of Data	Traffic Growth Factor from Base Year to Model Year	Accident Rate Decline Factor from Base Year	Heavy Vehicle PCU Factor
1.0	2	30.00	0	2007	1.04	0.00	2.5

Figure 13.2: Scenario parameters

In this example, the Base Year for the traffic data is 2007 and traffic growth from the base year to the model year 2011 is 4%. The accident rate is not expected to change. This table also specifies that the maximum delay per vehicle is 30 minutes and the threshold factor has been set to 0 in this example so that the maximum delay for all vehicles is capped at 30 minutes.

(b) Traffic and Network Data

The network description in INCA is given in Figure 13.3 below.

Link Between Junctions	Link Type (Network=1; Feeder=0)	Length (kms)	Two-way Base Year AADT (Veh/day)	Percentage of Heavy Veh during Flow Groups 1-3	Percentage of Heavy Veh during Flow Group 4	Number of Lanes per Direction		Proportion of Traffic Generated	Proportion of Basic Induction	Capacity per Lane (PCUs/Hr)	Road type	
						DM	DS				DM	DS
A-1	0	6.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
B-1	0	16.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
C-1	0	26.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
D-1	0	56.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
E-1	0	96.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
F-1	0	156.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
G-1	0	276.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
H-1	0	476.0	66527	20.0%	19.0%	3	3	0.00	0.00	2300	D3M	D3M
1-2	1	24.0	131963	20.0%	19.0%	3	4	0.10	0.00	2300	D3M	D3M-ATM with 60mph
Not used						3	3	0.00	0.00	2300		
Not used						3	3	0.00	0.00	2300		
Not used						3	3	0.00	0.00	2300		
Not used						3	3	0.00	0.00	2300		
Not used						3	3	0.00	0.00	2300		

Figure 13.3: Traffic and Network Definition

In this example link 1-2 (the scheme or network link) is the link where improvements are proposed. Links A-1 through to H-1 are feeder links that represent the different journey lengths of traffic using the scheme link. "Not used" links ensure that the total number of entries under links is 63.

Scheme Link

The link descriptions indicate that link 1-2 is a real network link 24 km in length. The Base year two-way AADT for the scheme link is 131,963 vehicles per day. The proportions of heavy vehicles in Flow Groups 1-3 is 20% while that for Flow Group 4 is 19%. Hourly link capacity for all links is 2,300 pcus per hour for each lane.

In order for the network link to be represented correctly as a hard-shoulder running scheme, the scheme link is defined as a 3-lane motorway (D3M) for the Do-minimum scenario and 'D3M-ATM with 60mph' for the DS scenario. This specifies the correct speed flow curves and DTDV relationships for the DM and DS TTV calculations.

Feeder Link

The flow on the feeder link is specified to ensure that representative journey times (and variability) are modelled to represent whole journey costs (and reliability) for vehicles on the scheme link. There are several methods of combining flows on real links to allow representation in feeder links. To ensure consistency between appraisals, we recommend using an AADT flow on feeder links to achieve a ratio of flow to capacity (RFC) of 0.60 during peak-hours (INCA Flow Group 4) in 2003, 0.65 in 2015, and 0.69 in 2025 (with straight-line interpolation for other years). Feeder link AADT is dependent, therefore, on capacity and the proportion of AADT in Flow Group 4:

Capacity / lane (pcus)	(A)	2300
Capacity / lane (veh)	(B) = (A) / 1 + 0.015 x %HGV[1]	1878
2-way capacity (veh)	(C) = (B) x No. of lanes	11265
Hourly 2-way flow at 0.60 RFC	(D) = (C) x 0.60	6759
Equivalent AADT	(E) = (D) / 0.1016[2]	66527
[1] From lane capacity formula COBA Part 5, Ch 3 [2] Hr / AADT factor from 'Flow Group Definition' table		

Figure 13.4: Flow Group Calculations

Any predicted changes in traffic flow between the Do-Minimum and Do-Something in the model (input as the proportion of traffic generated in INCA) should only be applied to the Scheme Link. No changes in flow should be applied to the Feeder Links. A sense check should be carried out on the induced traffic levels implied by the traffic model.

