A4 Travel time values

A4.1 Introduction

Introduction

This appendix contains travel time values for vehicle occupants, passenger transport users, pedestrians, cyclists, and freight vehicle travel time. The road user values are used to produce composite travel time values for the different road categories for uncongested and congested traffic conditions. Values and procedures are also provided to calculate the values for changes in road user journey time reliability.

The travel time benefits for a project option shall be calculated as the difference between the do minimum and option travel time costs as follows:

Total travel time savings	=	base travel time benefits for improved flow
	+	travel time benefits for reduced traffic congestion (if applicable)
	+	travel time benefits for improved trip reliability (if applicable).

In this appendix

This appendix contains the following topics:

A4.2 Base values for travel time

Base values for travel time

For vehicle occupants, dollar values are provided for travel time during the course of paid employment (work travel), commuting to and from work, and for other non–work travel purposes. Table A4.1 gives values of time for transport users, it also gives the maximum values for congestion (denoted as CRV), which may be added to the base values of time for transport users, as described in appendix A4.4. Table A4.2 gives values of travel time for vehicles and freight.

Mode switching

Lower travel time values are not used when evaluating the benefits of activities that encourage a change from car or motorcycle driver to shared or active modes.

The travel time values pertaining to the original mode (where these values are higher) should be adopted for proposals that have a high proportion of mode switching. This includes activities which have the primary objective of changing modes or maintaining mode share.

Table A4.1 Values for transport user time in $/h (all road categories; all time periods – July 2002)

Vehicle occupant	Work travel purpose	Commuting to/from work	Other non–work travel purposes
Base values of time for uncongested traffic ($/h)			
Car, motorcycle driver	23.85	7.80	6.90
Car, motorcycle passenger	21.70	5.85	5.20
Light commercial driver	23.45	7.80	6.90
Light commercial passenger	21.70	5.85	5.20
Medium/heavy commercial driver	20.10	7.80	6.90
Medium/heavy commercial passenger	20.10	5.85	5.20
Seated bus and train passenger	21.70	4.70	3.05
Standing bus and train passenger	21.70	6.60	4.25
Pedestrian and cyclist	21.70	6.60	4.25
Maximum increment for congestion (CRV, $/h)			
Car, motorcycle driver	3.15		2.75
Car, motorcycle passenger	2.35		2.05
Commercial vehicle driver	3.15		2.75
Commercial vehicle passenger	2.35		2.05

Table A4.2 Base values for vehicle and freight time in $/h (July 2002) for vehicles used for work purposes

Vehicle type	Vehicle and freight time ($/h)
Passenger car	0.50
Light commercial vehicle	1.70
Medium commercial vehicle	6.10
Heavy commercial vehicle I	17.10
Heavy commercial vehicle II	28.10
Bus	17.10

A4.3 Composite values of travel time and congestion

Composite values of travel time and congestion

Travel time values combining passenger and commercial (including freight) occupants, and vehicle types for standard traffic compositions are given in table A4.3. These include different time periods for the four road categories defined in appendix A2.2. The right–hand column gives the maximum additional values for traffic congestion (CRV), to be applied as described in appendix A4.4.

Table A4.3 Composite values of travel time in $/h (all occupants and vehicle types combined – July 2002)

Road category and time period	Base value of time ($/h)	Maximum increments for congestion (CRV $/h)
Urban arterial		
Morning commuter peak	15.13	3.88
Daytime inter–peak	17.95	3.60
Afternoon commuter peak	14.96	3.79
Evening/night–time	14.93	3.68
Weekday all periods	16.83	3.79
Weekend/holiday	14.09	4.26
All periods	16.27	3.95
Urban other		
Weekday	16.89	3.82
Weekend/holiday	14.10	4.32
All periods	16.23	3.98
Rural strategic		
Weekday	25.34	4.23
Weekend/holiday	19.21	5.22
All periods	23.25	4.39
Rural other		
Weekday	24.84	4.24
Weekend/holiday	18.59	5.23
All periods	22.72	4.40

A4.4 Traffic congestion values

Introduction

Road users value relief from congested traffic conditions over and above their value of travel time saving. The maximum increments for congestion values apply to vehicle occupants. or road category and time periods as indicated in tables A4.1, A4.2 and A4.3. The actual additional value for congestion used in the evaluation is adjusted according to the requirements set out below.

Treatment of passing lane projects

An exception to the procedures below is made in the case of passing lane projects evaluated using the procedures in appendix A7 of this manual. The procedures in appendix A7 include a separate value for the reduction in driver frustration and the effect of reducing travel time variability. When evaluating passing lanes using the procedures in appendix A7, no additional allowance shall be made for congestion or improvements in trip reliability. Similarly, if passing lanes are evaluated using the values for congestion and/or reliability outlined in this appendix, then no allowance can be included for driver frustration.

Congested traffic conditions – rural 2 lane highways

To allow for congestion, the following addition should be made on sections of rural 2 lane highways. Section lengths for this analysis should normally be greater than 2 km.

Peak traffic intensity and volume to capacity ratio (VC ratio) are first calculated in the normal manner (see appendix A3.17). Using the VC ratio, terrain type and percentage no–passing for the road section, the percentage of time delayed (PTD) following slower vehicles is selected from figure A4.1 or table A4.4. Alternatively, the formulae shown in figure A4.1 can be used to calculate PTD, within a limiting range of PTD greater than or equal to 30 percent. For lower values of PTD the curves are linear.

$$\text{Incremental value for congestion} = CRV \times \frac{PTD}{90} \ (\$/h)$$

where CRV is the value for congestion (in $/h) and is given in table A4.1 for drivers or passengers, and in table A4.3 for standard traffic compositions.

Percentage of time delayed has a maximum limit of <90%, for situations where PTD is ≥90%, the maximum increment for congestion (CRV) should be added to the base value of travel time.

Congested traffic conditions – urban roads, multi–lane rural highways and motorways

To allow for congestion, the following addition should be made to road section travel time values where the time period VC ratio exceeds 70%.

Incremental value for congestion =

$$CRV \times \frac{(\text{road section traffic volume} - 70\% \text{ of road section capacity volume})}{30\% \text{ of road section capacity volume}} \ (\$/h)$$

Bottleneck delay

For all bottleneck delay, the maximum increment for congestion from table A4.1 or table A4.3 should be added to the base value of travel time.

A4.4 Traffic congestion values, continued

Worked examples

Four worked examples are given below of the calculations for the value of congestion. In each case, the example describes the calculation for a single time period and for the base year. For a full project evaluation, the calculations would be made for each flow period and for future year traffic forecasts as necessary.

Example 1 – Rural highway: realignment

A project involves the realignment of a busy 2 km section of rural highway, which improves sight distances, providing more overtaking opportunities for following traffic. The road is classified as rolling terrain.

