Guidelines for the Selection of Pedestrian Facilities

The following guidelines are presented as an aid to the selection of the most appropriate pedestrian facility. Unlike previous numeric *warrants* the intention is to provide guidance rather than an inflexible set of rules.

The process for selecting the most appropriate pedestrian facility revolves around the question of why it is considered desirable to provide specific assistance for pedestrians at a particular location i.e. what is it that the designer seeks to achieve?

Once this overall need has been identified, the second stage is to identify the set of facilities that may be suitable for use in the particular context, bearing in mind that inappropriate facilities may have a detrimental impact on the safety of all users. Typically this choice of possible devices is based on the characteristics of the road on which the facility is to be installed and the basic choice sets are outlined in **Table 1** and **Table 2** below. These classifications have been derived from a combination of expert opinion (a working group commissioned for this task) and international literature. The focus has been on ensuring that all users operate in a no-surprises environment and that the safety of all users is maximised by ensuring facilities are not used inappropriately.

Having identified a preferred facility, it is essential that the designer checks that all the necessary design criteria for the installation of the proposed facility are met, in order to ensure that the facility operates as intended and does not pose a hazard to users.

Reason for Providing Pedestrian Facilities

There are four main reasons for choosing to provide specific crossing assistance to pedestrians and the underlying reasons for doing so impact on the selection process.

1. Level of Service – The crossing opportunities available to pedestrians are below the desired level of service

AND

there is sufficient demand including suppressed demand.

2. Safety – Historical records of crashes at, or in the vicinity, of the site have identified a group of crashes that may potentially be reduced by providing crossing assistance.

3. Specific Access Provisions – Provisions for a particular group, such as:
    - young children
    - school crossing
    - visually impaired
    - physically disabled

4. Integration – Integration and reinforcement of a wider traffic management plan for the area, e.g. local area traffic management, CBD traffic management

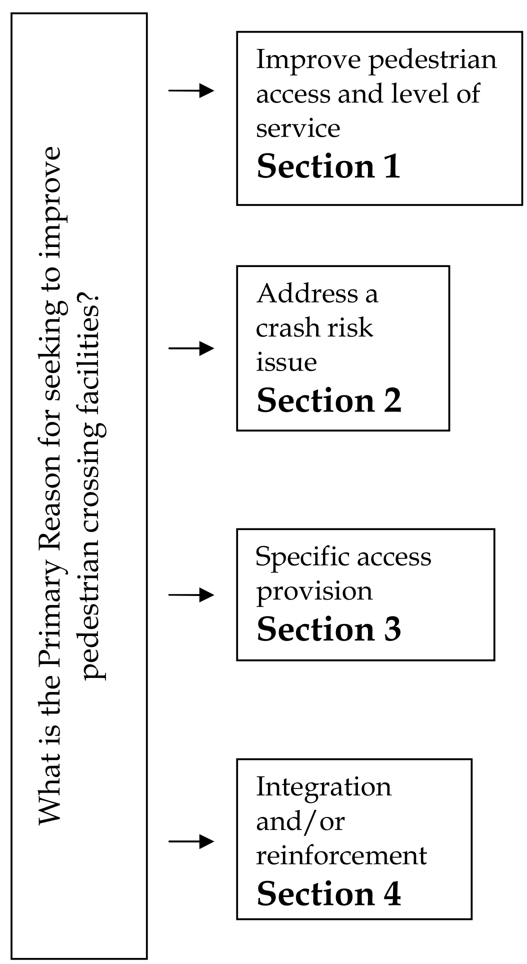


Table 1 Classification of Road Types

<table>
<tr><th colspan="9">Speed Limit
(Environment)</th></tr>
<tr><td>Road Layout</td><td>(30km/h)</td><td>(40km/h)</td><td>50km/h</td><td>(60km/h)</td><td>70km/h</td><td>(80km/h)</td><td>(90km/h)</td><td>100km/h</td></tr>
<tr><td>Two lane, two way
Road with no parking or shoulder</td><td rowspan="2">A</td><td rowspan="2">A1</td><td rowspan="2">B</td><td rowspan="2">B1</td><td>C</td><td colspan="3" rowspan="4">E</td></tr>
<tr><td>Two lane, two way
Road with parking or shoulder</td><td>D</td></tr>
<tr><td>Two lane, one way
Road with no parking or shoulder</td><td colspan="5">C</td></tr>
<tr><td>Two lane, one way
Road with parking or shoulder</td><td colspan="5">D</td></tr>
</table>

Table 1 Classification of Road Types (continued)

	Speed Limit (Environment)							
Road Layout	(30km/h)	(40km/h)	**50**km/h	(60km/h)	**70**km/h	(80km/h)	(90km/h)	**100**km/h
Four lane, two way No median Road with no parking or shoulder	**C**							
Four lane, two way No median Road with parking or shoulder	**D**							
Four lane, two way Median Divided Road with no parking or shoulder	**C**							
Four lane, two way Median divided Road with parking or shoulder	**D**							
Motorway	Not Applicable							**F**

Table 2 Most Appropriate Pedestrian Crossing Facilities

Facility	Type	Zone					
		A	B	C	D	E	F
Platforms	Aid	✓ may be used with care in A1					
Zebra Crossings	Priority	✓	✓ requires LTSA approval in B1				
Traffic Signals	Priority	✓ only as part of a total CBD Traffic Management plan	✓	✓	✓		
Median Refuges (see note 1)	Aid	✓	✓	✓	✓	✓	
Kerb Extensions (see note 2)	Aid	✓	✓		✓	✓	
Grade Separation	Segregation	maybe	maybe	maybe	maybe	✓	✓

Notes:

[1] the use of a central median reduces crossing distance and provides approximately half the safety benefits of kerb extensions. These should only be implemented where there is sufficient lane width (5m following installation) and the feature does not create a hazard.

[2] kerb extensions provide significant safety benefits but should only be installed where there is sufficient lane width (5m following installation) and the feature does not create a hazard. They are inappropriate where there is moving traffic against the kerb.

Section 1

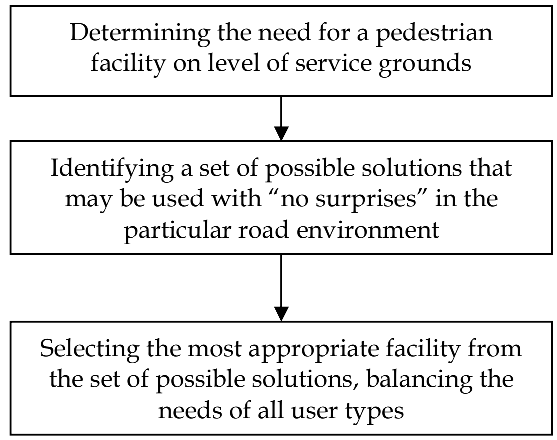
Pedestrian Level of Service

SECTION 1 – Level of Service (LOS)

This section applies when the selection of a pedestrian facility aims to address issues associated with levels of pedestrian accessibility and is based heavily on the work of Abley, (2002).

The selection process involves three steps:

1. Determining the **need** for a facility
2. Identifying the set of **possible solutions**
3. **Selecting the most appropriate** treatment



Determining Need

The need for specific pedestrian crossing facilities to improve pedestrian levels of service alone is determined by the Level of Service offered to pedestrians in the existing situation.

Existing Level of Service - The existing level of service quantifies the availability of pedestrian crossing opportunities. The procedure is based on determining the average time a pedestrian, or group of pedestrians, must wait until a sufficiently large gap appears in the traffic to allow them to cross.

The resulting delay represents the LOS.

Although Russell and Hine (1996) suggest that pedestrian crossing behaviour is far more complex than simply waiting at the kerb for a gap of at least x seconds, this approach provides a proxy measure of performance based on widely published and generally accepted models (Abley, 2002; Austroads, 1995).

Step 1 Determine Pedestrian Crossing Time

The pedestrian crossing time is the time it would take an average pedestrian to cross the road in question.

Although some sources (Abley, 2002) promote the use of 10 or 15 percentile walking speeds, this combination and the inclusion of a specific factor of safety results in an overly conservative walk speed.

Determine Pedestrian Crossing Time t_{cp}

$$t_{cp}=(d_c/v_w)F_s+C$$

where d_c=*crossing distance (m)*
v_c=*mean walk speed (m/s)*
F_s=*factor of safety*
C=*confirmation time (s)*

The crossing distance (d_c) is measured from the point where a crossing pedestrian would first become exposed to passing traffic until the point where the pedestrian is once again clear of the passing traffic stream. Typically this is the carriageway width less the width of a kerbside-parking zone where such parking exists. In the case of a median divided road the methodology treats the crossing as two separate movements.

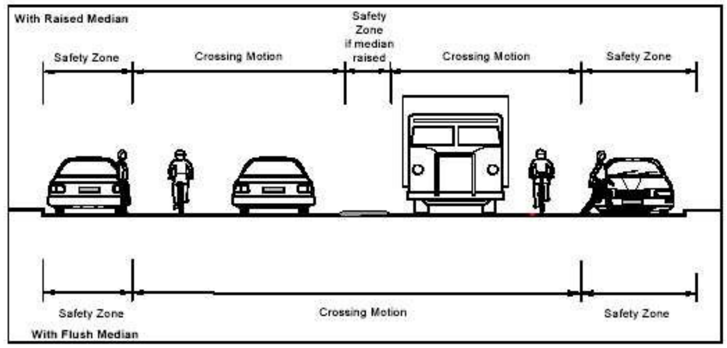


Figure taken from Abley, 2002

Free walk speeds vary greatly and typically range from 0.74 m/s to 2.39 m/s (Austroads, 1995). The basic mean walk speed reduces towards the 10 percentile walk speed of elderly pedestrians as the proportion of elderly pedestrians using the site increases.

Compute the Mean Walk Speed V_w

$V_w=1.2(1- p_a)+ 0.8\ p_o$

Where p_o*=the proportion of elderly pedestrians*
Assume $p_o= p_a$

Although walk speed is a function of pedestrian density, a correction is only necessary where high volumes of pedestrians are expected or the crossing width is limited e.g. in the CBD or at high use signalised crossings.