13.2 Secondary Input Sheet

(a) Application of incident parameters on scheme link

In the DM scenario, default incident parameters for 3-lane motorways are used. For the DS scheme with MM-DHS, the incident parameters for the 3-lane motorway are used with the following adjustments:

- Number of lanes affected increased by 1 for all incident types;
- Reduction of 5 minutes applied to all incident durations;
- Single-lane and multi-lane accident rates reduced by 15%.

13.3 Trip Matrix and VOT

(a) Movement Flows

Traffic demand in INCA is defined as movements from the start of a link to the end of another link. As in the Primary Input Sheet, traffic flows in this sheet are input in AADTs. However, whereas *total* link AADTs are used in the Primary Input Sheet, <u>only traffic using the scheme link are input into Movement Flows</u> (Figure 13.5). For example, the AADT on the scheme link from origin A (average journey length 30km) is 14,516 vehicles. These values can be calculated by applying the proportion of vehicles within each journey distance band to the total scheme link AADT.

Movement Flows											
		Movement Name									
	Total	A-2	B-2	C-2	D-2	E-2	F-2	G-2	H-2	-	-
Two-way Flows (Veh/day)	**131963**	14516	9237	10557	22434	17155	34310	22434	1320		

Figure 13.5: Movement Flows

If the network structure above is adopted, the 'links traversed by movement' table will look similar to Figure 13.6 below. One link is allocated to each journey length ('origin'), while all trips traverse the scheme links. For example, in Figure 13.6, OD movement A-2 traverses the feeder link A-1, and the scheme link 1-2.

Links Traversed by Movement											
		Movement as Named Above									
Links in Network	Total	A-2	B-2	C-2	D-2	E-2	F-2	G-2	H-2	-	IMPLIED LINK FLOWS
A-1	1	1									14,516
B-1	1		1								9,237
C-1	1			1							10,557
D-1	1				1						22,434
E-1	1					1					17,155
F-1	1						1				34,310
G-1	1							1			22,434
H-1	1								1		1,320
1-2	8	1	1	1	1	1	1	1	1		131,963
Not used	-										-
Not used	-										-
Not used	-										-

Figure 13.6: Definition of Routes and OD Movements

The 'Implied link flows' column is calculated by INCA and is, in this case, equal to the values in Figure 13.3 since there is only one movement per feeder link. These feeder link flows sum to give the total scheme link AADT.

The user should ensure that the scheme link AADT is consistent in the Primary input sheet and the trip matrix.

13.4 Additional years and linking sheets

An INCA run for each forecast year is required. In this example, six forecast years (the maximum) have been identified: 2011, 2016, 2021, 2026, 2031 and 2041. Universal growth factors have been applied (in scenario parameters table) as shown in Figure 13.7.

Scenario Name: **MM-DHS Scheme Example** **2016**

Parameters

Maximum Diversion Proportion	Directions for Calculation of Benefits	Average Delay Threshold (Min)	Threshold Factor	Base Year of Data	Traffic Growth Factor from Base Year to Model Year	Accident Rate Decline Factor from Base Year	Heavy Vehicle PCU Factor
1.0	2	30.00	0	2007	1.09	0.00	2.5

Figure 13.7: Future year Scenario Parameters

Following the completion of an INCA run for each forecast year, these are linked via the INCA Master spreadsheet to obtain reliability benefits across the 60-year appraisal period.

INCA SCENARIO		**INCA MM-DHS Scheme**					
APPRAISAL PEROID (Yrs)		**60**					
CURRENT YEAR		**2007**					
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Modelled Years		**2011**	**2016**	**2021**	**2026**	**2031**	**2041**
Source Files	**File Name and Folder (Double Click to Change)**	INCA_41_Single_Year_2011.xls	INCA_41_Single_Year_2016.xls	INCA_41_Single_Year_2021.xls	INCA_41_Single_Year_2026.xls	INCA_41_Single_Year_2031.xls	INCA_41_Single_Year_2041.xls
		C:\INCA\Manual Example\	C:\INCA\Manual Example\	C:\INCA\Manual Example\	C:\INCA\Manual Example\	C:\INCA\Manual Example\	C:\INCA\Manual Example\
	Clear						

Figure 13.8: Combining INCA Runs

13.5 Results Reporting

INCA produces the following table as an output.