From calculations in appendix A2 and/or A3, the road section carries 12,500 veh/day, with a peak interval intensity of 1,000 veh/h, 60/40 directional split and 12 percent heavy truck component. In the do minimum, the alignment offers no passing opportunities (0 percent overtaking sight distance), and after realignment there is no restriction on overtaking sight distance (100 percent overtaking sight distance). The hourly capacity of the road in the do minimum is calculated as:

$2{,}800 \times f_t \times f_d = 2{,}800 \times 0.675 \times 0.94 = 1{,}775$ veh/h

where: 2,800 is the ideal capacity of the road section; f_t and f_d are adjustment factors for directional distribution and the proportion of trucks (see appendix A3.11). The peak interval traffic intensity (1,000 veh/h) divided by capacity gives a VC ratio of 56 percent.

From figure A4.1(b), the PTD in the do minimum is 79 percent, and 71.5 percent after realignment. The maximum increment for congestion (CRV) for rural strategic roads is \$4.23 per veh/h (from table A4.3).

The incremental values for congestion for the do minimum and project option are calculated as follows:

Do minimum: $4.23 \times \frac{79}{90}$ = \$3.71 per veh/h

Project option: $4.23 \times \frac{71.5}{90}$ = \$3.36 per veh/h

The time period total average travel time for the road section is calculated using the procedures in appendix A3.22 (based on component values calculated in other sections of appendix A3). For this example, the average travel times per vehicle have been calculated as 1.70 and 1.30 min/veh for the do minimum and realignment option, respectively.

The congestion cost savings are calculated by multiplying the peak interval traffic intensity by the incremental value for congestion and the time period average travel time divided by 60. For example:

Do minimum = 1,000 × 3.71 × 1.70/60 = \$105.1/h

Project option = 1,000 × 3.36 × 1.30/60 = \$72.8/h

Congestion cost saving = \$105.1 – \$72.8 = \$32.3/h over the peak period.

A4.4 Traffic congestion values, continued

Example 2 – Rural highway: 4 laning

A section of 2–lane rural strategic road is approaching capacity. One option is 4 laning. The road carries 20,000 veh/day in rolling terrain with 20 percent overtaking sight distance, peak interval traffic intensity of 2,050 veh/h, 70/30 directional split and 7 percent heavy truck component. The ideal capacity for a 2–lane rural road is 2,800 vehicles/hour (total in both direction of travel).

For the do minimum, the congestion cost is calculated in the same way as in example 1. The capacity is $2{,}800 \times f_d \times f_t = 2{,}800 \times 0.89 \times 0.92 = 2{,}290$. This compares with a traffic volume of 2,050, which gives a VC ratio of 0.90. The percentage of time delayed is 90 percent from table A4.4. The incremental value of congestion is therefore equal to is the maximum incremental value of $4.23 per veh/h from table A4.3.

For the 4 laning option, assuming there are no restrictions requiring a reduction in the lane capacity, a capacity of 2,200 veh/h/lane is applicable (See appendix A3.10). The VC ratio is $2{,}050/(4 \times 2{,}200) = 0.23$, which is below 70 percent, so congestion costs are not applicable.

The saving in congestion costs over the peak period is $4.23 per veh/h multiplied by the section traffic volume and time period average travel time for the do minimum.

Example 3 – Urban arterial road: additional traffic lanes

A project provides a 4 lane clearway in the peak direction for an urban arterial road and improves the capacity of a signalised intersection half–way along the project length.

The morning peak interval traffic intensity is 1,000 veh/h in the peak flow direction (from appendix A3.16). Capacity has been established to be 1,250 veh/h for the do minimum and 2,000 veh/h with the clearway project (based on the multilane road capacity procedure in appendix A3). The road section VC ratio reduces from 80 percent to 50 percent as a result of the project.

Intersection stopped delay will be reduced from 15 s/veh in the do minimum to 6 s/veh after widening for the 2,000 veh/h through the intersection.

The incremental value of congestion for the road section in the do minimum for the peak direction of flow is given by:

$$\$3.88 \times \frac{(1{,}000 - 0.7 \times 1{,}250)}{0.3 \times 1{,}250} = \$1.29 \text{ per veh/h}$$

where: $3.88 per veh/h is the CRV value from table A4.3.

With the clearway, the VC ratio in the peak direction is below 70 percent, so no incremental value for congestion is applicable. The congestion cost saving for the road section travel time is therefore $1.29 per veh/h multiplied by the traffic volume and average vehicle travel time for the section.

A4.4 Traffic congestion values, continued

Example 3 – Urban arterial road: additional traffic lanes, continued

For the bottleneck delay, the incremental value for congestion is given by:

Do minimum = $3.88 ×15/3600 = $0.0162/veh through the intersection

Intersection improvement = $3.88 ×6/3600 = $0.0065/veh through the intersection.

Congestion cost saving per vehicle = $0.0162 – $0.0065= $0.0097/veh through the intersection.

The congestion cost saving attributable to reduction in bottleneck delay is $0.0097/veh multiplied by 2000 veh/h using the intersection = $19.40/h over the peak period.

Example 4 – Urban intersection improvement

A project proposal will reduce delay and improve safety at a priority–controlled T–intersection through the installation of a roundabout. Traffic volumes on the three approaches to the intersection are evenly balanced, there is a high proportion of turning traffic and the configuration of the site is such that a roundabout can be constructed without additional land take.

Bottleneck delay to side road traffic during the peak interval of the morning peak period has been observed to average 35 s/veh for the 500 veh/h on the side road approach, and 5 s/veh for the 300 veh/h turning off the main road. With the roundabout, traffic volume and bottleneck delay for the three approaches has been modeled at: 500 veh/h and 7 s/veh; 700 veh/h and 5.5 s/veh; and 600 veh/h and 6 s/veh.

Total bottleneck delay is calculated as:

Do minimum = (500 ×35 + 300 ×5) / 3600 = 5.28 veh/h

Roundabout option = (500 ×7 + 700 ×5.5 + 600 ×6) / 3600 = 3.04 veh/h

Reduction in bottleneck delay = 5.28 – 3.04 = 2.24 veh/h

Congestion cost saving = 2.24 ×CRV = 2.24 ×$3.88 = $8.68/h over time period.