Where pedestrian demand exceeds 50 pedestrians per metre width per minute the mean pedestrian walk speed should be reduced in accordance with Austroads Part 13 Figure 1.7

The pedestrian crossing time is a function of:

- the crossing distance, and
- mean pedestrian walk speed.

Compute the Pedestrian Crossing Time t_{cp}

$t_{cp}=(d_c/v_w)F_s+C$

where d_c*=crossing distance (m)*
v_w*=mean walk speed (m/s)*
C *=confirmation time (s)*
F_s*=factor of safety*

The confirmation time, the time interval required by sensitive pedestrians seeking to confirm the traffic situation (i.e. all vehicles have been perceived), and that the gap presented is indeed adequate for their needs. The approach adopted here is to increase the confirmation time allowance from 0 to 3 seconds in proportion to the number of sensitive pedestrians defined as those <12 years of age and the elderly.

$C=3\ p_s$

Where p_s*= the proportion of sensitive users typically young children (<12 years) and the elderly*

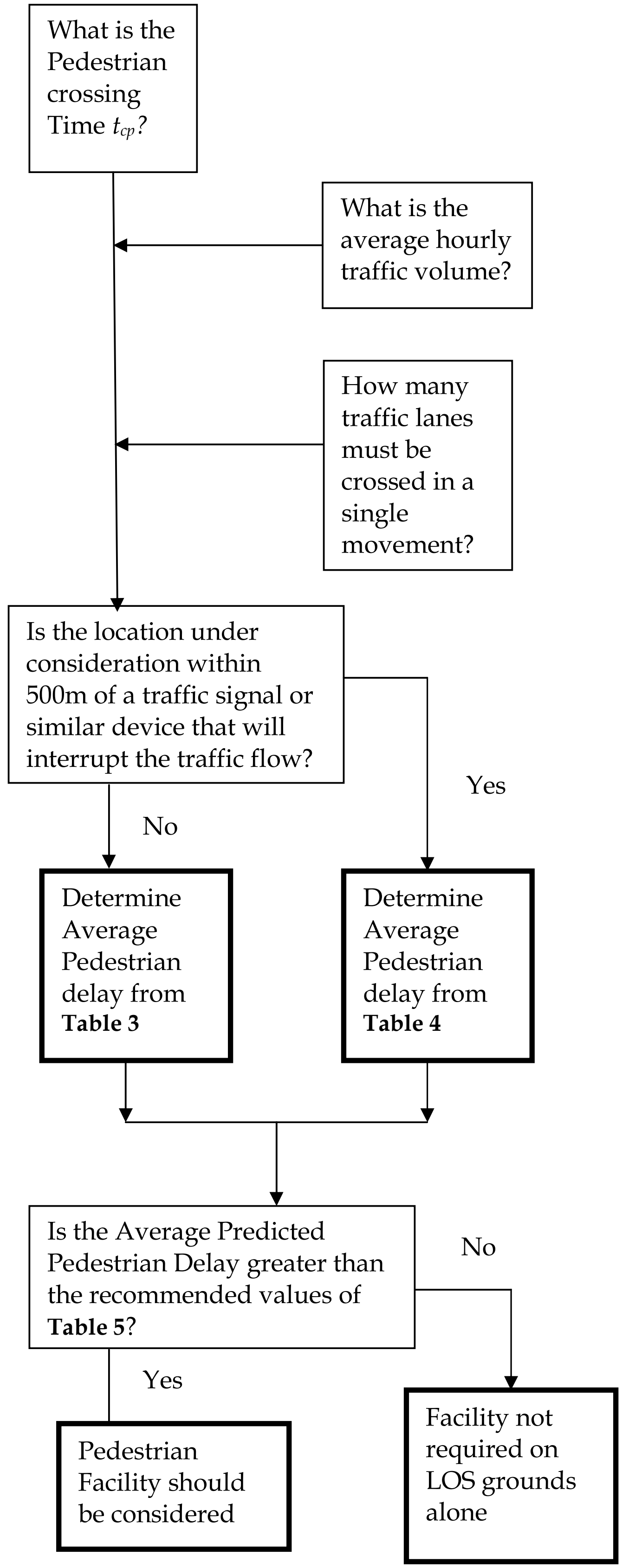
The factor of safety F_s is applied to the crossing time as recommended by Abley, (2002) to adjust for possible distance related errors.

$F_s =1.1$

Step 2 Determine the Pedestrian Delay

The expected pedestrian delay is determined using **Table 3** where pedestrians are required to cross an uninterrupted traffic flow and **Table 4** where the traffic flow is interrupted. These tables have been developed from the Tanners Extended Model for the distribution of gaps in a traffic stream. However the bunching parameters are those proposed by Abley (2002).

The choice of interrupted or uninterrupted traffic flow depends on the proximity of the crossing site to bunching devices such as traffic signals and whether or not traffic may and does join the roadway between the signals and the crossing location under consideration. As a general rule if the crossing location is within 500m of a traffic signal and there is little scope for additional traffic to enter the stream, and therefore fill the gaps created by the traffic signals the traffic stream is said to be interrupted.



Step 3 Determining the Level of Service

The pedestrian level of service is simply the average pedestrian delay d_p, from **Table 3** or **Table 4** as appropriate. The values are then compared to the desirable standard for the type of road.

As a rule, delays of more than 30 to 40 seconds are considered as intolerable for pedestrians and may lead to riskier crossing behaviour by some (Queensland Main Roads 2004, Abley 2002, and Department of Environment 1974). While the value of 40 seconds may be an upper bound, Abley (2002) argues for a lower level of acceptable crossing delay where the function of the surrounding street network is primarily one of access. For example for residential streets and collector roads a low level of pedestrian delay should be sought e.g. 15 seconds.

Where the predicted pedestrian level of service is less than adequate, facilities should be provided.

Table 3 Average Delay to Pedestrians Crossing Uninterrupted Traffic Streams (sec/ped)

Situation	Traffic Flow	Pedestrian Crossing Time (sec)								
	(veh/h)	4	6	8	10	12	14	16	18	20
Single Lane Uninterrupted Traffic Flow	200	1	1	2	4	5	8	11	14	18
	400	1	3	6	10	16	24	35	50	70
	600	2	6	12	23	40	67	108	171	267
	800	4	11	26	55	111	215	409		
	1000	6	22	64	169	429				
	1200	12	58	241						
	1400	32	324							
	1600	415								
Two Lane Uninterrupted Traffic Flow	200	0	1	2	3	5	7	10	13	17
	400	1	3	5	9	14	22	32	45	62
	600	2	5	10	19	32	52	82	125	190
	800	3	8	18	36	68	122	213	366	
	1000	4	13	32	71	149	304			
	1200	6	21	58	148	358				
	1400	9	35	112	337					
	1600	14	62	239						
	1800	21	119							
	2000	36	263							
	2200	67								
	2400	150								
	2600	452								
More Than Two Lanes Uninterrupted Traffic Flow	200	1	2	3	4	6	9	12	15	19
	400	2	4	7	11	17	25	36	50	68
	600	3	7	13	23	38	61	95	146	221
	800	4	11	23	45	84	150	263	455	
	1000	7	18	42	93	196	402			
	1200	10	30	81	207					
	1400	14	52	169						
	1600	23	99	399						
	1800	38	213							
	2000	70								
	2200	150								
	2400	413								

Table 4 Average Delay to Pedestrians Crossing Interrupted Traffic Streams (sec/ped)

Situation	Traffic Flow	Pedestrian Crossing Time (sec)								
	(veh/h)	4	6	8	10	12	14	16	18	20
Single Lane Interrupted Traffic Flow	200	1	1	2	3	5	6	9	11	14
	400	1	3	5	7	10	15	20	27	35
	600	3	5	8	12	18	26	37	50	67
	800	4	8	13	20	30	43	61	85	117
	1000	7	12	20	32	48	71	103	148	210
	1200	12	20	34	54	86	132	200	301	448
	1400	20	37	67	117	202	343			
	1600	42	108	269						
Two Lane Interrupted Traffic Flow	200	0	1	2	3	4	6	8	10	13
	400	1	2	3	5	8	11	15	21	27
	600	1	3	5	8	11	16	22	30	39
	800	2	4	6	10	14	20	28	38	50
	1000	3	5	8	12	17	24	32	43	57
	1200	4	6	9	14	20	27	36	48	62
	1400	5	8	12	16	22	30	40	52	67
	1600	7	10	14	19	26	34	44	57	72
	1800	10	13	18	23	31	39	50	63	78
	2000	13	17	23	29	37	46	58	71	87
	2200	18	23	29	37	45	56	68	83	101
	2400	25	31	39	47	57	70	84	101	120
	2600	35	43	52	63	75	90	107	127	151
	2800	50	60	72	85	102	121	144	170	201
	3000	71	85	102	122	147	175	209	248	295
	3200	103	128	157	194	238	291	357	436	
	3400	171	235	323	442					
More Than Two Lanes Interrupted Traffic Flow	200	1	2	3	4	5	7	9	11	14
	400	2	3	5	7	10	13	17	23	29
	600	3	4	6	9	13	19	25	33	43
	800	4	5	8	12	17	23	31	41	54
	1000	5	7	10	14	20	27	36	48	62
	1200	6	8	12	17	23	31	40	53	68
	1400	8	10	14	19	26	34	45	57	73
	1600	10	13	17	23	30	39	49	62	78
	1800	13	16	21	27	35	44	55	69	85
	2000	17	21	26	33	41	51	63	77	94
	2200	22	27	33	41	50	61	74	90	108
	2400	29	36	43	52	63	76	90	108	128
	2600	40	47	57	68	81	96	114	135	160
	2800	54	65	77	92	109	129	152	180	211
	3000	76	91	109	130	155	185	220	261	309
	3200	110	136	167	205	251	308	376	459	
	3400	186	255	350	478					