Report 1 TOTAL BENEFITS
All entries are present values discounted to 2002, in 2002 prices

	£
TOTAL BENEFITS	228,372,519
Total Incident and DTDV TTV Benefit	260,825,171
Total Delay Benefit	-32,452,653

Figure 13.9: INCA Benefits Table

Note that:

- These are net present values of benefits, over a 60 year appraisal period, discounted to 2002 prices;
- In this case the negative benefits in delay might reflect benefits of increasing capacity being offset by traffic generation on the scheme link in the DS.
- Results can be very sensitive to any change in ‘Proportion of Traffic Generated’, and hence this input should be based on a traffic model, and applied with care.

In general, the eventual specification of an INCA network is, as with all models, an issue of judgement, and will be based on the scheme and knowledge of existing / potential traffic patterns. As INCA becomes more widely used, it is envisaged that this Guidance will develop to reflect users’ experiences and feedback on its use would be most welcome.

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Abbreviations

DTDV Day-to-day variability.

PIS Primary input sheet. INCA network and floe data is captured in this spreadsheet

SIS Secondary input sheet. This captures incident-related data.

TTV Travel time variability.

Appendix A Additional material for Delay and TTV Formulations

A.1 Overview

A.1.1 Link-based calculations

As described in the INCA Project managers' guide, INCA starts with a sequence of calculations for each combination of scenario (DM/DS), link, incident type and flow group. These are summarised inFigure A.1, which is followed by a brief text description of the process.

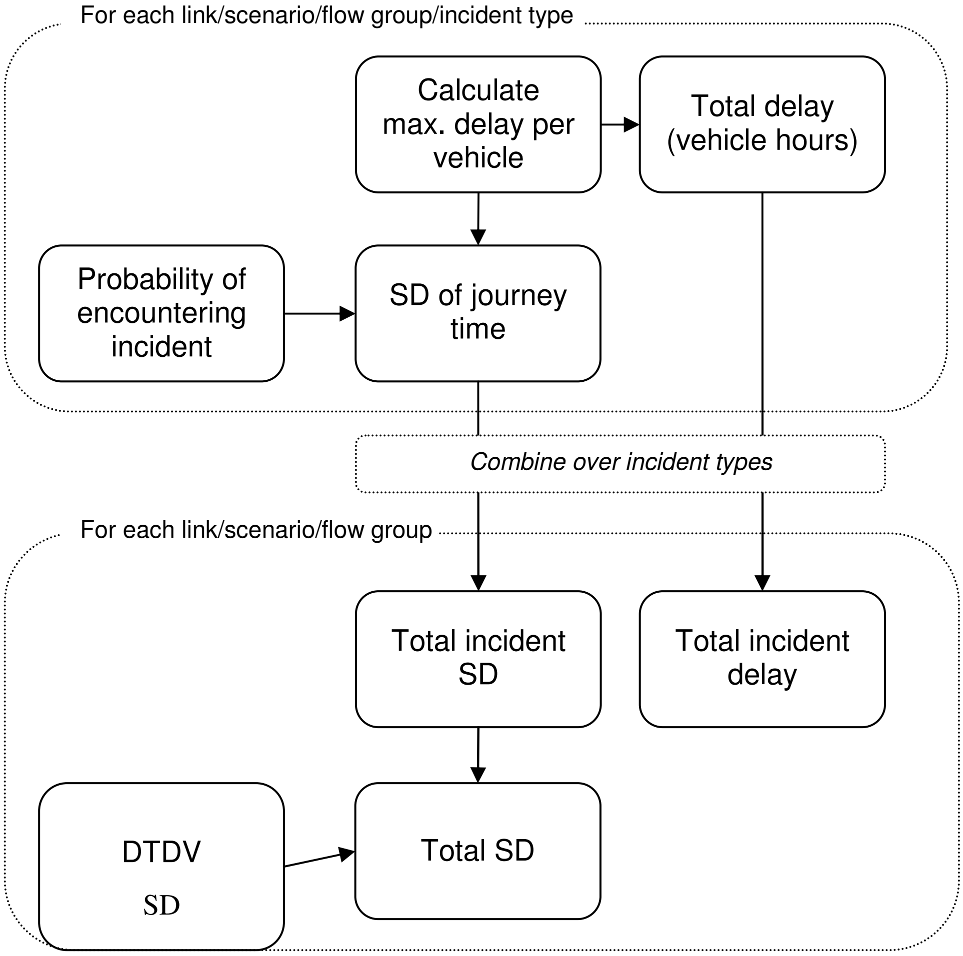

Figure A.1: Overview of link-based calculations in INCA (SD=standard deviation; DTDV=day to day variability).