A4.4 Traffic congestion values, continued

Table A4.4(a) VC ratios for level terrain, overtaking sight distance and percentage of time delayed (PTD) following slow vehicles

PTD %	Level terrain – percentage of overtaking sight distance										
	100	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00
15.0	0.07	0.07	0.06	0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.00
22.5	0.11	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.02	0.02
30.0	0.15	0.13	0.11	0.10	0.09	0.07	0.06	0.06	0.05	0.04	0.04
37.5	0.18	0.16	0.15	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.07
45.0	0.23	0.22	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12
52.5	0.30	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.20
60.0	0.39	0.38	0.37	0.36	0.35	0.34	0.33	0.32	0.31	0.30	0.30
67.5	0.50	0.49	0.49	0.48	0.47	0.46	0.45	0.44	0.44	0.43	0.42
75.0	0.64	0.63	0.63	0.62	0.61	0.61	0.60	0.60	0.59	0.58	0.58
82.5	0.80	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.77	0.77
90.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A4.4(b) VC ratios for rolling terrain, overtaking sight distance and percentage of time delayed (PTD) following slow vehicles

PTD %	Rolling terrain – percentage of overtaking sight distance										
	100	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
15.0	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00
22.5	0.11	0.09	0.07	0.06	0.05	0.03	0.02	0.02	0.01	0.01	0.01
30.0	0.15	0.12	0.10	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02
37.5	0.18	0.15	0.13	0.11	0.10	0.09	0.07	0.06	0.06	0.05	0.04
45.0	0.23	0.20	0.18	0.16	0.15	0.13	0.12	0.11	0.10	0.09	0.08
52.5	0.30	0.27	0.25	0.23	0.21	0.20	0.18	0.17	0.16	0.15	0.13
60.0	0.38	0.36	0.33	0.32	0.30	0.28	0.27	0.25	0.24	0.23	0.21
67.5	0.49	0.47	0.44	0.42	0.41	0.39	0.38	0.36	0.35	0.34	0.32
75.0	0.62	0.60	0.58	0.56	0.54	0.53	0.52	0.51	0.49	0.48	0.47
82.5	0.78	0.76	0.74	0.73	0.71	0.70	0.69	0.68	0.67	0.67	0.66
90.0	0.97	0.96	0.94	0.93	0.92	0.92	0.91	0.91	0.90	0.90	0.89

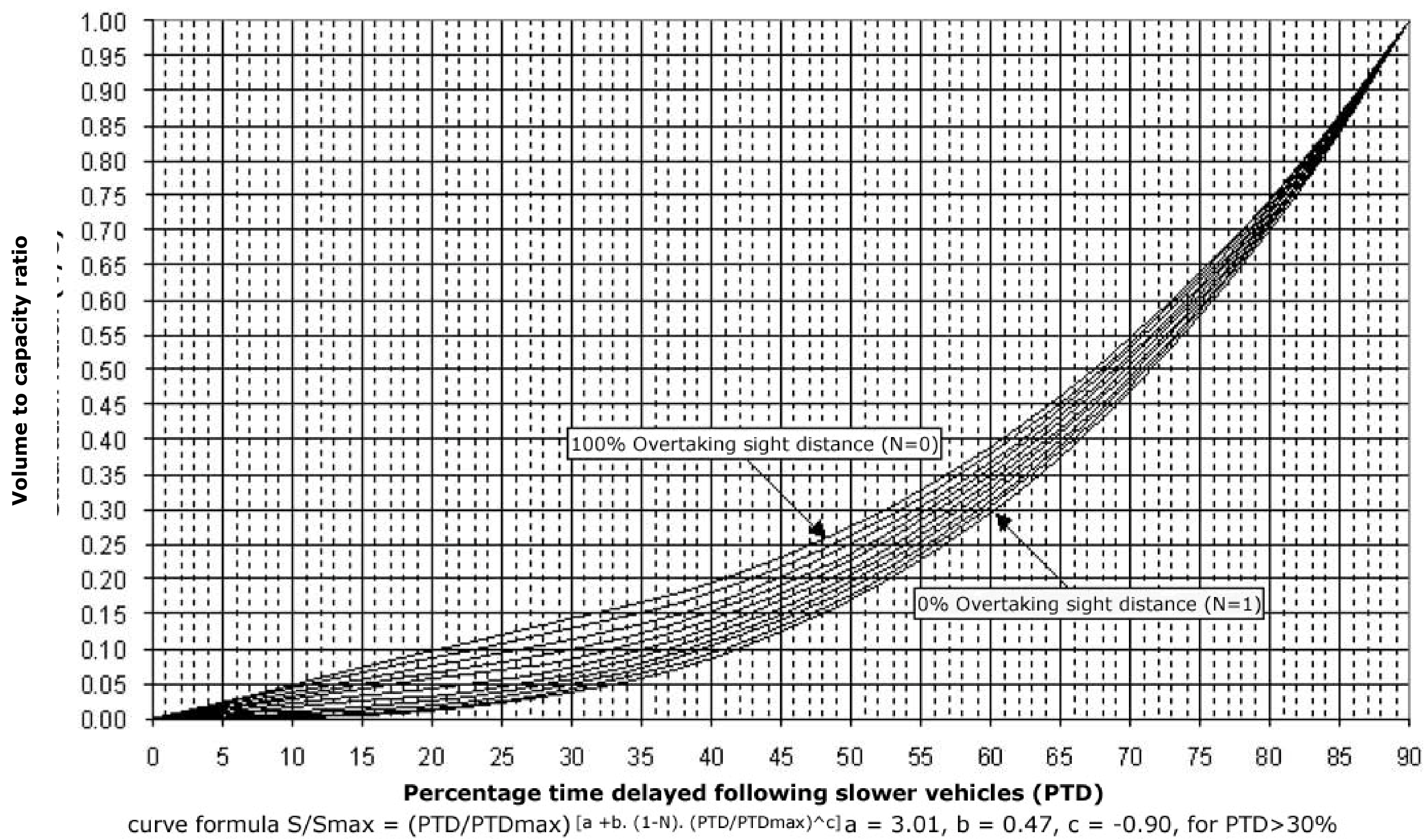
A4.4 Traffic congestion values, continued

Table A4.4(c) VC ratios for mountainous terrain, overtaking sight distance and PTD following slow vehicles

PTD %	Mountainous terrain – percentage of overtaking sight distance										
	100	**90**	**80**	**70**	**60**	**50**	**40**	**30**	**20**	**10**	**0**
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5	0.03	0.03	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
15.0	0.07	0.05	0.04	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00
22.5	0.10	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00
30.0	0.14	0.10	0.07	0.06	0.04	0.03	0.02	0.02	0.01	0.01	0.01
37.5	0.17	0.13	0.11	0.08	0.07	0.05	0.04	0.03	0.03	0.02	0.02
45.0	0.22	0.18	0.15	0.13	0.11	0.09	0.08	0.06	0.05	0.05	0.04
52.5	0.28	0.24	0.21	0.18	0.16	0.14	0.13	0.11	0.10	0.09	0.08
60.0	0.36	0.32	0.29	0.26	0.24	0.22	0.20	0.18	0.16	0.15	0.13
67.5	0.46	0.42	0.39	0.36	0.34	0.31	0.29	0.27	0.26	0.24	0.22
75.0	0.58	0.55	0.52	0.49	0.47	0.45	0.43	0.41	0.39	0.37	0.35
82.5	0.73	0.70	0.68	0.65	0.63	0.62	0.60	0.58	0.57	0.55	0.53
90.0	0.91	0.89	0.87	0.86	0.84	0.83	0.82	0.81	0.80	0.79	0.78

