Separated Cycleway Options Tool

TN001 April 2016

1. Introduction

The 'separated cycleway options tool' (SCOT) was developed to partially address some of the gaps identified in Stage 1 of the Cycling Network Guidance project relating to separated cycleways.

Regardless of its current or eventual accuracy, it is not intended that SCOT be used as the sole deciding factor regarding the form of separated cycleway; it should form part of a multi-criteria analysis. There will be other factors to consider beyond those covered in the tool, including how a particular section connects to the greater route at each end and the physical constraints of accommodating the cycleways within the existing corridor.

SCOT is intended as an interim guidance tool, it is expected that it be improved after more separated cycleways have been constructed and evaluated in New Zealand.

SCOT has been developed based on professional judgement by experienced practitioners and it is to be used as interim guidance by the industry.

2. Tool application

SCOT can be applied to choose between two facility types, by evaluating the risk at certain types of conflict locations along the route, within a certain road layout and traffic environment.

2.1 Facility types

SCOT gives two main options for type of separated cycleway:

1. One-way (i.e. uni-directional, with cycling in the same direction as adjacent traffic on each side of the road)
    - Users have the option of individual inputs for each side of the road. Therefore this tool could be used to assess a single one-way cycleway on one side of the road, including one-way streets, as long as the cycle flow is in the same direction as adjacent traffic. Note that it does not yet cover, however, the case of a one-way cycleway for contraflow cycling.
2. Two-way (i.e. bi-directional, with cycling in both directions, hence involving a component of contraflow cycling)
    - Users have the option of individual inputs for cycle volumes in each direction.

Figure 1 illustrates a two-way separated cycleway. As people can cycle in both directions, some of them will be cycling in the same direction as adjacent traffic (i.e. 'with-flow' cycling) and others will be cycling in the opposite direction to adjacent traffic (i.e. 'contraflow' cycling).

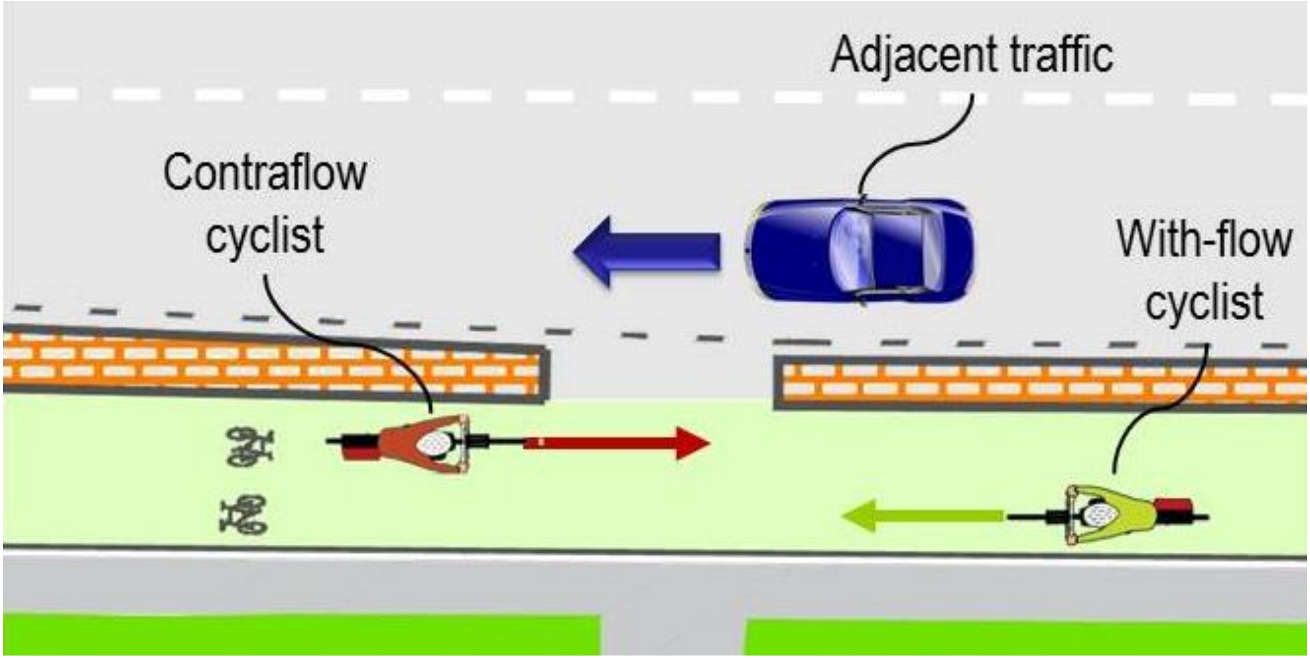

Figure 1: With-flow and contraflow cycling on two-way facility

2.2 Conflict locations

There will be a number of potential conflict locations where vehicles have access across a separated cycleway; SCOT considers:

- Residential driveways;
- Non-residential driveways;
- Priority controlled side streets / intersections; and
- Signalised intersections.