A.1.2 Incident delays

Initially INCA considers each combination of link, scenario, flow group and incident type in turn. Using standard deterministic queuing formulae[2] it calculates various delay measures for each incident. These include the maximum delay per vehicle and the total delay in vehicle hours.

The flow used in these calculations is the AADT, multiplied by the relevant flow group multiplier[3]. For the DS scenario any generated traffic specified by the user is included. This flow may be further reduced to account for diversion. When an incident occurs 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.

A.2 Notation

In this Appendix the derivation of the formulae for incident queue time and TTV estimation is set out in more detail. The derivation uses the following notation:

C - The maximum one-way capacity of the link in vehicles per minute for the flow group under consideration.

F - The one-way demand flow on the link, in vehicles per minute for the flow group under consideration. In general this is capped and not allowed to exceed 95% of C. If some traffic diverts to other routes during incidents then F is reduced to exclude any diverted traffic using the 'diversion model' as set out in detail later.

C' - The capacity remaining during an incident.

B - The build-up duration in minutes during which the incident blocks all or part of the running carriageway. The build-up duration which is used in the formulae set out below is weighted to take account of the effect of the distribution of individual incident build-up durations and the number of lanes closed.

D - The time at which the queue completely disappears. There are no delays after this time.

The ensuing analysis is dependent on a number of assumptions that are outlined later, but the key assumption to consider when interpreting Error! Reference source not found. is that we are only considering a vertical queue. This means that all vehicles are assumed to be queuing at the point of the incident in a vertical stack. The vertical queuing assumption also makes redundant the debate about whether delay is measured relative to the arrival time at the back of the queue or relative to the normal arrival time at the incident site – the two become the same. This also means that there is no difference between the time D when the queue clears and D' when the last vehicle affected by the queue normally passes the incident site.

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2 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.

3 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.

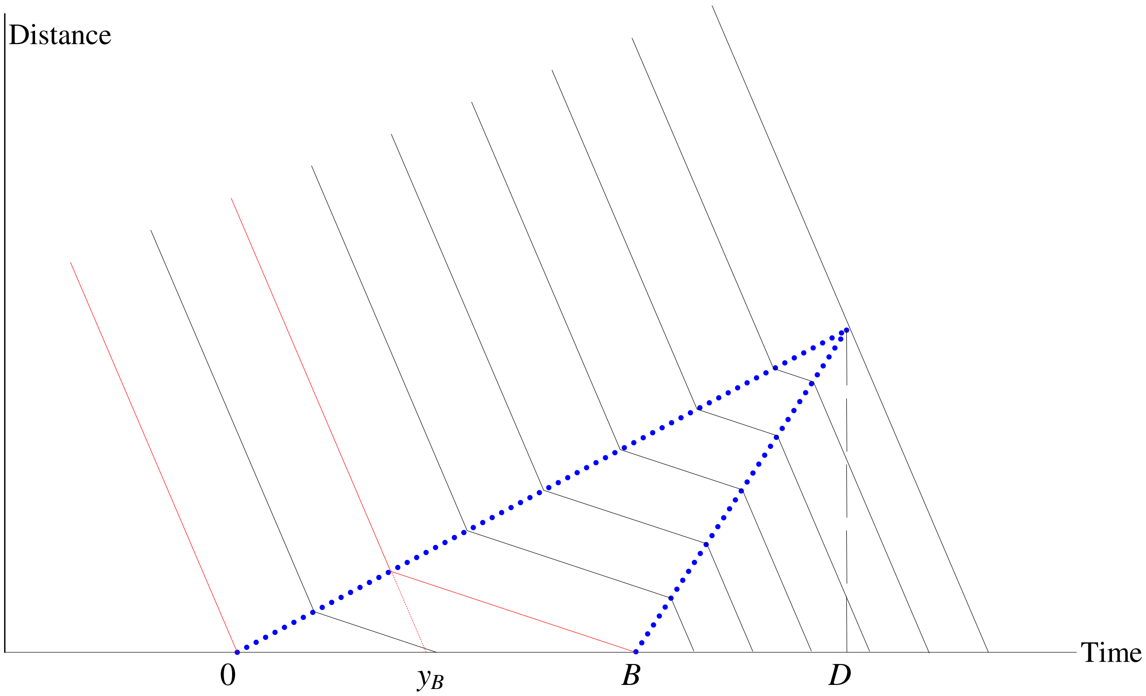

Figure A.2: Space-time diagram of vehicle trajectories

For calculation of queue time the incident queuing period may be split into the following:

a) Queue Build-Up Period - The time from the beginning of the incident to it ceasing to obstruct the carriageway - the build-up duration (B above);

b) Final Period - The time from the end of the build up period, B , to the time when the queue clears completely, D (assuming first in, first out (FIFO)).

INCA calculates the length of the final period in terms of the incident duration, and the maximum and minimum delay for each driver, assuming all lanes are equally affected to accord with FIFO. Total delay is then estimated by calculating the area under the delay function. The derivation assumes that arrival and departure rates are constant (i.e. there is only deterministic queuing).

A number of further assumptions are made in this analysis:

I) Only the vertical queue is considered, that is, we do not take into account the vehicles that would be displaced by the horizontal queue.
II) The road capacity is greater than the demand flow, which in turn is greater than the restricted capacity, i.e. $C > F > C'$.
III) We take no account of the effect on travel times of the traffic speed downstream of the incident site[4].

The derivation of journey standard deviations commences with the calculation of the square of the delay per delayed vehicle (related to the variance per vehicle) for one incident of each type for one link. This is then extended using the probability of *encountering* each incident type to give the variance and standard deviation for all vehicles for all links for each journey.

A.3 Build-up period (B)

During the queue build-up period BC' vehicles pass the incident, i.e. discharge, and BF arrive at the back of the queue. The delay for a vehicle arriving at y minutes after the start of the incident is:

$$D = y\frac{(F - C')}{C'} \text{ minutes} \qquad ..(1)$$

For a given incident type *i*

$$C_i' = (NLANE - ALC_i) * Q_c * BLCF \qquad ..(2)$$

Because we are assuming vertical queuing *y* is time at which the vehicle would normally arrive at the incident site *and* the time it arrives at the back of the vertical queue.

This can be rewritten as:

$$D = ky \qquad ..(3)$$

where the gradient of the build-up of the delay,

$$k = \frac{(F - C')}{C'} \qquad ..(4)$$

The last driver who discharges in the build-up period does so at time B. That driver would have arrived at the end of the queue at y_B, and would therefore queue for a length of time ky_B before departing at time B. Hence

$$B = y_B + ky_B \qquad ..(5)$$

Rearranging gives

$$y_B = \frac{B}{1+k}. \qquad ..(6)$$

[4] For vehicles discharging during the build up period traffic flow downstream of the incident will be lower than usual (flow C’ instead of F) and hence speeds will be higher, partially mitigating the extra delay time. For vehicles discharging during the period of queue decline the downstream flow will be higher (C instead of F), adding to the delay.

After time B, more vehicles will depart the queue (at a rate *C*) than will join it (at a rate *F*) and the delay will decrease. Hence, from equations (8) and (9), the maximum delay, D_B, for vehicles *discharging* in the build-up period (i.e. the vehicle discharging at B) is calculated as

$$D_B = \frac{Bk}{1+k} \qquad .. (7)$$

By using equation (3) the above equation may be expressed in terms of the original variables as:

$$D_B = \frac{B(F-C')}{F} \qquad .. (8)$$

A.4 Final Period ($D-B$)

For the whole of the queue decline period, ($D-B$), the total discharge is:

(All vehicles in the queue at time $y = B$) + (Any vehicles that enter the queue in this period)

i.e.

vehicles discharged in Final Period $= B(F-C') + (D-B)F = DF - BC'$.