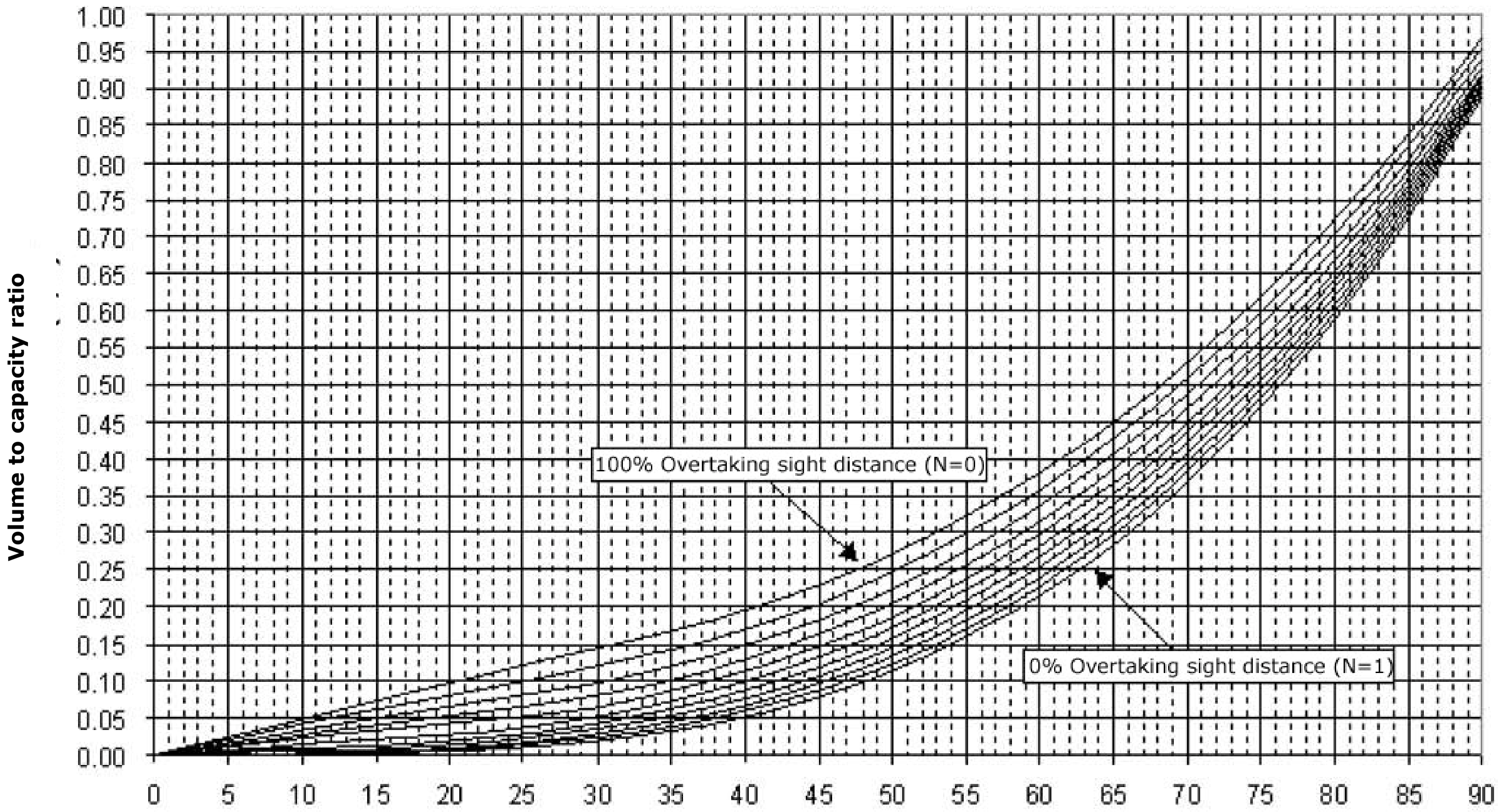
A4.4 Traffic congestion values, continued

Figure A4.1(a) Percentage of time delayed (PTD) two lane rural roads, level terrain



A4.4 Traffic congestion values, continued

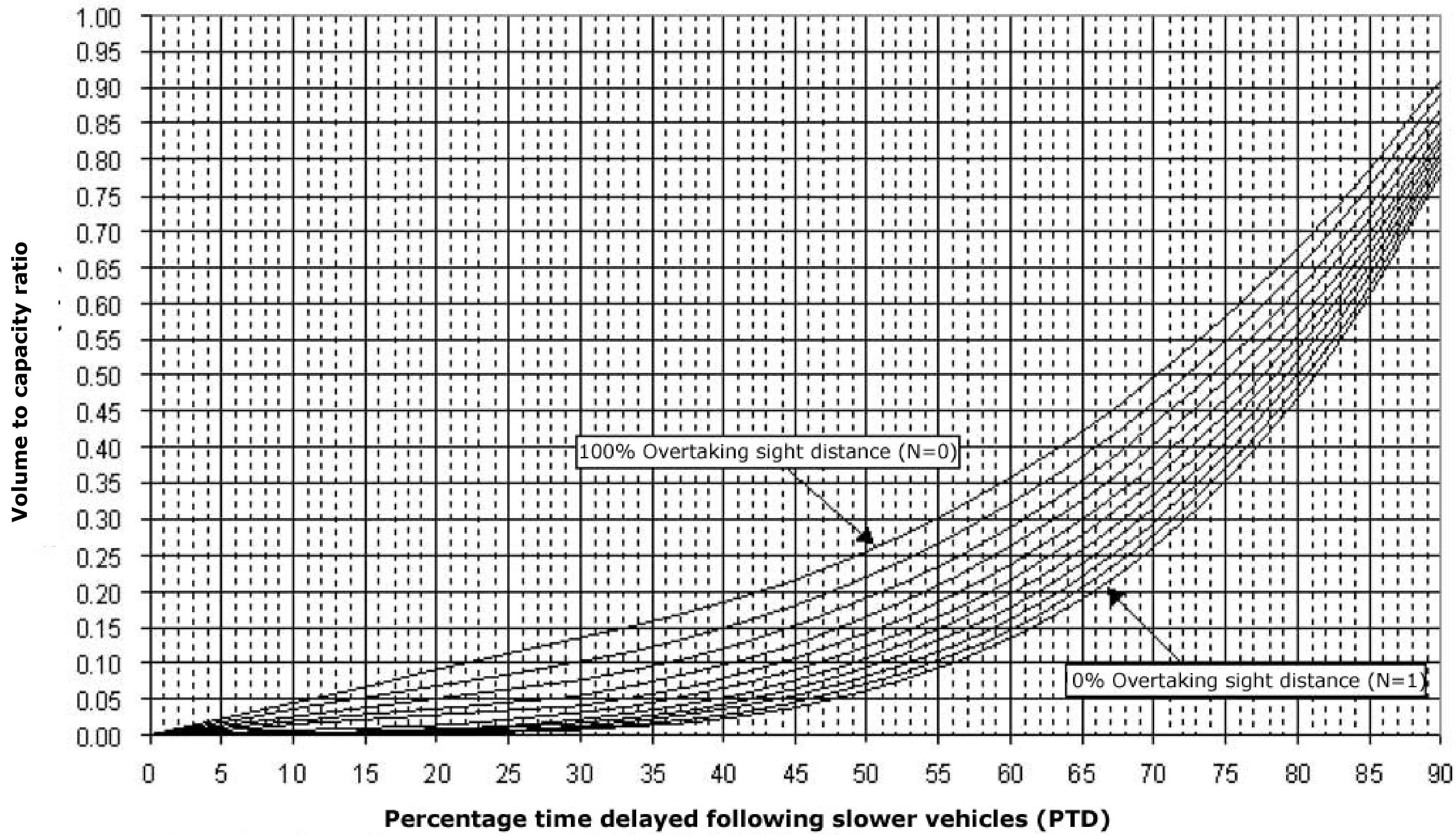
Figure A4.1(b) **PTD for two lane rural roads, rolling terrain**