Note that SCOT has been developed assuming streets allow for two-way traffic and all turning movements are accommodated at accessways (i.e. left and right turns in and out). It is reasonable to assume that restricting certain movements across a cycleway (especially movements that affect contraflow cycling) will reduce the risk of conflict.

Whilst no specific consideration of one-way streets has been made, SCOT should be suitable for one-way separated cycleways where cycle flow is in the same direction as adjacent traffic. The case of a one-way separated cycleway for contraflow cycling could be covered by defining a two-way cycleway with a volume of zero for cyclists travelling in the with-flow direction.

2.3 Parameters affecting risk

At each type of conflict location, the risk is affected by certain parameters:

- Cyclist volumes;
- Direction of cycle travel with respect to adjacent traffic;
- Motor vehicle volumes for conflicting movements;
- Proportion of heavy vehicles involved; and
- Occupancy of adjacent on-street parking.

2.4 Conflict scenarios

A type of cycleway at a specific conflict location with its unique parameters is termed a 'conflict scenario'. The methods of deriving the risk factors for various conflict scenarios are discussed in section 4.1

3. Instructions for use of tool

3.1 Overview of Excel workbook

SCOT consists of a Microsoft Excel workbook containing three worksheets:

Table 3-1: Protected cycleway evaluation v09.xlsx – description of individual sheets

Sheet name	Description
1. **Notes**	General notes outlining tool development.
2. **Conflict evaluation**	Separated cycleway options tool (intended for industry guidance)
3. **Actual crash prediction**	Notes on development of the factor to convert from crash risk to actual crashes.

The second sheet, "Conflict evaluation" contains the tool itself and all relevant output for users; the others provide documentation on the tool development and application, as a supplement to this guidance.

3.2 Facility selection tool colour coding

A variety of colours is applied to the cells in the facility selection tool spreadsheet ("conflict evaluation") to assist the user:

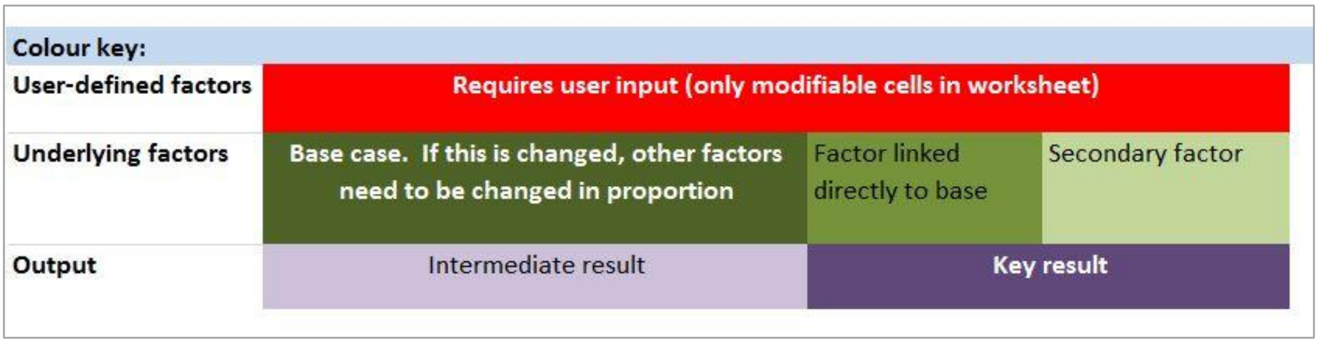

Figure 2: Selection of spreadsheet tool showing colour key for cell types

The only cells that can be modified by users are the red cells; the spreadsheet is password protected, but still allows users to see the underlying factors.

3.3 User inputs

SCOT is configured to give the two facility options: one-way separated cycleways (with the option of being on one or both sides of the road) and two-way separated cycleways, as identified in section 2.1.