As the one direction carriageway capacity for this period is C the time to clear is:

$$D - B = \frac{DF - BC'}{C}. \qquad ..(9)$$

Rearranging gives:

$$D = \frac{B(C-C')}{C-F}. \qquad ..$$

(10)

A.5 Delay formulae

The total delay is the integral of the delay per vehicle over the length of the period. The numbers of vehicles discharging in each period are:

a) Queue Build-Up Period: BC'

b) Final Period: $(D-B)C = \dfrac{BC(F-C')}{C-F}$

Maximum delays are:

a) Queue Build-Up Period: $\dfrac{B(F-C')}{F}$

b) Final Period: $\dfrac{B(F-C')}{F}$

Minimum delays are:

a) Queue Build-Up Period: 0

b) Final Period: 0

Assuming that arrival rates are constant, the build-up or decline of delay between each of these maxima and minima will be linear. In consequence the total delay can be calculated using simple geometry for each of the periods as follows:

a) Build-up period total delay $= \dfrac{B^2C'(F-C')}{2F}$ .. (11)

b) Final period delay $= \dfrac{B^2C}{2F(C-F)}(F-C')^2$ .. (12)

By rearranging and simplifying the total delay over all periods this becomes

$$\frac{B^2(F-C')(C-C')}{2(C-F)}$$ .. (13)

The total number of vehicles delayed is

$$BC'+(D-B)C = \frac{BF(C-C')}{C-F}$$ .. (14)

The average delay per vehicle is the total delay divided by the total number of vehicles, i.e.

$$\frac{B(F-C')}{2F}$$ .. (15)

which is also the area of the (queuing time-time) triangle, divided by the base time and one half of the maximum delay.

A.6 Diversion Proportion

The delays which occur on road sections are dependent on the proportion of traffic diverting to avoid the incident, which in turn is dependent upon the overall duration of the incident, the length of the backed up queue and the availability of alternative routes and reliable information. Thus the total level of this diversion will depend on:

(c) The availability and attractiveness of alternative routes;

(d) The flow on the main carriageway and the proportion of capacity reduction;

(e) The duration of the incident; and

(f) The average or maximum delay per vehicle caused by the incident.

The diversion mechanism in INCA is that recommended in TRL report *"Updating and Validating parameters for incident appraisal model INCA*:

Diversion Proportion, $DP = 0.004168 * \frac{B(F - C')}{F}$ .. (16)

where

B is the incident build-up duration for the relevant incident type.

F is the (capped) demand flow.

C' is the reduced capacity of the link calculated for the relevant incident type and network link.

The traffic diverting is capped at 90% of excess demand (**F-C'**).

This relationship has been developed from observed data. Where queues from an incident tail back towards an upstream junction some drivers divert to alternative routes. This will also be the case where route guidance information is available. However, diversion from the main route will only occur where there is meaningful alternative route.

Very few drivers will divert until the queue has reached a suitable junction. Therefore, the diversion rate is likely to build up gradually as queues lengthen and subsequently be limited by the capacity of any available diversion route for that or earlier diversion opportunities. The TRL formula for diversion proportions increases the diversion proportions for longer queues and is intended to represent the net effect of all the diversion opportunities.

It is assumed that diverted traffic experiences the same delay as the traffic that remains on the main carriageway in INCA.

A.7 Variance and Delay Weightings

Simulation methods based on actual incidents have been used to calculate the combined effects of the build-up duration and lanes closed distributions on delay and TTV. These have derived

a) a weighted build-up duration B_0 to reflect the effect of the distributions on incident delay, and

b) a factor W (which is a multiplicative factor applied after the weighted duration B_0) to reflect the further effects on the travel time variance.

Separate values of B and W have calculated for each incident type, and these are reported in Table 1.

If a distribution of B_i is to be represented by a mean value it follows that the required mean build-up duration B_0 calculated from i incidents is the Root Mean Square (RMS) of B_i if C'_i is constant ie:

$$B_0 = RMS = \left(\sum_i \frac{B_i^{\,2}}{n} \right)^{\frac{1}{2}} \text{ or } \sqrt{\sum_i \frac{B_i^{\,2}}{n}} \qquad .. (17)$$

where: n = total number of incidents designated by the suffix i.

If a distribution of build-up periods is to be represented by a mean value B_0 the required mean build-up duration calculated from i incidents is the Cube Root Mean Cube (CRMC) of B_i i.e.:

$$CRMC = \left(\sum_i \frac{B_i^{\,3}}{n} \right)^{\frac{1}{3}} \qquad .. (18)$$

and that the variance multiplier factor

$$W_t = \frac{CRMC^3}{\left(\sum_i \frac{B_i^{\,2}}{n} \right)^{\frac{3}{2}}} \qquad .. (19)$$

where n = total number of incidents designated by the suffix i.