curve formula S/Smax = (PTD/PTDmax)$^{[a + b.(1-N).(PTD/PTDmax)^c]}$ a = 3.51, b = 0.94, c = -0.59, for PTD>30%

A4.4 Traffic congestion values, continued

Figure A4.1(c) PTD for two lane rural roads, mountainous terrain



curve formula $(S/Smax) = (PTD/PTDmax)^{[a + b.(1-N).(PTD/PTDmax)^{\wedge}c]}$ a =4.34, b = 1.75, c = -0.37, for PTD>30%)

A4.5 Benefits from improved trip time reliability

Introduction

This section outlines how likely variations in journey time can be assessed and the benefits from improvements to trip time reliability incorporated into project evaluation. Trip time reliability is measured by the unpredictable variations in journey times, which are experienced for a journey undertaken at broadly the same time every day. The impact is related to the day–to–day variations in traffic congestion, typically as a result of day–to–day variations in flow. This is distinct from the variations in individual journey times, which occur within a particular period.

Travel time reliability is in principle calculated for a complete journey and the total network variability is the sum of the travel time variability for all journeys on the network. In practice, models may not represent the full length of journeys and this is accounted for in the procedure.

Travel time variability is expressed as the standard deviation of travel time. The sources of variability are road sections and intersections. Reduced variability arises from a reduction in congestion on links and at intersections along a route. For a single section or intersection approach the standard deviation of travel time can be calculated using that section or intersection movement's VC ratio:

$$s_0 + \frac{\left(s - s_0\right)}{1 + e^{b\left(\frac{v}{c} - a\right)}} \quad \text{(min)}$$

where: the VC ratio is represented by s, s_0, *b* and *a* are taken from table A4.5

Major incidents

The travel time variability that may result from major incidents on the road network is not accounted for in this procedure. For example, where there are high levels of congestion on motorways, a major incident will produce large travel time delays. These delays are not included in the day–to–day variability calculations.

The effect of a major incident will be related to the amount of spare capacity at the location. A specific analysis should be undertaken to determine the economic cost of delays from major incidents.

Reliability benefits calculation

The claimable benefits from improving trip reliability are calculated as:

0.9	×	travel time value ($/h) (table A4.1, A4.2 or A4.3)
	×	reduction in the network variability (in min) / 60
	×	traffic volume for time period period (veh/h)
	×	correction factor (table A4.6)

where the reduction in network variability is the difference between the sums of the variability for all journeys in the modelled area for the do minimum and project option. The 0.9 factor is the value of reliability based on a typical urban traffic mix. For projects with a significantly different vehicle mix, evaluators should use 0.8 for cars and 1.2 for commercial vehicles.

A4.5 Benefits from improved trip time reliability, continued

Table A4.5 Coefficients to calculate standard deviation of travel time

Context	S	b	a	S_0
Motorway/multilane highway (70 – 100 km/h)	0.90	−52	1	0.083
Urban arterial	0.89	−28	1	0.117
Urban retail	0.87	−16	1	0.150
Urban other (50 km/h)	1.17	−19	1	0.050
Rural highway (70 – 100 km/h) (2 lanes in direction of travel)	1.03	−22	1	0.033
Signalised intersection	1.25	−32	1	0.120
Unsignalised intersection	1.20	−22	1	0.017

Note: Evaluations of small retail areas on 50 km/h sections of a rural highway should use the urban other (50 km/h) context.

Adjustment factor for variability calculations

In many cases, a project evaluation will consider a defined area which does not represent the full length of most journeys. As a result, the changes in journey time reliability will be overestimated. In these cases the variability estimates need to be adjusted. Table A4.6 gives some illustrative contexts where different factors might apply. An estimation of the variance of journey times which occurs outside of the evaluation area must be made and the appropriate correction factor in table A4.6 applied.

The trip time reliability benefit is adjusted by multiplying the calculated variability benefit by the factor.

Table A4.6 Adjustment factors to apply to variability calculations

Percentage of variance outside of study area	Factor for benefit calculation	Indicative transport network model coverage
<20 %	100 %	Regional model
20 %	90 %	Sub−regional model
50 %	70 %	Area model
75 %	50 %	Corridor model
90 %	30 %	Intersection model, individual passing lane

A4.5 Benefits from improved trip time reliability, continued

Process for evaluating reliability benefits

1. Calculate standard deviation of travel time on each link between intersections and for each intersection movement or approach.
2. Square the standard deviations to produce variances.
3. Sum variances along each origin–destination path to obtain the total variance for journeys between each origin and destination.
4. Take the square root of the aggregated variance for a journey to give the standard deviation of the journey time.
5. Multiply the total trips for each origin–destination pair by the standard deviation of travel time and sum over the matrix to give the network–wide estimate of the variability.
6. Calculate the difference in variability between the project and do minimum networks.
7. Assess the percentage of variance occurring outside of the selected study area and select the adjustment factor.
8. Calculate the benefit from improving trip reliability using the formula provided above, namely: 0.9 × travel time value × reduction in the network variability/60 × traffic volume for time period period (veh/h) ×adjustment factor.

Network models with origin–destination information

Intersections should be analysed by movement at traffic signals and by movement or by approach for roundabouts and priority intersections. Variability for the uncontrolled movements at priority intersections should be set to zero.