Table 5 Acceptable Levels of Service for Pedestrians Crossing

Average Pedestrian Delay (sec)	Level of Service	Definition	Description	Appropriate Situation
<5	A	Excellent	Pedestrians able to cross almost immediately on arrival	Local Streets Collector Roads
5-10	B	Very Good	Most pedestrians able to cross with little delay 95^{th} percentile delay $\approx$40 secs	
10-15	C	Satisfactory	Most able to cross with acceptable period 95^{th} percentile delay $\approx$60 secs	Minor Arterial Major Arterial
15-20	D	Some Concern	Some pedestrians must wait longer than desirable for an acceptable gap 95^{th} percentile delay $\approx$80 secs	
20-40	E	Major Concern	Most pedestrians must wait longer than desirable for an acceptable gap 95^{th} percentile delay $\approx$80 secs	Inappropriate All Situations
>40	F	Unsatisfactory	Almost all pedestrians must wait longer than desirable for an acceptable gap 95^{th} percentile delay $\approx$80 secs	

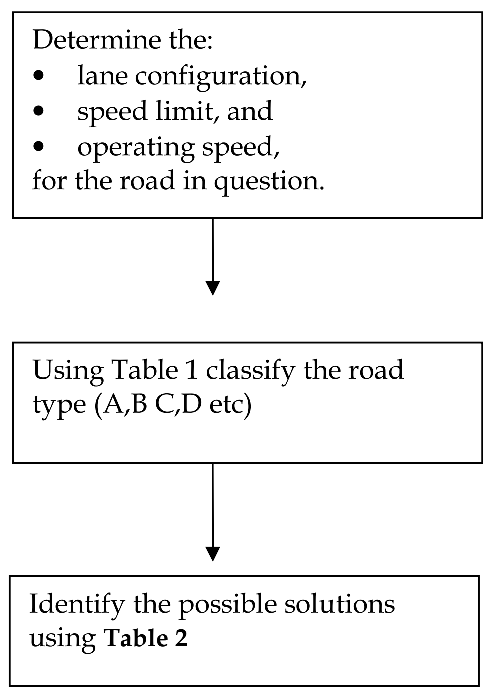
Step 4 Identifying the Set of Possible Solutions

Although there are a wide range of possible pedestrian treatments available it is important to recognise that some facilities may not be appropriate on particular roads and overall safety may be reduced.

Particular examples of **inappropriate facilities** would be the use of:

- kerb extensions where there is no parking and moving traffic abuts the kerb;
- platforms in high speed environments;
- zebra crossing where there are two lanes of traffic travelling in the same direction.

The key determinants of safety relate to the speed of the road in question (either speed limit or environment), the number of traffic lanes and their configuration. **Table 1** classifies roads on the basis of these characteristics and the set of possible treatments associated with each classification is given in **Table 2**.



Step 5 Selecting the Most Appropriate Facility

Having identified the need for a pedestrian facility (Steps 1-3) and the set of possible facilities (Step 4), it is now necessary to determine which particular facility should be considered for use to address level of service issues.

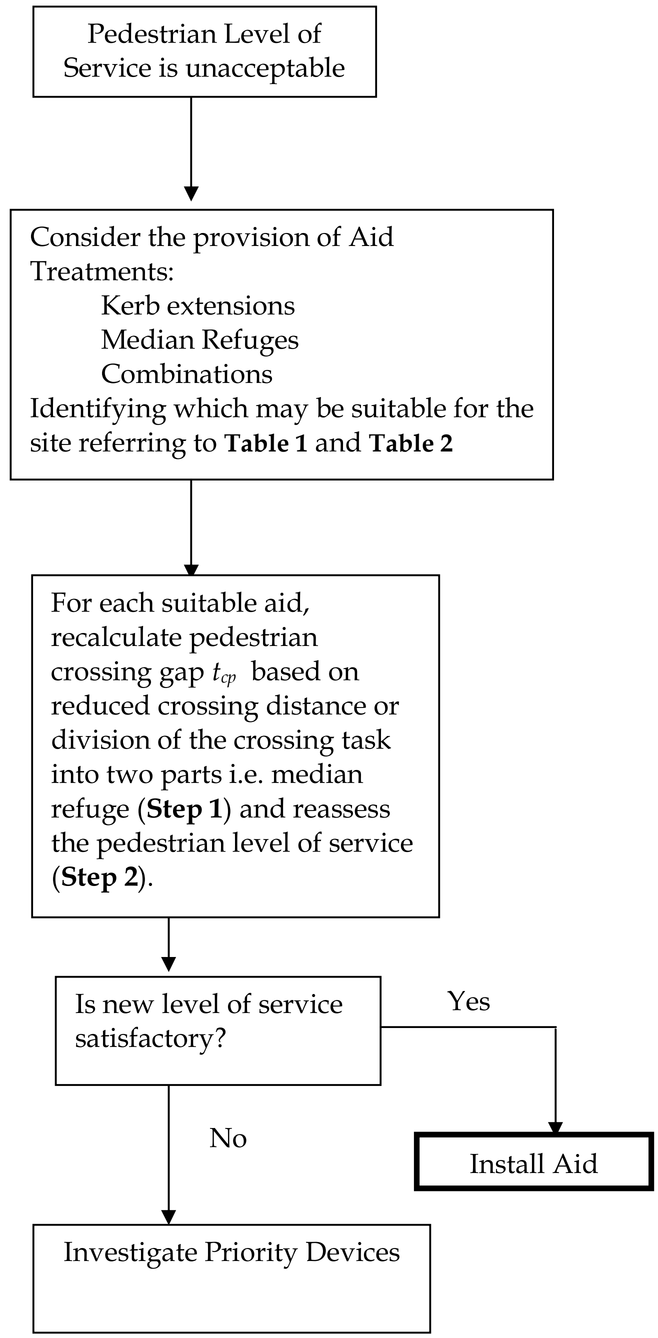
The overall approach is based on balancing the competing accessibility needs of the pedestrians and the conflicting traffic stream. In doing so it is useful to view possible solutions in terms of a hierarchy:

Physical Aids	Kerb extensions Median refuges Combinations (refuge and kerb extensions)
Priority Devices	Zebra Crossings Traffic Signals
Segregation	Over-bridge Underpass

At the lowest level, crossing aids such as kerb extensions and median refuges ease the crossing task but afford pedestrians no special priority.

When, following the provision of a pedestrian aid, the level of service offered to pedestrians is still less than desired, it may be necessary to allocate specific priority rights to pedestrians. This may be permanent in the form of a zebra crossing or may rotate priority in the form of a traffic signal.

Finally when the provision of priority based facilities fails to provide an adequate solution then consideration should be given to grade separation. The benefits of which should be assessed on economic grounds.



Two types of Priority Devices are available. Zebra Crossings which give pedestrians explicit priority over the traffic stream and Signalised Crossings which rotate priority.

The decision between which of these two devices is more appropriate is made first on the basis of consistency of treatment using **Table 1** and **Table 2**. So, for example, if the road on which a facility is to be installed has a speed limit of greater than 60km/h or has more than two lanes of traffic travelling in one direction, a zebra crossing is not considered an appropriate treatment.

The delay to users is modelled using the theoretical gap acceptance model, Tanners Extended Equation. This model approaches infinity when the conflicting volumes are high. As a consequence a large delay may be experienced by a small number of users and bias facility selection. To overcome this problem and to ensure that sufficient pedestrians are using the zebra crossing, so that drivers are not surprised by occasional users, a minimum pedestrian volume is set.

If a zebra crossing is considered an appropriate treatment, the installation of the crossing is determined by balancing the delays that would accrue to pedestrians in the absence of a zebra crossing with the delays that would accrue to vehicles if a zebra crossing was installed. Vehicle occupant delay is calculated using Tanners Equation.

However, the delay to vehicles is factored by 1.2 to the average vehicle occupancy. As a consequence, the balancing is on a per traveller basis.

If the user delay for a zebra crossing is greater than that when no facility is installed, or if a zebra crossing is **not** considered an appropriate treatment, the analyst should investigate whether a signalised crossing point is a viable alternative.

Given the range of potential scenarios and variables this analysis is best undertaken using a model such as aaSIDRA to analyse the peak performance.

For segregated facilities (overbridges or underpasses) a full economic analysis is required.

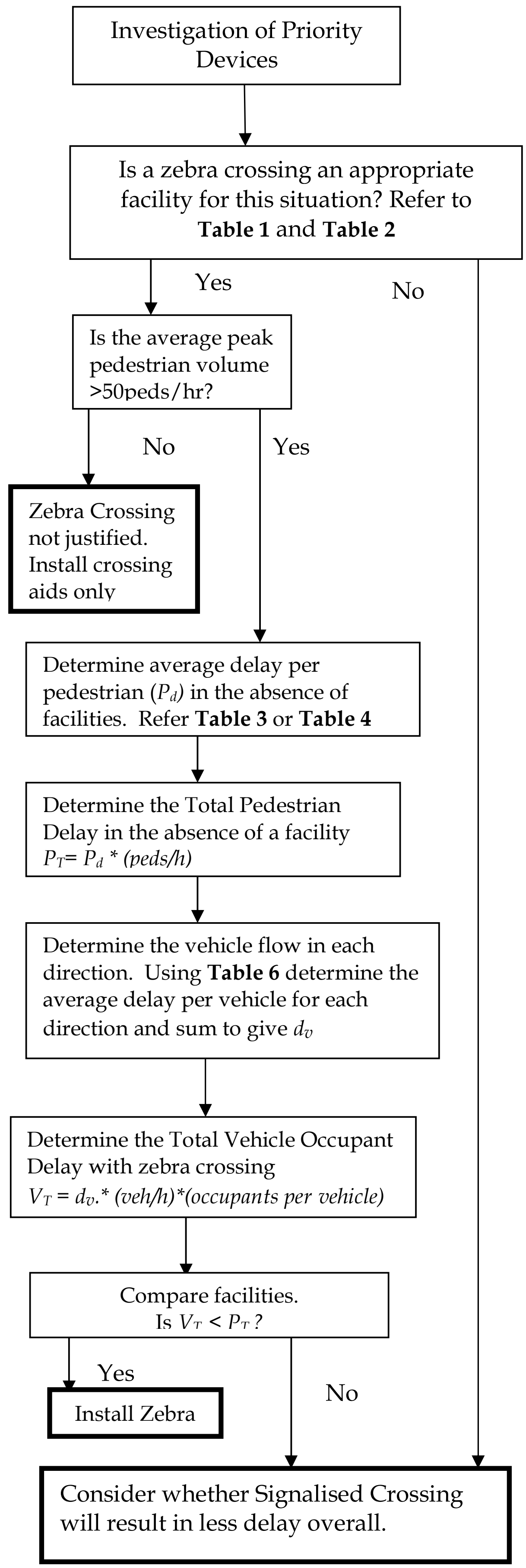


Table 6 Average Delay per Vehicle (sec/veh)