A.8 Probability of encountering an incident on a journey

For any vehicle traversing a link *l* the probability of encountering an incident i of type t in any flow group g is

$$p_{tgl} = \frac{n_{tlg} \sum_{i \in t} \left(B_{i \in t} + D'_{i \in t} \right)}{FGH_g} \qquad .. (20)$$

where: n_{tlg} = The number of incidents of type t on link l in flow group g

$B_{i \in t}$ = Build-up duration of incident i of type t

$D'_{i \in t}$ = Queue decline duration of incident i of type t

FGH_g = Total flow group hours for flow group g

This can be simplified to:

$$p_{tgl} = n_{tlg} \frac{\left(B_t + D'_t \right)}{FGH_g} \qquad .. (21)$$

where: B_t = Build-up duration of incident type t, weighted to allow for the Root Mean Square of the build-up duration and the number of lanes affected

D'_t = Queue decline duration of incident type t calculated from B_t

A.9 Travel time variability Calculation

The calculation of travel time variability at journey level involves all variability components affecting a journey. These are:

- Incident variability on all links
- Day-to-day variability on all links, i.e. variability not caused by incidents but by fluctuations in demand, weather, etc.

For each incident type the real-life build-up periods and numbers of lanes closed are distributed around the mean values.

In order to calculate TTV, the standard deviation of travel time for whole journeys is established by:

i) Calculating the variance of travel time for a typical single incident of each type for each individual link for each flow group; and multiplying this by the appropriate probability and

ii) Calculating from (i) the variance and standard deviation of travel for journeys whose route is via one or more links affected by the scheme.

Variances per vehicle may be summed over a series of links and incident types, assuming the probability of incidents on one link/type is independent of the probability on other links/types. Standard deviations may not be summed in that way.

The variance of travel time for each incident takes into account how delays change during the build up and decline phase of that incident. The variance on each link is multiplied by the probability that a trip will encounter an incident of each type for each flow group in turn.

The variance VAR_{ti} per vehicle encountering an average incident of type *t* on link *i* is approximately:

$$VAR_{ti} = \frac{W_{ti} M_{ti}^{2}}{3} \qquad \text{.. (22)}$$

where:

W_{ti} is a variance weighting for incident type *t*, required for each *i* defined in Appendix B. INCA provides default variance weightings for incident types.

M_{it} is the maximum delay for incident *i* .

The variance for all incident types *t* on link *i* per vehicle in flow group *g* is calculated as:

$$VAR_{ig} = \sum_t p_{tgi} VAR_{ti} \qquad \text{.. (23)}$$

where

p_{tgi} is the probability of encountering an incident of type *t* on link *i* in a flow group *g*

INCA calculates the probability p_{tgi} as

$$p_{tgi} = n_{tig} \frac{(B_t + D_t)}{FGH_g} \qquad \text{.. (24)}$$

where:

B_t is the build-up duration of incident type t, weighted to allow for the Root Mean Square of the build-up duration as discussed in Appendix B.

D_t is the queue decline duration of incident type t.

n_{tig} is the number of incidents of type t on link i in flow group g.

FGH_g is the total flow group hours for flow group g.

INCA calculates this for every link, every incident type and every flow group.

A.10 Estimating standard deviations for a journey

The overall journey variability is a function of all variance components, variability on links used to reach the scheme also needs to be allowed for. This is achieved in INCA by modelling typical feeder links in addition to the scheme and network links. The variance for each origin to destination journey can then be calculated by summing the variances per vehicle over all links traversed i.e.

$$VAR_{OD} = \sum_{i \in OD} VAR_{i \in OD}$$

where $VAR_{i \in OD}$ is the variance for link i which is traversed on journey O to D.

The total travel time standard deviation for that particular origin to destination journey (by flow group) can then be calculated for the Do Minimum and Do Something scenarios as the square root of the summed variances.

Travel time standard deviation $SD_{OD} = \sqrt{VAR_{OD}}$

This calculation is repeated for all trips T_{OD} using the links under examination, where trips T_{OD} include diverted traffic.