For road sections, the calculation of the standard deviation of travel time assumes there is only one link between junctions or between changes in link context. If the model has more than one link between junctions then variability associated with such artificial network nodes should be set to zero.

Network skims compatible with the assigned flows should be used to aggregate travel time variances (square of standard deviation) along paths to create a matrix (or matrices where multiple paths are used) of journey time variance for origin–destination pairs. The square root of each cell in the resulting matrix will provide the variability (standard deviation) of travel time for that journey.

The total network variability is the sum of the products of the number of journeys between O/D pairs and the standard deviation of travel time for that journey.

It is important to note that the process above produces estimates of travel time variability as a function of VC ratio, reflecting the impact of day–to–day variations in travel demand. This is not the same as variations in individual journey times within a modelled period, a possible output of micro–simulation models. The variation in individual journey times from such models will be influenced by the driver, vehicle type, and generation factors used in the stochastic processes used in the model.

A4.5 Benefits from improved trip time reliability, continued

Evaluations without origin destination information

For individual intersection upgrades, the turning movements can be used as a proxy origin–destination matrix with the movement–weighted standard deviation being calculated for the intersection.

For project areas with more than a single congested intersection or link, an estimate of the proportion of trips that travel through more than one of these sources of variability must be made in order to approximate the total study area variability.

Two sources of variability

For two sources of variability, the reliability estimate for each trip direction is the sum of:

Variability for trips which travel only through source x: $(F_x)(SD_x)$

and, for trips travelling through both source x and y: $(F_{x.y})\sqrt{(SD_x)^2 + (SD_y)^2}$

where: F_x = trips that travel through only source x

$F_{x.y}$ = trips that travel through both x and y

SD_x = standard deviation of travel time for trip at source x

SD_y = standard deviation of travel time for trip at source y

Note: The result of the above method should be multiplied by a correction factor from table A4.6.

Three sources of variability

For each of the three sources of variability, the reliability estimate is the sum of the individual components below:

Through source x only: $(F_x)(SD_x)$

Through sources x and y only: $(F_{x.y})\sqrt{(SD_x)^2 + (SD_y)^2}$

Through sources x and z only: $(F_{x.z})\sqrt{(SD_x)^2 + (SD_z)^2}$

Through sources x, y and z only: $(F_{x.y.z})\sqrt{(SD_x)^2 + (SD_y)^2} + (SD_z)^2$

Where: $F_{x,y,z}$ = trips that travel through all three sources x, y and z.

The result should be multiplied by a correction factor from table A4.6.

If traffic passes through more than three sources of significant congestion in the modelled area then evaluators must estimate the trip matrix and perform the calculation using the aggregation of journey variance method (with the correction factor from table A4.6).

A4.5 Benefits from improved trip time reliability, continued

Rural 2 lane roads

Table A4.7 contains travel time variability values for rural 2–lane roads of varying terrain and the volume to capacity ratio (see appendix A3.17). The time period used to calculate the VC ratio must contain a relatively constant level of traffic volume.

Table A4.7(a) Travel time variability – rural 2 lane road, level terrain

Standard deviation of travel time (minutes) – percent no–passing for level terrain						
VC ratio	**0 %**	**20 %**	**40 %**	**60 %**	**80 %**	**100 %**
0.00	0.01	0.04	0.07	0.11	0.13	0.14
0.10	0.07	0.07	0.08	0.09	0.10	0.11
0.20	0.09	0.08	0.08	0.08	0.08	0.08
0.30	0.09	0.08	0.08	0.07	0.07	0.06
0.40	0.07	0.06	0.06	0.05	0.05	0.04
0.50	0.05	0.05	0.05	0.04	0.04	0.03
0.60	0.03	0.03	0.03	0.03	0.03	0.03
0.70	0.03	0.03	0.03	0.04	0.03	0.03
0.80	0.05	0.05	0.05	0.05	0.04	0.06
0.90	0.10	0.10	0.09	0.09	0.08	0.10
1.00	0.18	0.18	0.15	0.15	0.17	0.18

A4.5 Benefits from improved trip time reliability, continued

Table A4.7(b) Travel time variability – rural 2 lane road, rolling terrain

Standard deviation of travel time (minutes) – percent no–passing for rolling terrain						
VC ratio	**0 %**	**20 %**	**40 %**	**60 %**	**80 %**	**100 %**
0.00	0.03	0.09	0.15	0.17	0.24	0.27
0.10	0.11	0.13	0.15	0.17	0.17	0.18
0.20	0.13	0.13	0.12	0.13	0.12	0.12
0.30	0.12	0.10	0.09	0.09	0.08	0.08
0.40	0.09	0.07	0.06	0.06	0.06	0.05
0.50	0.06	0.05	0.05	0.05	0.06	0.06
0.60	0.05	0.06	0.07	0.08	0.09	0.08
0.70	0.07	0.10	0.12	0.14	0.15	0.14
0.80	0.14	0.18	0.21	0.23	0.23	0.22
0.90	0.26	0.29	0.32	0.34	0.34	0.34
1.00	0.43	0.44	0.47	0.46	0.47	0.49

Table A4.7(c) Travel time variability – rural 2 lane road, mountainous terrain

Standard deviation of travel time (minutes) – percent no–passing for mountainous terrain						
VC ratio	**0 %**	**20 %**	**40 %**	**60 %**	**80 %**	**100 %**
0.00	0.13	0.25	0.32	0.40	0.51	0.65
0.10	0.18	0.21	0.26	0.28	0.32	0.33
0.20	0.17	0.17	0.20	0.21	0.20	0.18
0.30	0.15	0.15	0.17	0.16	0.15	0.13
0.40	0.14	0.15	0.16	0.16	0.15	0.15
0.50	0.15	0.18	0.18	0.18	0.18	0.20
0.60	0.21	0.23	0.22	0.23	0.24	0.26
0.70	0.28	0.30	0.29	0.30	0.32	0.34
0.80	0.37	0.36	0.37	0.38	0.41	0.43
0.90	0.43	0.40	0.44	0.45	0.50	0.55
1.00	0.43	0.39	0.50	0.51	0.59	0.73

A4.6 Worked examples of trip reliability procedure

Introduction

Three worked examples of the calculations for trip reliability benefits are given below.

Example 1 – signalised intersection upgrade

An urban arterial project involves the addition of traffic lanes to the north and south approaches of a 4–leg intersection. This will improve the reliability of travel time. The traffic volumes for the north, south, east and west approaches are 1,506 veh/h, 168 veh/h, 1,662 veh/h and 57 veh/h respectively.

The average delay for do minimum is 30 seconds and average delay for the project option is 20.8 seconds. Total flow is 3,393 veh/h.