	Pedestrian Flow (per hour)																										
Traffic Volume One Lane One Direction (veh/h)	50	60	70	80	90	100	150	200	250	300	350	400	450	500	550	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700
50	0.2	0.3	0.3	0.3	0.4	0.4	0.6	0.8	1.1	1.3	1.5	1.8	2.1	2.4	2.7	3.0	3.7	4.5	5.4	6.5	7.6	8.9	10.4	12.2	14.1	16.5	19.1
100	0.3	0.3	0.3	0.4	0.4	0.5	0.7	0.9	1.1	1.4	1.7	1.9	2.2	2.6	2.9	3.3	4.1	5.0	6.0	7.2	8.6	10.3	12.2	14.6	17.4	20.9	25.3
150	0.3	0.3	0.4	0.4	0.5	0.5	0.7	1.0	1.2	1.5	1.8	2.1	2.4	2.8	3.1	3.5	4.4	5.5	6.7	8.2	9.9	12.1	14.7	18.1	22.5	28.4	36.9
200	0.3	0.4	0.4	0.5	0.5	0.6	0.8	1.0	1.3	1.6	1.9	2.2	2.6	3.0	3.4	3.8	4.9	6.1	7.5	9.3	11.6	14.5	18.3	23.6	31.4	43.9	67.2
250	0.4	0.4	0.5	0.5	0.6	0.6	0.9	1.1	1.4	1.7	2.1	2.4	2.8	3.2	3.7	4.2	5.4	6.8	8.6	10.9	13.9	18.0	24.1	33.8	51.5	94.3	342.3
300	0.4	0.5	0.5	0.6	0.6	0.7	0.9	1.2	1.5	1.9	2.2	2.6	3.1	3.5	4.0	4.6	6.0	7.7	9.9	12.9	17.2	23.8	34.9	58.4	137.8		
350	0.5	0.5	0.6	0.6	0.7	0.7	1.0	1.3	1.7	2.0	2.4	2.8	3.3	3.9	4.4	5.1	6.7	8.8	11.7	15.9	22.5	34.4	62.3	202.7			
400	0.5	0.6	0.6	0.7	0.8	0.8	1.1	1.4	1.8	2.2	2.6	3.1	3.6	4.2	4.9	5.7	7.6	10.3	14.2	20.4	32.1	61.2	266.2				
450	0.6	0.7	0.7	0.8	0.8	0.9	1.2	1.6	1.9	2.4	2.8	3.4	4.0	4.7	5.5	6.4	8.8	12.2	17.8	28.3	54.9	257.7					
500	0.7	0.7	0.8	0.8	0.9	1.0	1.3	1.7	2.1	2.6	3.1	3.7	4.4	5.2	6.2	7.3	10.3	15.1	23.9	45.5	181.4						
550	0.7	0.8	0.9	0.9	1.0	1.1	1.4	1.8	2.3	2.8	3.4	4.1	4.9	5.9	7.0	8.4	12.3	19.4	35.7	111.8							
600	0.8	0.9	1.0	1.0	1.1	1.2	1.6	2.0	2.5	3.1	3.8	4.6	5.5	6.7	8.1	9.8	15.3	27.0	68.7								
650	0.9	1.0	1.0	1.1	1.2	1.3	1.7	2.2	2.8	3.4	4.2	5.1	6.2	7.7	9.5	11.8	20.1	43.6	721.1								
700	1.0	1.1	1.2	1.2	1.3	1.4	1.9	2.4	3.0	3.8	4.7	5.8	7.2	9.0	11.4	14.7	28.7	109.3									
750	1.1	1.2	1.3	1.4	1.5	1.5	2.1	2.7	3.4	4.2	5.3	6.6	8.4	10.7	14.1	19.4	49.3										
800	1.2	1.3	1.4	1.5	1.6	1.7	2.3	2.9	3.8	4.8	6.0	7.7	10.0	13.3	18.5	27.8	164.7										
850	1.3	1.4	1.5	1.7	1.8	1.9	2.5	3.3	4.2	5.4	7.0	9.1	12.3	17.2	26.3	48.4											
900	1.5	1.6	1.7	1.8	2.0	2.1	2.8	3.7	4.8	6.2	8.2	11.2	15.8	24.3	45.0	172.5											
950	1.7	1.8	1.9	2.0	2.2	2.3	3.1	4.1	5.5	7.3	10.0	14.2	21.8	40.2	144.2												
1000	1.8	2.0	2.1	2.3	2.4	2.6	3.5	4.7	6.4	8.7	12.5	19.1	34.6	110.0													
1050	2.1	2.2	2.4	2.5	2.7	2.9	4.0	5.5	7.5	10.8	16.5	29.0	80.3														
1100	2.3	2.5	2.7	2.9	3.1	3.3	4.6	6.4	9.2	13.9	23.8	58.0															
1150	2.6	2.8	3.0	3.3	3.5	3.7	5.3	7.7	11.6	19.3	42.1																
1200	3.0	3.2	3.5	3.7	4.0	4.3	6.3	9.5	15.4	30.8	160.6																
1250	3.4	3.7	4.0	4.3	4.7	5.1	7.6	12.2	22.7	72.3																	
1300	4.0	4.3	4.7	5.1	5.5	6.0	9.6	16.9	41.7																		
1350	4.7	5.1	5.6	6.1	6.7	7.4	12.6	26.8	214.8																		
1400	5.6	6.2	6.8	7.6	8.4	9.4	18.1	61.0																			
1450	6.9	7.7	8.6	9.7	11.0	12.6	31.2																				
1500	8.9	10.1	11.6	13.4	15.7	18.8	100.3																				
1550	12.1	14.2	17.0	20.8	26.3	35.1																					

SECTION 2 –Safety problem

This section applies when the selection of a pedestrian facility aims to address a specific pedestrian safety problem.

The approach to facility selection on safety grounds is to provide safety, or rather address a safety problem, at the lowest possible cost. Thereby allowing the remaining resources to be used to address other problems within the network to provide the greatest overall benefit to users.

The procedure begins with quantification of the annual cost of the safety problem at the site.

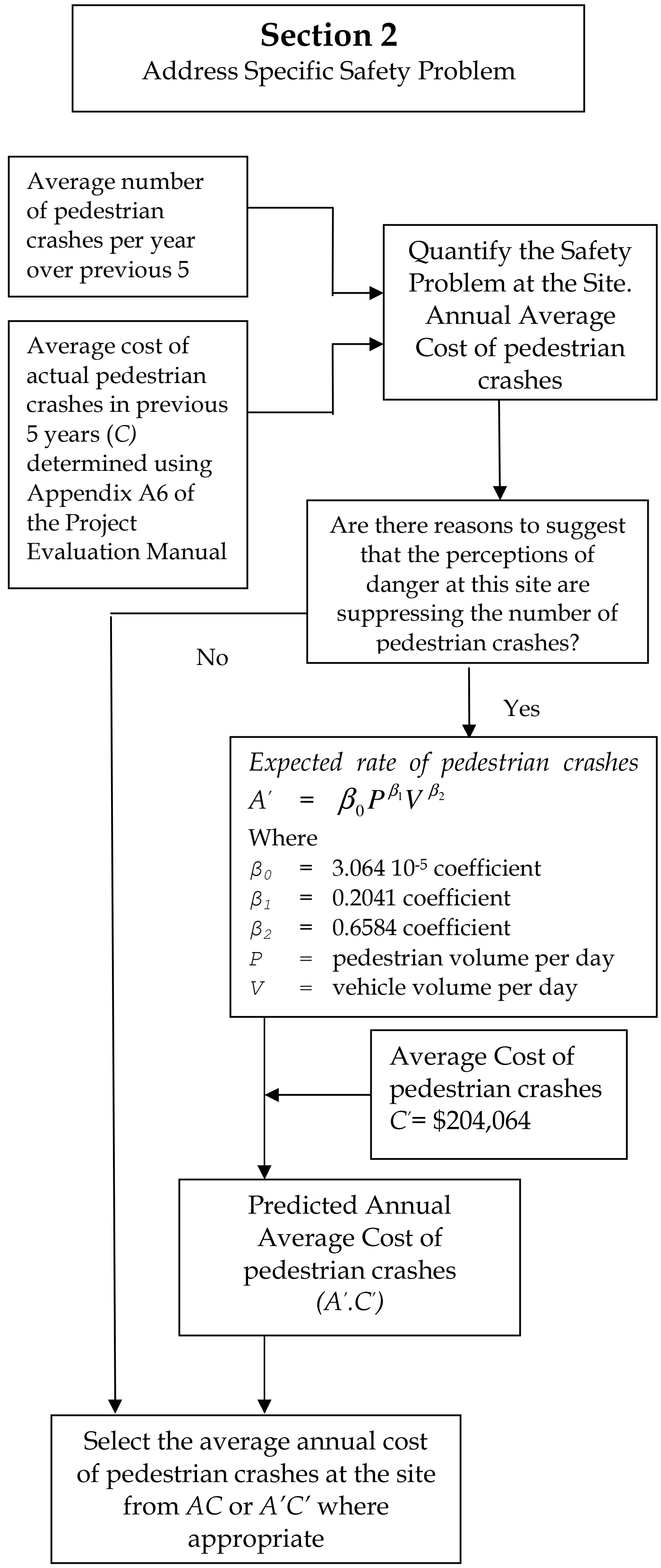
The safety problem may be either real, in that it is supported by a crash record history which identifies specific pedestrian related crashes, or perceived.