To calculate total TTV values the SD_{OD} values are multiplied by T_{OD} separately for each OD movement. This gives

Total Incident TTV $= \sum_{OD} T_{OD} SD_{OD}$

T_{OD} is one of the user-defined inputs to INCA. It may be reduced for certain flow groups if link flows exceed 95% of capacity.

Appendix B Incident parameters

Table B.1: Recommended incident rates (Source TRL PPR030 Report (D3M/D4M figures) and HA guidance on MM-DHS)

Incident Category	Incident Rates (incidents per million veh kms)	
	D3M and D4M with standard hard shoulder	MM-DHS
Multi-lane accident	0.0267	0.0227
Single lane accident	0.1173	0.0997
Non-HGV breakdown	0.1047	0.1047
HGV breakdown	0.2412	0.2412
Non-HGV Fire	0.0084	0.0084
HGV fire	0.0110	0.0110
Load shedding	0.0025	0.0025
Debris	0.1928	0.1928
SL emergency Roadworks	0.0410	0.0410
ML emergency Roadworks	0.0118	0.0118
Spillage	0.0022	0.0022
Animal	0.0032	0.0032

Table B.2: Incident duration parameters (Source TRL PPR030 Report)

Incident Category	Mean Incident (Build-up) Duration (mins) – (D3M/D4M)	Mean Incident (Build-up) Duration (mins) – (MM-DHS)	RMS Duration Weighting	Variance Weighting
Single lane accident	24.6	19.6	0.99	1.70
Multi-lane accident	86.4	81.4	0.71	2.69
Non-HGV breakdown	16.8	11.8	1.04	1.64
HGV breakdown	51.6	46.6	0.76	1.21
Non-HGV Fire	39.4	34.4	0.96	1.95
HGV fire	138.8	133.8	0.80	1.21
Load shedding	17.6	12.6	0.99	1.51
Debris	19.6	14.6	1.04	1.76
SL emergency Roadworks	241.9	236.9	1.20	1.42
ML emergency Roadworks	29.5	24.5	1.10	2.12
Spillage	46.5	41.5	0.95	1.60
Animal	27.0	22	1.22	2.92
Fire, spillage, load shedding	57.1	52.1	0.89	2.12

Table B.3: Lane closure parameters

Incident Category	Average Lanes Blocked (D3M/D4M)	Average Lanes Blocked (MM-DHS)	Build-up Lane Capacity Factor (BLCF)
Multi-lane accident	2.22	3.22	0.76
Single lane accident	1.11	2.11	0.76
Non-HGV breakdown	1.26	2.26	0.76
HGV breakdown	1.04	2.04	0.76
Non-HGV Fire	1.22	2.22	0.76
HGV fire	1.36	2.36	0.76
Load shedding	1.22	2.22	0.76
Debris	1.43	2.43	0.76
SL emergency Roadworks	1.00	2.00	0.76
ML emergency Roadworks	1.82	2.82	0.76
Spillage	1.25	2.25	0.76
Animal	1.52	2.52	0.76
Fire, spillage, load shedding	1.29	2.29	0.76

Table B.4: Values of Time and TTV (2002 values and market prices, WebTAG 3.5.6)

	Delay		TTV	
Type of Vehicle	***Pence/Hr***	***Pence/Min***	***Pence/Hr***	***Pence/Min***
Working Car	3018	50.30	2414	40.23
Non-Working Car	749	12.48	599	9.98
Average LGV	1163	19.38	930	15.50
OGV	1018	16.97	1222	20.37
PSV	7162	119.37	5730	95.50

Table B.5: Discount Rates

Start Year	End Year	Rate (%)
1	30	3.5
31	75	3.0
76	80	2.5

Table B.6: Value of time growth (% p.a., WebTAG 3.5.6)

Start Year	End Year	Business trips	Non-business trips
2003	2003	1.98	1.58
2004	2004	2.22	1.78
2005	2005	3.21	2.57
2006	2006	2.96	2.37
2007	2007	2.46	1.97
2008	2011	2.2	1.76
2012	2021	1.94	1.55
2022	2031	1.55	1.24
2032	2051	1.99	1.59
2052	2061	1.81	1.45
2062	onwards	2.00	1.60