Travel time savings

Travel time savings = \$15.13 × 3393 × (30 – 20.8) / 3600 = \$131.19/h
where \$15.13 is value of travel time for morning commuter peak hour (table A4.3)

Trip reliability savings

The standard deviation of delay (in min) is calculated by:

$SD(TT) = S_0 + (S - S_0) / (1 + e^{b*(VC\ ratio - a)})$

For signalised intersections: $S = 1.25$, $b = -32$, $a = 1$, $S_0 = 0.120$ (table A4.5).

Do minimum

Approach	Lane no	Movement	Traffic volume (veh/h)	VC ratio	SD(TT) (min)	SD(TT) x volume (veh–min)
South	1	LT	1370	0.901	0.166	226.924
	2	R	136	1.09	1.190	161.832
East	1	L	44	0.163	0.120	5.280
	2	TR	124	1.179	1.246	154.546
North	1	L	416	0.551	0.120	49.920
	2	T	1232	0.868	0.136	167.927
	3	R	14	0.149	0.120	1.680
West	1	LTR	57	0.626	0.120	6.840
						774.950

For the do minimum, the total standard deviation in delay for the intersection is 774.950 veh–min.

A4.6 Worked examples of trip reliability procedure, continued

Example 1 – intersection upgrade, continued

Project option

Approach	Lane no	Movement	Traffic volume (veh/h)	VC ratio	SD(TT) (min)	SD(TT) x volume (veh–min)
South	1	LT	702	0.807	0.122	85.886
	*2	T	668	0.807	0.122	81.726
	3	R	136	0.837	0.126	17.150
East	1	L	44	0.103	0.120	5.280
	2	TR	124	0.324	0.120	14.880
North	1	L	416	0.487	0.120	49.920
	2	T	616	0.743	0.120	74.107
	*3	T	616	0.743	0.120	74.107
	4	R	14	0.097	0.120	–1.680
West	1	LTR	57	0.417	0.120	6.840
* Additional traffic lane						411.574

With additional traffic lanes for the north and south approaches, the standard deviation drops to 411.574 veh–min.

The drop in standard deviation of delays is due to:

1. Increase in capacity for North and South approaches as an extra lane is added for the through traffic.
2. Increase in capacity for East and West approaches as the signal controller can allocate a higher proportion of cycle time to movements on these approaches.

Variability benefits per hour of the time period are calculated as:

0.9 × \$15.13 × (774.950 – 411.574) / 60 × 30 % = \$24.74/h.

Where \$15.13 is the value of travel time for morning commuter peak hour (table A4.3), 0.9 is the variability travel time factor and the correction factor for an intersection model of 30 percent has been judged to be appropriate.

A4.6 Worked examples of trip reliability procedure, continued

Example 2 – rural highway: 4 laning

A section of rural strategic road is approaching capacity. One option is 4 laning part of this section. The road carries 20,000 veh/day in level terrain, with a peak period intensity of 2,050 veh/h, 70/30 directional split, 7 percent heavy truck component and has 60 percent no–passing.

For the do minimum, the capacity is calculated as 2800 × f_d × f_t = 2,800 × 0.89 × 0.92 = 2,290 veh/h. The values for f_d and f_t are drawn from appendix A3.11. With a traffic volume of 2,050 veh/h, the VC ratio = 2,050 / 2,290 = 0.90. The standard deviation of travel time (denoted as SD(TT)) is 0.09 min (from table A4.7).

For the project option, assuming there are no restrictions requiring a reduction in the lane capacity, a capacity of 2,200 veh/h/lane is applicable (see appendix A3.10). The VC ratio is 2,050 / (4 × 2,200) = 0.23.

The standard deviation of delay (in min) is calculated by:

$$SD(TT) = S_0 + (S - S_0) / (1 + e^{b * (\text{VC ratio} - a)})$$

For a rural highway (2 lanes in each direction of travel):

$S = 1.03$, $b = -22$, $a = 1$, $S_0 = 0.033$ (from table A4.5)

$$SD(TT) = 0.033 + (1.030 - 0.033) / (1 + e^{-22 * (0.23-1)})$$
$$= 0.033 \text{ min}$$

Variability benefits per hour are calculated as:

0.9 × $25.34 × (0.09 – 0.033) × 2,050 / 60 × 30 % = $13.32/h

where: $25.34 is the value of travel time for weekday period for rural strategic roads (from table A4.3)

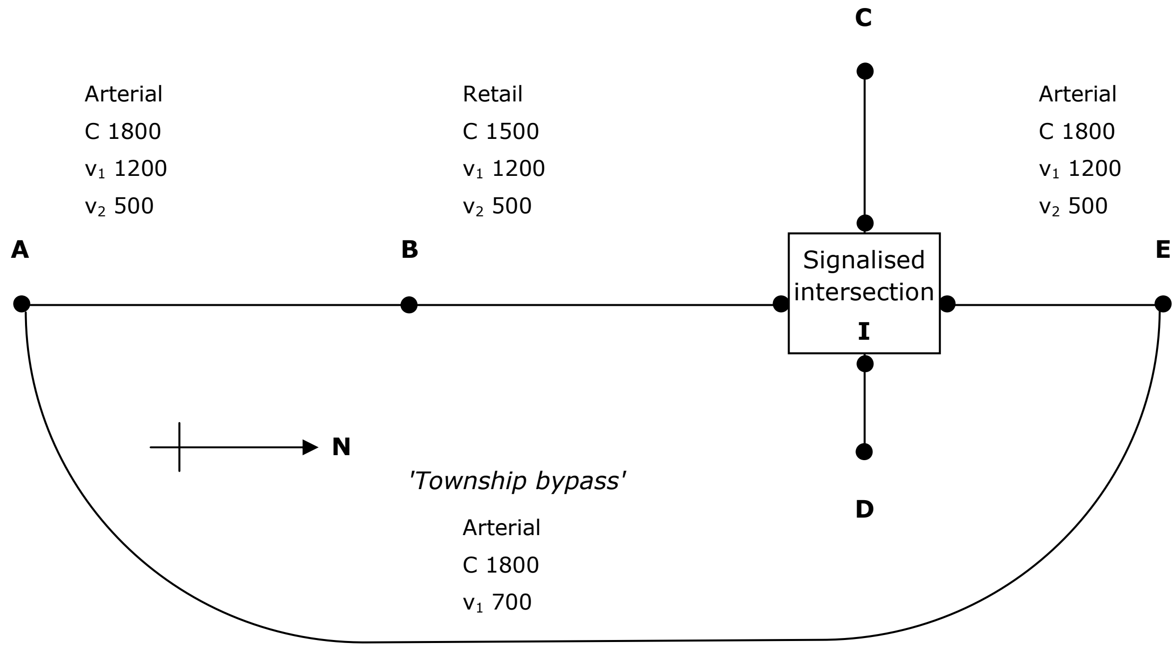
0.9 is the variability travel time factor and

30% is selected as the appropriate adjustment factor (from table A4.6).