In the latter case, perceptions of danger at the site may result in suppression of the actual crash rate. In such cases, the expected number of pedestrian crashes (determined from a crash rate model) may be used in preference to the historic crash records.

Calculation of the expected pedestrian crash rate requires information on the AADT and the average daily pedestrian crossing volume. The latter may be approximated using 6.6 times the average hourly volume for the four highest hours for suburban areas and 8.6 times the average hourly volume for the four highest hours for CBD areas (Turner, 2004).

The expected rate of pedestrian crashes per year (*A′*) should be multiplied by the average cost of a pedestrian crash (*C′*), which has been calculated using the historic proportion of fatal, serious, and minor injury crashes nationwide.

Where the expected annual cost of pedestrian crashes *(A′C′)* exceeds the actual cost of crashes *(AC)*, **and** there is good reason to believe that perceptions of danger are suppressing the pedestrian crash rate, the higher cost should be used.



As with the level of service criteria, the set of potential facilities have been classified in terms of their function into:

- physical aids,
- priority devices, and
- segregation.

The resulting hierarchy represents increasing orders of magnitude in terms of whole life costs of construction and operation.

Physical Aids

Physical Aids to crossing provide users with both level of service improvements (Section 1) and a documented safety benefit.

Given their relatively low cost, physical crossing aids represent a particularly worthwhile treatment providing significant safety improvements, as shown in **Table 7**. Provided the proposed location is suitable for treatment both in terms of the road type and the ability to meet the required design standards.

Where a rational basis for providing physical aids to crossing on safety grounds exists, provided the crash reduction benefits exceed the construction cost, provision of a physical crossing aid is recommended.

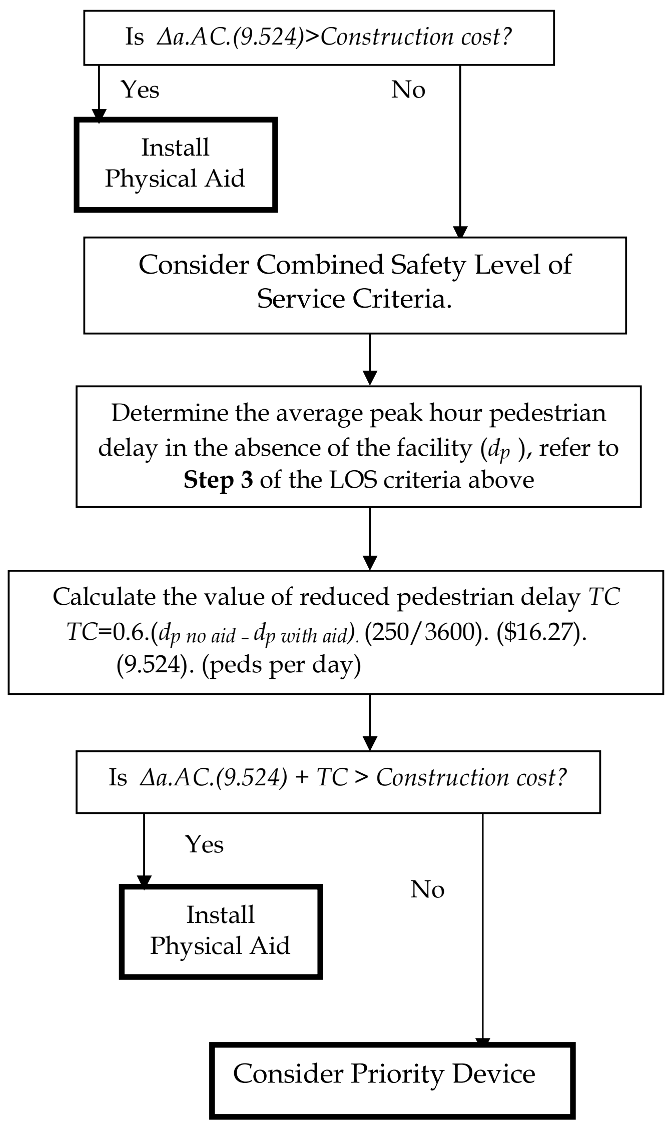
This approach assumes pedestrians derive no additional level of service benefits from the installation of the physical aid.

Where the installation of a physical crossing aid cannot be justified solely on safety grounds, a combined criteria that considers both the improved level of service and safety improvements is provided.

The combined assessment includes both the safety benefits as calculated above and an assessment of the daily reduction in pedestrian delay. This reduction is based on the assumption that the average delay to all pedestrians is approximately 0.6 times the average peak hour delay. The value of this delay is $16.27 per hour, which applies for 250 days per year. The associated discounting factor is 9.524.

Table 7 Expected Crash Reductions for Physical Aids to Crossing

Facility	**Expected Crash Reduction Δa**
Platform	60%
Median Refuge	18%
Kerb Extensions (no zebra)	36%
Kerb Extensions at Zebra	44%
Kerb Extension and Median Refuge	32%



Priority Facilities

Two types of priority facility have been identified above:

- zebra crossings, and
- signalised crossings.

A review of international literature for zebra crossings (see Appendix) shows that **there are no safety benefits associated with zebra crossings** and in some situations there is a suggestion that poorly or inappropriately located zebra crossing will increase crash risk.

The exception is the crash rate reduction associated with pedestrian crossing platforms. However, these can only be used where the requirements of Section 4 are met.

Given that Priority Facilities involve a reallocation of delay a comprehensive assessment should include **both** the crash reduction and delay to each user group.

Calculate the value of existing delays to pedestrians at the location.

If a zebra platform is being considered it must fulfil the requirements of Section 4 and Section 2 Step 5 and be an appropriate treatment for the site (see **Table 1** and **Table 2**).

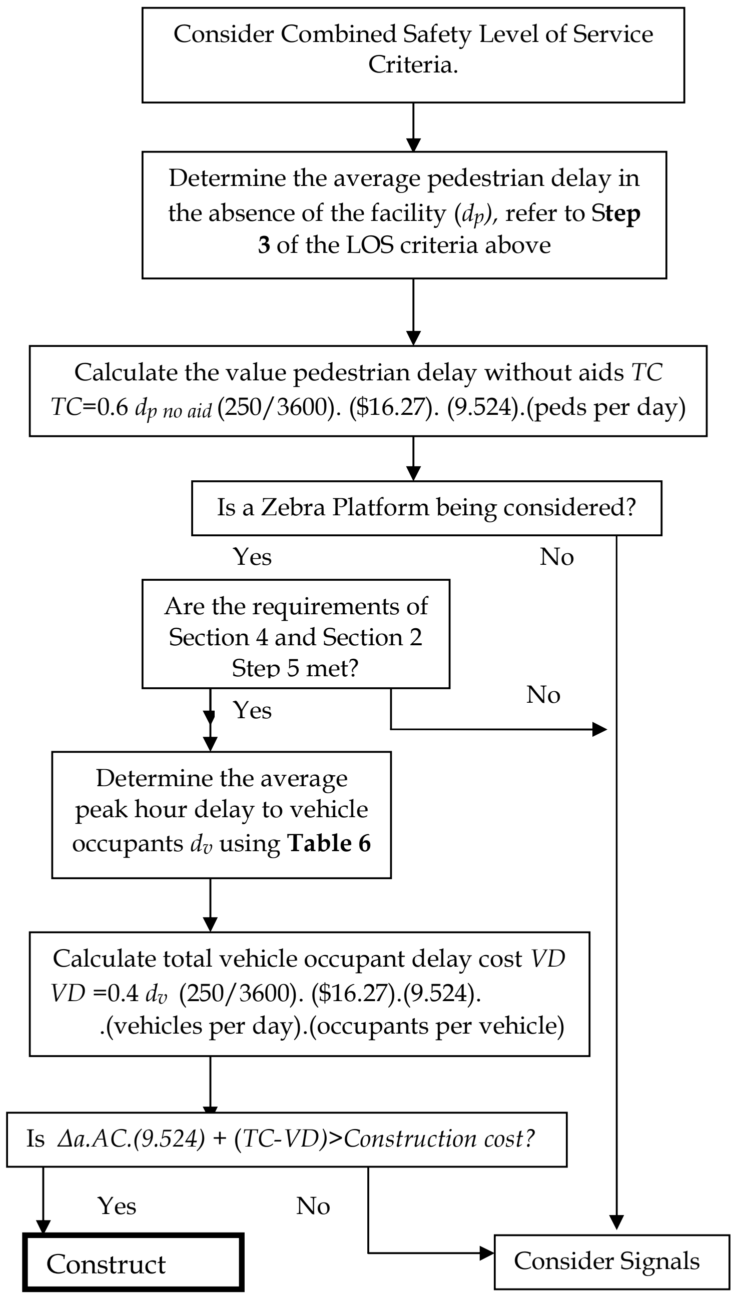
If so, calculate the peak hour pedestrian delay for the existing facility, and the vehicle occupant delay for the proposed zebra platform.

If the total benefits in terms of crash reduction and overall reduction in delay amount to more than the construction cost, the facility should be constructed.

If, however, the situation does not suit a platform zebra, or the solution would generate insufficient crash reduction and travel time benefits, then the analyst should consider signalised crossing points.