Tool users are required to describe the conflict scenarios by entering values in the red cells, which cover:

- Cyclist volumes
  - For one-way cycleways daily volumes are specified for each side of the road
  - For two-way cycleways, daily volumes are specified for "with-flow" and "contraflow" directions (as illustrated in Figure 1)
- Number of driveway movements generated per residence per day (a default value of 10 is used)
- Number of driveways servicing a given number of residential properties, at a given parking occupancy rate (see below for more information on assessing parking occupancy)
- Total daily traffic movements at non-residential driveways (sum of vehicles in and out)
- Total daily traffic movements crossing cycleway at side streets and intersections
- Percentage of heavy vehicles in the traffic crossing the cycleway at non-residential driveways, side streets and intersections
- Occupancy of parking adjacent to cycleway;
  - This factor applies to driveways and priority-controlled side streets / intersections.
  - This should be approximated based on a 50 m section of parking prior to (i.e. in the direction of an approaching cyclist) the conflict location
    - For one-way facilities, consider the parking occupancy for 50 m in the upstream direction (as illustrated in Figure 3)
    - For two-way facilities, therefore, consider the parking occupancy for 50 m either side of the driveway / side street (as illustrated in Figure 4)
  - Where parking occupancy is likely to vary throughout the day, the peak periods should be considered.
  - Where no on-street parking is provided, the parking occupancy is 0%.