A4.6 Worked examples of trip reliability procedure, continued

Example 3 – township bypass project

A project provides a township (urban arterial) bypass from A to E to remove through traffic from the town centre. The existing through–traffic between A and E is 2,400 veh/h with 1,200 vehicles in each direction. It is expected that the traffic volumes between A and E will remain the same once the bypass is built, but 1400 vehicles will use the new bypass each hour (700 in each direction).



Traffic volume and VC ratio at the signalised intersection I are summarised on the following page.

Do minimum

Approach	Lane no.	Movement	Traffic volume (veh/h)	VC ratio
South (B)	1	LT	1121	0.840
	2	R	82	0.595
East (D)	1	L	249	0.706
	2	TR	62	0.442
North (E)	1	L	252	0.271
	2	T	947	0.774
	3	R	9	0.072
West (C)	1	LTR	35	0.290

A4.6 Worked examples of trip reliability procedure, continued

Example 3 – township bypass project, continued

Project option

Approach	Lane no.	Movement	Traffic volume (veh/h)	VC ratio
South (B)	1	LT	421	0.664
	2	R	82	0.330
East (D)	1	L	249	0.286
	2	TR	62	0.246
North (E)	1	L	252	0.237
	2	T	247	0.433
	3	R	9	0.040
West (C)	1	LTR	35	0.161

Matrices of flows

Do minimum		To A	To B	To C	To D	To E via town	To E via bypass	Sum
From	A	0	0	1	82	1120	0	1203
	B	0	0	0	0	0	0	0
	C	4	0	0	11	20	0	35
	D	249	0	2	0	60	0	311
	E via Town	947	0	9	252	0	0	1208
	E via bypass	0	0	0	0	0	0	0
Sum		1200	0	12	345	1200	0	2757

Project option		To A	To B	To C	To D	To E via town	To E via bypass	Sum
From	A	0	0	1	82	420	700	1203
	B	0	0	0	0	0	0	0
	C	4	0	0	11	20	0	35
	D	249	0	2	0	60	0	311
	E via Town	247	0	9	252	0	0	508
	E via bypass	700	0	0	0	0	0	700
Sum		1200	0	12	345	500	700	2757

A4.6 Worked examples of trip reliability procedure, continued

Example 3 – township bypass project, continued

For road section, standard deviations of travel times in minutes are calculated by:

SD(TT) $= S_0 + (S - S_0) / (1 + e^{b*(\text{VC ratio} - a)})$

For urban arterial: S = 0.89, b = –28, a = 1, S_0 =0.117 (table A4.5)

For urban retail road: S = 0.87, b = –16, a = 1, S_0 =0.150 (table A4.5)

From	To	Do minimum	Project option
A	B	0.117	0.117
B	I	0.178	0.150
I	E	0.117	0.117
A	E	–	0.117

For intersection C, standard deviations of delays in minutes for each movement are calculated by:

SD(TT) $= S_0 + (S - S_0) / (1 + e^{b*(\text{VC ratio} - a)})$

For signalised intersection: S =1.25, b = –32, a = 1, S_0 =0.120 (table A4.5)

From	To	Do minimum	Project option
B	C	0.127	0.120
B	E	0.127	0.120
B	D	0.120	0.120
D	B	0.120	0.120
D	C	0.120	0.120
D	E	0.120	0.120
E	D	0.120	0.120
E	B	0.121	0.120
E	C	0.120	0.120
C	E	0.120	0.120
C	D	0.120	0.120
C	B	0.120	0.120

A4.6 Worked examples of trip reliability procedure, continued

Example 3 – township bypass project, continued

The total variability is the square root of the sum of individual link / intersection variability. For instance, from origin A to destination C, the total variability for 'do minimum' and 'project option' are calculated by:

$$\text{Variability A–C}_{\text{do minimum}} = \sqrt{(SD_{Link(AB)})^2 + (SD_{Link(BI)})^2 + (SD_{Intersection(BC)})^2}$$

$$= \sqrt{0.117^2 + 0.178^2 + 0.127^2}$$

$$= 0.248 \text{ min}$$

$$\text{Variability A–C}_{\text{project option}} = \sqrt{0.117^2 + 0.150^2 + 0.120^2}$$

$$= 0.225 \text{ min}$$

Matrices of standard deviations of travel times

Do minimum		To A	To B	To C	To D	To E via town	To E via bypass
From	A	0	0	0.248	0.244	0.274	0
	B	0	0	0	0	0	0
	C	0.244	0	0	0.120	0.168	0
	D	0.244	0	0.120	0	0.168	0
	E via town	0.271	0	0.168	0.168	0	0
	E via bypass	0	0	0	0	0	0

Project option		To A	To B	To C	To D	To E via town	To E via bypass
From	A	0	0	0.225	0.225	0.254	0.117
	B	0	0	0	0	0	0
	C	0.225	0	0	0.120	0.168	0
	D	0.225	0	0.120	0	0.168	0
	E via town	0.254	0	0.168	0.168	0	0
	E via bypass	0.117	0	0	0	0	0

A4.6 Worked examples of trip reliability procedure, continued

Example 3 – township bypass project, continued

Network–wide estimate of variability

Multiply the element in the flow matrix with the corresponding element in the standard deviation matrix to derive the variability for each movement. Sum each line to get the total for the approach. Add the final column together to derive the network–wide variability.

Matrixes of flow × standard deviation of travel time

Do minimum		To A	To B	To C	To D	To E via town	To E via bypass	Sum
From	A	0	0	0.248	20.008	306.880	0	327.136
	B	0	0	0	0	0	0	0.000
	C	0.976	0	0	1.320	3.360	0	5.656
	D	60.756	0	0.240	0	10.080	0	71.076
	E via Town	256.637	0	1.512	42.336	0	0	300.485
	E via bypass	0	0	0	0	0	0	0.000
Sum		318.369	0	2.000	63.664	320.320	0	704.353

Project option		To A	To B	To C	To D	To E via town	To E via bypass	Sum
From	A	0	0	0.225	18.450	106.680	81.9	207.255
	B	0	0	0	0	0	0	0.000
	C	0.900	0	0	1.320	3.360	0	5.580
	D	56.025	0	0.240	0	10.080	0	66.345
	E via Town	62.738	0	1.512	42.336	0	0	106.586
	E via bypass	81.9	0	0	0	0	0	81.900
Sum		201.563	0	1.977	62.106	120.120	81.900	467.666

The total variability for 'do minimum' is 704.353 veh–min and for 'project option' is 467.666 veh/min. Variability benefits per peak hour are calculated as:

$0.9 \times \$15.13 \times (704.353 - 467.666) / 60 \times 30\ \% = \$16.11/h$

Where $15.13 is the value of travel time for morning commuter peak hour for urban arterial (table A4.3), 0.9 is the variability travel time factor, and 30 percent is the adjustment factor as there is only one major source of variability.