Table 8 Expected Crash Reductions for Physical Aids to Crossing

Facility	**Expected Crash Reduction Δa**
Zebra Platform	0.80
Traffic Signal	0.45



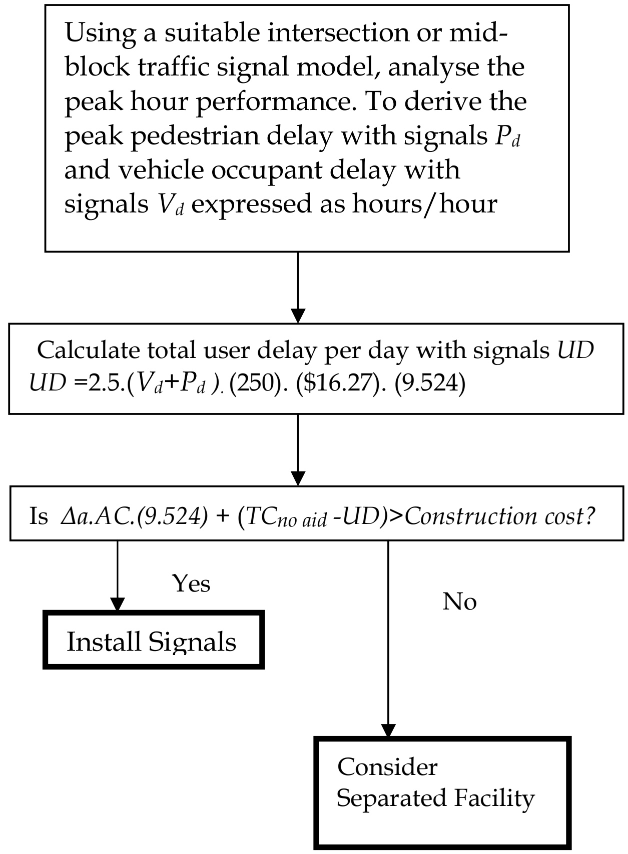
Signalised crossings may be implemented either as mid-block crossings or at an adjacent intersection. Although not specifically discussed in international literature, there appears to be a consensus in the various guidelines that where the distance to an adjacent intersection exceeds 150 to 200 meters, mid-block signals (co-ordinated where appropriate) should be considered.

In either case the benefits in terms of reductions in delay for one or more user groups are most easily determined using a signalised intersection model such as aaSIDRA or similar. The delay should however be weighted to reflect average levels of vehicle occupancy (1.2 persons/vehicle).

Because of the high capital cost separated facilities must be justified on full economic grounds. Crash reductions of 60% are typically reported in the literature.

This reduction may be increased to 70% where pedestrian barrier fencing is installed

Typically for such facilities to be more effective the path at grade should be more than 2.5 to 3 times longer than the path using the facility.



SECTION 3 –Specific Access

This section applies where the primary purpose for the pedestrian facility is to provide specific access to a particular pedestrian group.

Typically such groups include:

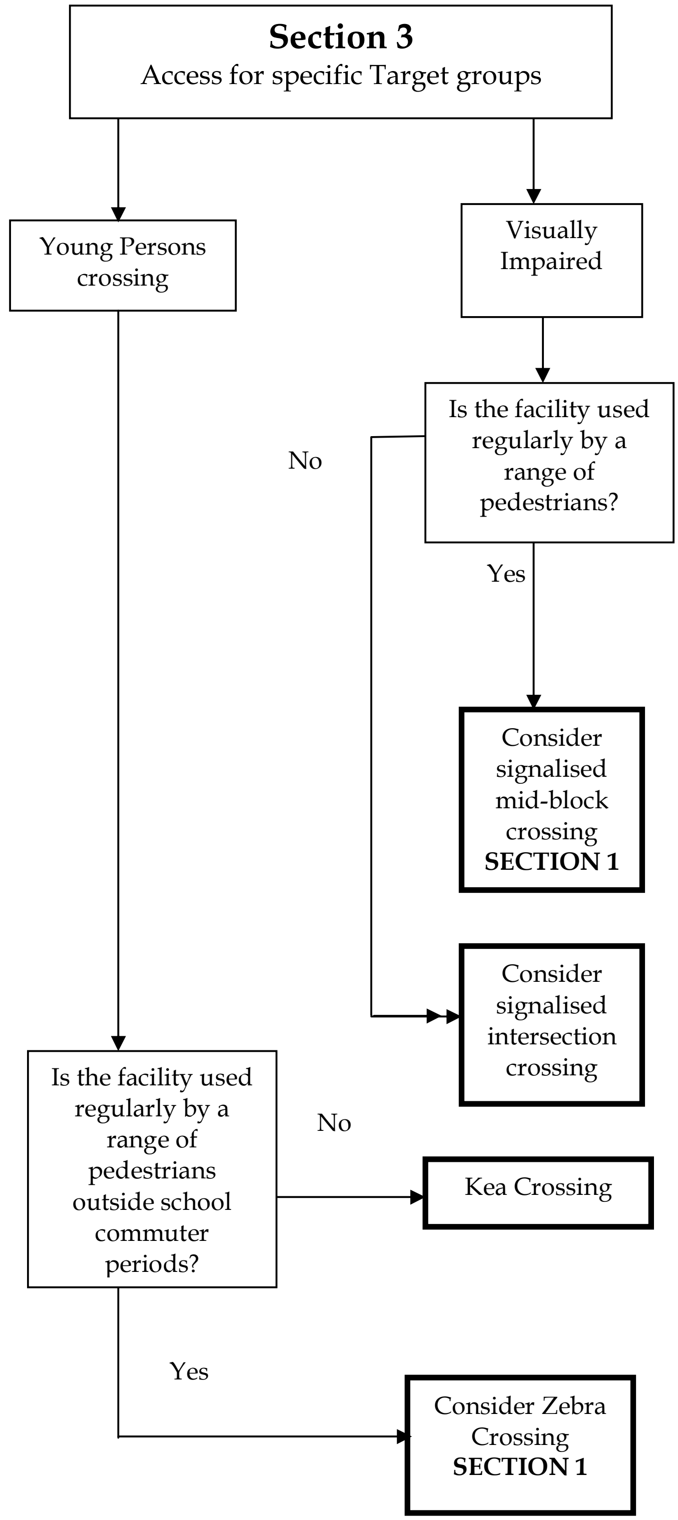
- Young Children
  - travelling to and from school
  - general travel outside school commuter times
- Visually impaired

Children- there is a wealth of literature covering the development of cognitive skills for young children, typically those less than 8 years of age but extending to those less than 12 years of age. The particular concern is their inability to judge the speed and distance of approaching traffic. For this reason it is important, in some cases, to provide dedicated facilities. While zebra crossings are often requested, these should be used with care, as it is often difficult for children to judge where a vehicle will, or can, stop as they step out onto the crossing.

Visually Impaired- the visually impaired have particular problems when seeking to determine if a vehicle is approaching and secondly if it has in fact stopped, particularly when other traffic streams around them are moving. In general the preference is for signalised crossings to over come this barrier.

However, both signalised crossings and zebra crossings will only be effective if there is sufficient regular use of the facility to ensure that drivers recognise the existence of the facility and that it will be used.

If this is not the case there is a possibility that the pedestrian will be exposed to increased danger. To overcome this, the recommendation is that where a crossing facility is only used periodically consideration should be given to the use of a Kea crossing in the case of school use, or directing the visually impaired to an adjacent intersection which is signalised with a specific pedestrian phase. Although this may increase walking distances it should in the longer term be safer.



SECTION 4 -Integration

This selection applies where the primary purpose for the pedestrian facility is to reinforce wider local area traffic management (LATM) or traffic calming.

Typically such plans will target:

- CBD
- Residential areas
- Sub-arterial management

In each case the focus is on providing a consistent and recognisable change in the nature of the road environment with each adjacent feature reinforcing the other, from both a pedestrian and road user perspective.

The key issues are the:

- desired or resulting traffic speed, the
- density or effectiveness of the plan, and the
- boundary treatment

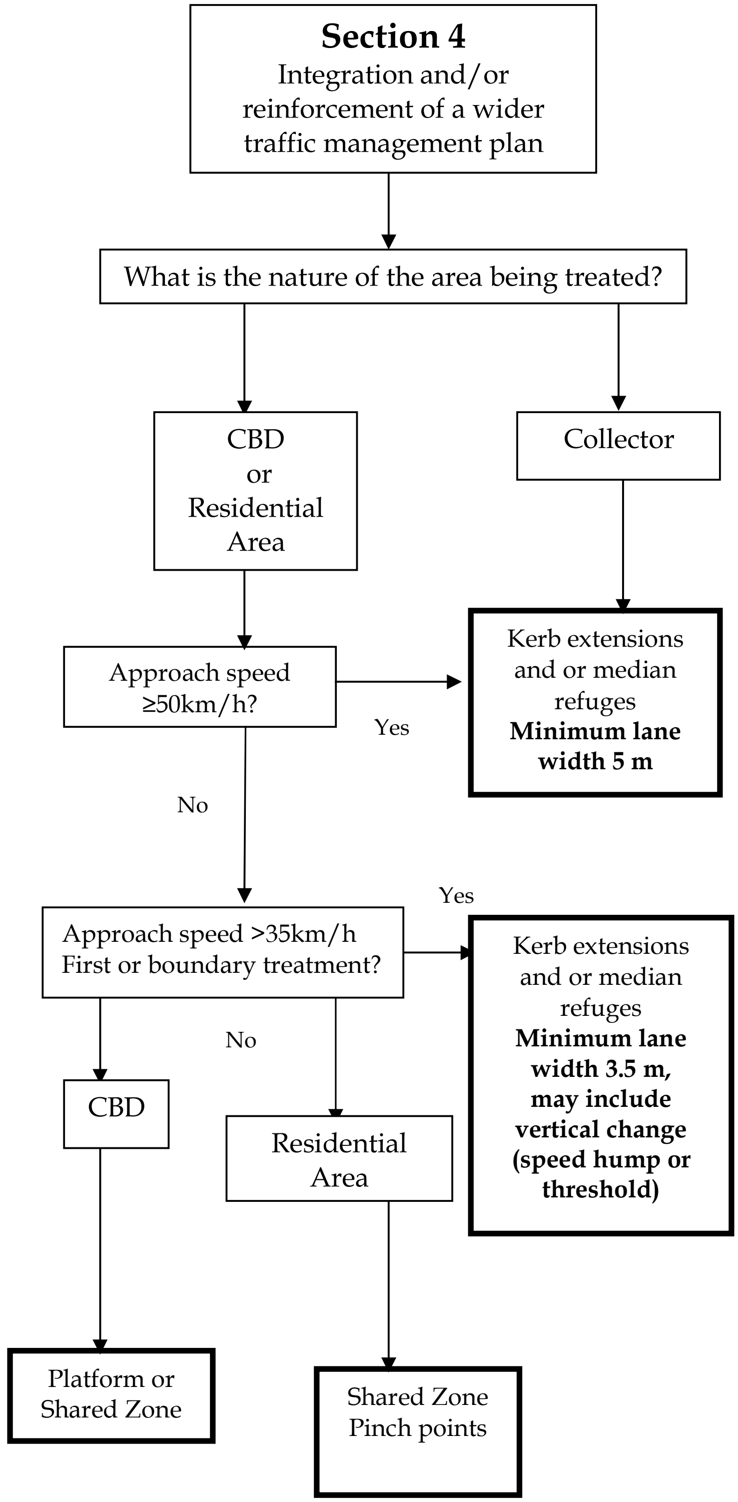
Even though the overall plan for an area may be targeting a particular traffic speed outcome, it is the approach speed to each individual facility in the scheme that will determine the type of facility that should be used. This requirement will assist to determine both boundary treatments, and inner treatments, where for some practical reason the facilities are too widely spaced and speeds have increased between devices.

Where traffic speeds are low it may be possible to reduce the lane width between kerb extensions and median islands down to 3.5 m as cyclists are less likely to squeezed by approaching traffic at such low speeds.

When seeking to establish shared spaces, research shows that effective devices will incorporate at least 4 to 5 features such as:

- vertical changes,
- hold lines,
- narrowing,
- changes in pavement texture and or colour,
- signs, and
- stepping off lines,

in order to provide clear signals that the environment, and therefore user behaviour expectations, have changed. In all cases facilities that look like zebra crossings but which **are not legal crossings should be avoided.**



APPENDIX

DEVELOPMENT OF THE METHODOLOGY

1 INTRODUCTION

Historically the need for pedestrian crossing facilities has been determined on the basis of warrants. These warrants define minimum thresholds for particular treatments. In New Zealand warrant criteria exist for the installation of:

- zebra crossings,
- signalised mid block crossings, and
- school patrols.

These warrants are based on consideration of the volume of pedestrians and vehicles at the site, delay, and crash history. There is also a combined warrant that considers cases where, even though the individual components of crash history and delay are not met, a signalised pedestrian crossing may still be considered.

A recent review of warrant criteria (Roads and Traffic Authority of New South Wales 2001a, 2001b) has identified that while the New Zealand warrant systems are in many cases similar to those used internationally, New Zealand warrants are restricted in their application and are in many cases more stringent than those used in other countries.

Recognising the restricted scope of existing New Zealand warrants and their inability to take account of all, or even the majority of relevant factors, the Land Transport Safety Authority has commissioned Opus International Consultants to review current international initiatives aimed at providing practitioners with advice on the selection of the most appropriate pedestrian facilities, and on this basis develop or extend the current criteria to cover a wider range of facilities.

2 OVERAL PHOLOSOPHY

Literature on the types of pedestrian facilities typically differentiates between facilities that act as:

1. Crossing aids,	e.g. kerb extensions and median islands that simplify the crossing task by reducing the crossing distance or dividing the task into two parts
2. Priority facilities,	e.g. zebra crossings, or signalised pedestrian crossings (mid-block or at intersections)
3. Segregated facilities	e.g. overbridges and underpasses.

From a pedestrian perspective facilities that provide the pedestrian with explicit priority e.g. zebra crossings may be the most desirable solution in terms of mobility and accessibility. However, such facilities will only operate safely if they are appropriate for the traffic environment and target users. Given the potential harm that could result from a collision between a vulnerable, unprotected pedestrian and a moving motor vehicle it is simply not sufficient to say "the vehicle should have given way" or that "the pedestrian should have used the overbridge".

When presented with a potential pedestrian crossing decision both drivers and pedestrians should be able to recognise the situation and clearly understand what is expected of them and the other party.

While the recognition and understanding of crossing scenarios is the responsibility of both the driver and the pedestrian, there are some important reasons why particular emphasis should be placed on the role of the driver:

1. the vehicle has the greatest potential to cause harm,
2. the vehicle is travelling much faster and will cover a far greater distance in the time it takes a person to perceive a potentially dangerous situation and take avoidance actions,
3. drivers are in many ways a more homogenous group than pedestrians, since this group do not include the young nor representatives of particular disability groups.

One of the major tenets of transport network planning relates to consistency of expectations and being able to recognise a particular situation and knowing what the appropriate action is.

Hazard recognition and action selection by drivers is based on cognitive processes that match the actual road scene against known situations. Once recognised, the driver's actions are based on their knowledge and previous experience. If the scene matches a known hazardous situation drivers' recognition and reactions are much quicker. However, if the actual road scene differs greatly from that expected, hazard recognition and responses are slower (Abely 2002 citing Chapman et al., 1982).

These findings have important implications for the way in which we match pedestrian crossing facilities to the road environment in order to provide the greatest safety for pedestrians while still providing the best possible level of service.

3 Safety Literature

A range of studies into the safety effectiveness of various pedestrian facilities have been reviewed. While these have generally been one-off studies, there are also a small number of compilation documents which have sought to provide summaries of the literature existing at the time of publication and to compare the results of various other studies.

The range of facilities considered in these studies has been limited. The majority of studies have focussed on the safety benefits of:

- traffic signal controlled crossing points, be these at intersections, mid-block signals or pelican signals, or
- marked pedestrian crossings, which although broadly grouped as zebra type crossings may include a wide range of marking layouts, locations types, and road rules depending on the country in question.

The one marked exception is a large study of pedestrian facilities in Sydney (Geoplan, 1993)

While in many cases there is general agreement between the conclusions of the various studies, in almost every case the researchers have been forced to qualify their findings recognising, methodological issues have disguised or at least confounded the results. Such issues typically include sample size problems, problems with unequal before and after periods, regression to the mean effects, and selection bias that results from local conventions that limit the application of particular facilities to high risk situations. There are also variations in the units of risk measurement e.g. per pedestrian, per vehicle or per cross-product unit, or simply crashes per year.

The following sections outline the key findings of the literature reviewed and the resulting formulation of the selection criteria for the following facilities:

1. Physical Aids to Pedestrian Crossing
   a) Kerb Extensions
   b) Central Refuges

2. Priority Devices
   a) Zebra Crossings
   b) Pedestrian Platforms (marked as crossings)
   c) Intersection Traffic Signals
   d) Mid-block Traffic Signals and Pelican Crossings

4. Segregated Facilities
   a) Underpasses
   b) Overbridges

In seeking to establish the likely safety benefits of each treatment the following approach has generally been adopted:

i. Where there is reliable New Zealand data this has been used in preference to other sources.
ii. In the absence of New Zealand Specific data, international data has been used with added weight given to studies undertaken in Australia and the United Kingdom where road rules and conditions are more broadly similar to New Zealand.
iii. Finally, the results of studies from other countries where road rules and conditions are known to be markedly different from New Zealand are considered.

The expected crash reduction estimates obtained through the above process are then applied to the New Zealand pedestrian crash risk models developed by Turner (2004). It should, however, be noted that these models have been developed for only a small sub-set of pedestrian crash situations. Namely pedestrians crossing without facilities in 50km/h speed zones associated with shopping and CBD areas. However, in the absence of models for other situations, this is the best data available and one recommendation of this study is that further research to build a wider range of models is required.

3.1 Physical Aids to Pedestrian Crossing

3.1.1 Kerb Extensions

The intention of kerb extensions, blisters, or bulbous kerbs, is to assist pedestrians to cross by reducing the crossing distance. Not only does this reduction facilitate crossing by reducing the time gap required to complete the crossing, thereby allowing pedestrians to utilise smaller gaps in the opposing traffic stream, but it also reduces the time that the pedestrian is exposed to the approaching traffic.

The Geoplan study (1993) analysed data from 43 sites where kerb extensions had been installed and a further 20 sites where kerb extensions had been installed at previously marked zebra crossings, in Sydney. The study found significant crash reductions of 48% and 32% respectively, rising to 74% and 55% when considering only those sites where pedestrian crashes had occurred prior to treatment. The results from the LTSA Crash Reduction Monitoring System suggest that in New Zealand the provision of kerb extensions result in pedestrian crash reductions of 36%, a figure similar to that found in the Sydney study. It should, however, be noted that the LTSA Crash Reduction Monitoring System data is related to the treatment of sites to improve an existing safety problem, in which case the comparison should really be made against those Sydney sites where crashes occurred prior to treatment. A simple pro-rata reduction would suggest that if widely applied (to sites without an existing crash history) the crash reduction benefits of kerb extensions could reduce to around 20% to 25%. This is, however, a bold assumption.

Cariney (1999) suggests that the use of kerb extensions at existing zebra crossings appear to reduce crashes by 44%.

In assessing the potential benefits of kerb extensions an expected crash reduction of 36% has been assumed based on New Zealand specific data.

3.1.2 Median Refuges

Median refuges allow pedestrians to cross busy roads in two steps, focussing on one traffic stream at a time. This improves the pedestrian level of service, the total time exposed to traffic remains essentially the same, and the complexity of the crossing task is reduced.

In the United States the provision of raised medians or central refuges are associated with a significantly lower risk of pedestrian crossing crashes (Zegeer et al 2002; Garder 1989). However, it appears (although it is not explicitly stated) that many of the sites in the studies were median divided dual carriageways. The reductions reported in the United States are in direct conflict with the Sydney study (Geoplan, 1993). That study found no significant pedestrian crash reduction at the 225 sites investigated, nor did the study find significant pedestrian crash reductions at sites where both median refuges and kerb extensions were installed.

The latter is of interest when making a comparison with New Zealand data from the LTSA Crash Reduction Monitoring System. Although the LTSA data reports an 18% reduction in pedestrian crashes at sites where only central refuges have been installed (LTSA, 1994), sites where both refuges and kerb extensions have been installed show a lower crash reduction (32%) than when kerb extensions alone are installed.

It is suggested that the differences in these findings are most likely related to the range of situations in which these devices are installed, as one would expect effectiveness to vary between two-lane two-way roads, and dual carriageways, as well as between facilities installed at intersections, and those installed mid-block. However, no such data are presented, and even if the results were disaggregated on this basis, the resulting sample sizes are likely to preclude meaningful analysis.

In assessing the potential benefits of median refuges an expected crash reduction of 18% has been assumed based on New Zealand specific data.

In assessing the potential benefits of combinations of kerb extensions and median refuges an expected crash reduction of 32% has been assumed based on New Zealand specific data.

3.1.3 Development of Selection Criteria –Physical Aids

The physical aids to pedestrian crossing discussed above have low installation costs and the choice of whether to install a particular facility is based on a trade-off between the costs of installation and any subsequent delay, and the resulting crash reduction benefits.

Predictions of the likely crash reduction benefits are based on applying the estimated crash reduction associated with each facility to the expected crash rate at the site, calculated using the no-facility pedestrian crossing crash model developed by Turner (2004). This model is used in the absence of a better alternative, recognizing that the model has been constructed from a relatively confined dataset.

The average cost of a pedestrian injury crash has been based on the proportion of fatal, serious, and minor injury pedestrian crashes (crash codes NA and NB) recorded in the LTSA Crash Analysis System (CAS) over the three years 2001 to 2003 inclusive:

- Fatalities resulted in 4.4% of crashes,
- Serious injuries resulted in 26.4% of crashes, and
- Minor injuries resulted from 69.2% of crashes.

Combining these proportions with the average cost of a pedestrian crash from Transfund's Project Evaluation Manual (Transfund New Zealand, 2002) provides an average economic cost, of a reported injury crash involving a pedestrian (crossing the road), of $204,000.

Provided the crash reduction benefits over the life of the project exceed the construction costs, the facility is justified in that the social benefit cost ratio exceeds 1.0. Note that thiscriteria may well differ from that required to secure funding when available resources are limited.

$$1 \leq \frac{a \times d \ \ \times \Delta a \times A}{C}$$

Where

C = facility construction cost

a = average cost of a reported pedestrian injury crash ($204,064) or the average cost of pedestrian crashes recorded at the site based on the social cost of crashes provided in Appendix A6 of Transfund's Project Evaluation Manual

d = uniform series present worth factor from 0 to 25 years at 10% discount rate 9.524

Δ = crash reduction factor for the facility

A = the number of pedestrian crashes per year averaged over the pervious 5 years, or in cases where the perception of danger is far higher than the actual danger (crashes per year) the expected pedestrian crash rate should be calculated using the model below, which was derived by Turner (2004)

$$A = \beta_0 P^{\beta_1} V^{\beta_2}$$

Where

β_0 = 3.064 10^{-5} coefficient

β_1 = 0.6584 coefficient

β_2 = 0.2041 coefficient

P = pedestrian volume per day

V = vehicle volume per day

From a review of construction estimates, a rough order cost for a pair of kerb extensions incorporating pedestrian cut downs is around $10,000, although this value is highly dependant on the level of traffic control required for construction. The cost for a 7-10 metre median island (without significant carriageway widening is of a similar order, and the combination of kerb extensions and median island is approximately $15,000.

3.2 Priority Devices

3.2.1 Zebra Crossings

The provision of marked pedestrian crossings (zebras) to improve pedestrian safety has been a contentious issue for many road controlling authorities and managers. While the public perception is often that the provision of a zebra crossing will improve crossing safety, the opinion of many in the profession is that this is not necessarily the case.

The general argument from the profession is that, while zebra crossings provide pedestrians with priority over the traffic stream, this right is not always recognised, or adhered to, by drivers. Given the danger posed by moving vehicles, providing pedestrians with a false sense of security may be either unwise or even irresponsible.

There have been numerous studies of the pedestrian crossing risk at marked (zebra crossings) and unmarked locations. Early studies, such as those by Mackie and Older (1965), and Jacobs and Wilsson (1967), each identified that pedestrian crossing risk was less at formal crossings than within the 50m either side, supporting the perception that marked crossing increased safety. Conversely, US studies around the same time (Herms, 1972) suggest that crossing risk per pedestrian was almost twice as high at marked crossing sites than unmarked crossing sites.

A before and after study into the provision of 62 zebra crossings in London (Landles and Lloyd, 1982) disaggregated crossing locations on the basis of the before crash risk. The study found a significant (50%) reduction in pedestrian crashes occurred at those sites where prior to marking of the zebra, the crash rate (crashes per year) was above the London average of 3 crashes per year. For average sites, those with 2 to 3 pedestrian crashes per year, the resulting reduction of 16% was not statistically significant, while for below average sites a statistically significant increase in pedestrian crashes of 50% was recorded. Adjusting for regression to the mean effects resulted in no significant changes in crash rate being identified, probably due to the small sample size in each group. A further study (Daly et al., 1991) comparing crash rates at zebra crossings and pelican signals against no-formal crossing facilities, found a constant crash rate (crashes per year) best fitted the data for the no-crossing situation and zebra crossings. The respective rates were 0.48 pedestrian crashes/year when no-crossing facilities were present and 0.44 pedestrian crashes/year when a zebra crossing was installed. Although the selection of facilities to be installed was regulated under the governing criteria of the time, the result adds further to the proposition that zebra crossing result in little safety benefit.

A controlled study of zebra crossings in Lund Sweden, (Ekman and Hyden, 1999) found that the risk to pedestrians crossing on a zebra crossing would be twice that of crossing in the same situation without a crossing. In a later study (Ekman 1996) suggests that risk (per pedestrian) is greater at marked crossings when traffic volume exceeds 100 vehicles per hour.

In a review of Dutch research into pedestrian crossing facilities (Hummel, 1999) cites research by Boot (1987) that found unsignalised crossings (zebras) did not increase pedestrian safety.

Possibly the largest study of marked and unmarked crossings, involving 2000 crossing locations (1,000 marked 1,000 unmarked) has been undertaken by Zegeer et al (2002). Although the US legislation covering crosswalks differs significantly from that in New Zealand, a study of mid-block and intersection crosswalks found that when traffic volumes are less than 10,000 ADT the pedestrian crossing risk (pedestrian crashes per 10^6 pedestrian crossings) was similar for both unmarked and marked (zebra) crossings. However, at higher traffic volumes (i.e. >10,000 ADT) the pedestrian crash risk was significantly higher at marked (zebra) crossings than at unmarked crossing locations, and importantly, increased more rapidly with increasing traffic volumes. These findings have prompted Campbell et al (2004) to conclude that the marking of crossing points (zebra crossings or similar variants) provides no increase in safety at lower traffic volumes (less than 10,000 ADT), and that such treatments result in an increased risk for pedestrians at higher volumes.

The Geoplan (1993) study of 108 newly installed zebra crossings in Sydney found that pedestrian crashes increased by between 15% and 29%, although the change was not statistically significant.

On balance, it would appear likely that the use of zebra crossings cannot be justified on safety grounds, and it is possible that in some situations zebra crossings may increase the risk to pedestrians.

Based on a review of international studies of zebra crossing facilities (or their equivalents), zebra crossings, in general, do not result in reduced crash risk for pedestrians. Furthermore, inappropriate use, in areas where the speed limit is greater than 50km/h, and in situations where the pedestrian is required to cross more than two lanes of traffic moving in the same direction, may increase crash risk.

3.2.2 Elevated Pedestrian Platforms

Constructed in association with local traffic management or calming schemes, raised pedestrian platforms reduce the speed of approaching vehicles, and when marked with zebra crossings provide priority for pedestrians. Interestingly Dixon and Jacko (1998) found that vehicles are more likely to yield to pedestrians in the presence of a change in vertical profile (speed hump).

Few studies have specifically considered the crash risk implications of such facilities. One such study is the Sydney study, (Geoplan, 1993) which investigated the crash reduction impacts of 30 such facilities and found significant crash reductions of between 78% and 83%. While it is difficult to separate the contribution of the crossing from that of the traffic calming, such features should only be used as part of a wider traffic-calming plan.

In assessing the potential benefits of pedestrian platforms an expected crash reduction of 80% has been assumed based on international literature.

3.2.3 Traffic Signals

Mid-block traffic signals in New Zealand operate in a very different manner to the Pelican that are typically used in such situations in the UK. Consequently, much of the UK research available is unlikely to be directly applicable to New Zealand. This may provide some level of comfort, since a review of 45 new pelican installations found that, only when installed at sites with average or above average crash rates did the installation of pelican crossings result in a reduction in pedestrian crashes, although the reductions were not statistically significant. At low risk sites, the installation of pelican crossings resulted in a significant increase in risk, although following correction for regression to the mean effects all variations proved insignificant.

The Geoplan (1993) study considered both mid-block pelican crossings and traditional mid-block signals. The study found significant reductions in crashes for Pelicans, but not for either mid-block signals or those installed at intersections. However, Cairney (1999) reports that pedestrian operated mid-block signals generated pedestrian crash reductions of 49%, and that pelican crossings provided a 90% pedestrian crash reduction, and refers to the Geoplan (1994) finding that installation of pedestrian signals at existing intersections results in no reduction in pedestrian crashes.

Hummel (1999) reports the finding of Boot (1987) that the provision of signalised mid-block crossings is associated with a significant reduction in pedestrian crash rate, but does not report the value of this reduction. Campbell et al (2004) also references a range of studies including one undertaken in Tokyo which suggests the provision of pedestrian signal facilities at intersections results in a 37% reduction in pedestrian crashes.

There appears to be some form of convention in the literature which suggests that it is reasonable for pedestrians to use an adjacent signalised intersection when this is within 150m. The basis of this assertion is unknown.

In assessing the potential benefits of mid-block pedestrian signals an expected crash reduction of 45% has been assumed based on international literature. For pedestrian signals at intersections no crash reduction benefits are assumed.

3.2.4 Development of Selection Criteria –Priority Devices

Given that each of the priority devices results in a transfer of delay as well as safety benefits a combined warrant is required.

Rather than a full multi-time period analysis, the recommendation is that a simple factoring of the peak hour performance be undertaken.

For traffic signals, aaSIDRA should be used to determine the peak hour performance.

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