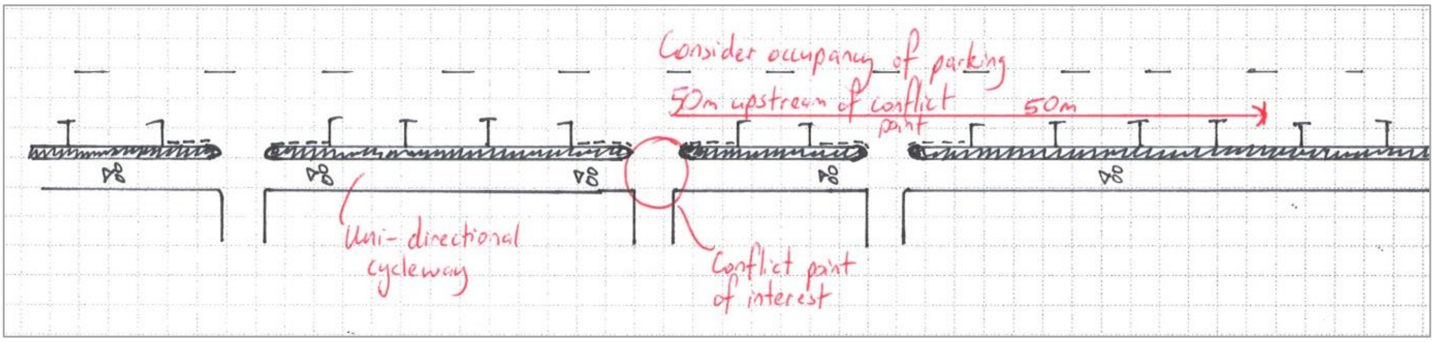

Figure 3: Where to consider parking occupancy adjacent to one-way cycleway

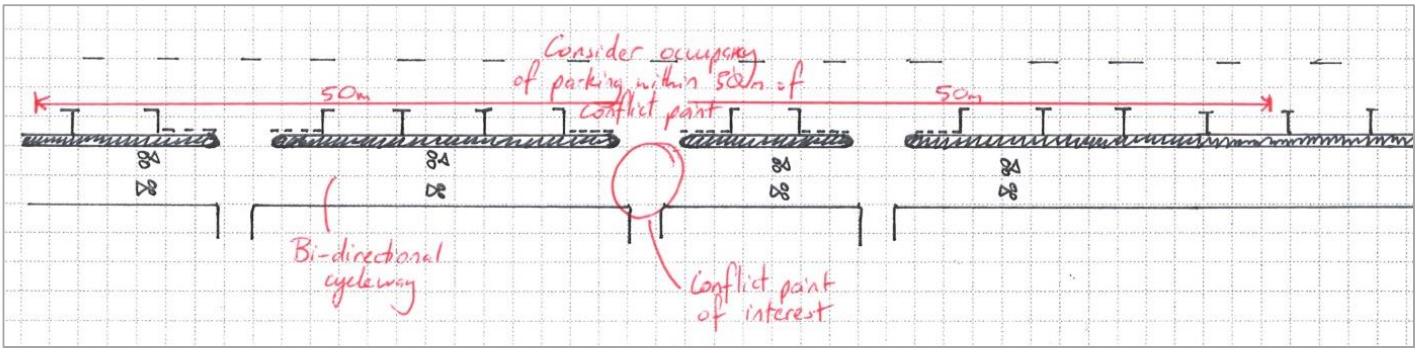

Figure 4: Where to consider parking occupancy adjacent to two-way cycleway

3.4 Outputs

SCOT shows a risk rating for each individual conflict location (except that risk at residential driveways can be grouped together for driveways servicing the same number of properties / movements and with the same expected parking occupancy on the frontage road). Risk is summed for each conflict type on each side of the road (for a pair of one-way cycleways), or each cycling direction (for a two-way cycleway).

A conversion factor is used to convert the risk scores to predicted actual crash rates.

A summary table at the bottom of the conflict evaluation worksheet presents the relevant risks and predicted crash rates. This can be used to identify which option is considered safer, by what proportion and by what number of actual expected crashes.

The summary table can also be used to identify which aspects contribute the most to the risk rating of a particular option and therefore which locations could be addressed to reduce an option's risk rating or achieve an acceptable predicted crash rate.

The summary table for an example where SCOT was applied to a section of Sawyers Arms Road in Christchurch is shown in Figure 5:

Summary	2x one-way cycleways			1x two-way cycleways			Ratio (1*two-way/ 2*one-way)
	Side 1	Side 2	Total	With-flow	Contraflov	Total	
Residential driveways	659	2615	**3274**	330	989	**1318**	0.40
Non-residential driveways	2761	0	**2761**	2239	4337	**6577**	2.38
Unsignalised side streets	0	2610	**2610**	0	0	**0**	0.00
Signalised intersections	1013	36	**1050**	1013	2724	**3737**	3.56
Relative Risk Analysis	**4434**	**5261**	**9695**	**3582**	**8050**	**11632**	**1.20**
			safer			**less safe**	
Predicted Crashes / year			**0.63**			**0.76**	

Difference in actual crashes: 0.13 injury crashes per year

Difference over ten years: **1.26** injury crashes per 10 years

Figure 5: Summary table of output for Sawyers Arms Road example

3.5 Caveats

Current crash prediction models[1] focus on on-road cycling environments which differ from separated cycleways in terms of relative position to moving traffic and parked cars, visibility, directional flow and user familiarity. The current models available also include a high degree of aggregation; for example, they consider entire midblock sections without allowing for any distinction between the number and type of driveways along the section. Thus, until more separated cycleways are built and observed there is little information available to accurately validate the values that have been assumed. In the meantime, it is anticipated that this interim guidance tool will provide practitioners with a useful basis of evaluation. Professional judgement on site-specific criteria must always be applied.

4. Tool development

This section gives further explanation of the underlying factors used by SCOT to evaluate risk and crash rates.

4.1 Conflict scenarios and parameters

As discussed in section 2.2, a conflict scenario depends on the facility type, location type and parameters. The factors used in SCOT to determine the risk at various conflict scenarios are presented in Figure 6, and the rationales for these are discussed in this section.

[1] E.g. NZTA Research Reports 289 and 389.

Definition and quantification of underlying factors (no user-input required):					
		Cycling type within facility			
		No adjacent parking provision		Adjacent parking at 100% occupancy (1)	
Conflict point type	**Relevant vehicle and flow**	**Contraflow cycling**	**With-flow cycling**	**Contraflow cycling**	**With-flow cycling**
Residential driveways (light vehicles) (2)	Light vehicle movements per residence per day (3)	3	**1**	4	2
Non-residential vehicle access (e.g. carparks)	Light vehicle flow in and out per day	6	**2**	8	4
	Heavy vehicle flow in and out per day	15	**10**	15	10
Side streets (priority)	Light vehicle movements crossing cycleway per day	6	**2**	8	4
	Heavy vehicle movments crossing cycleway per day	15	**10**	15	10
Signalised intersections	Light vehicle movements crossing cycleway per day	3	**1**	N/A	N/A
	Heavy vehicle movments crossing cycleway per day	7.5	**5**	N/A	N/A

Figure 6: Risk factors applied in tool for various conflict scenarios

Note that the risk factors have been developed assuming that the design complies with the relevant guidance regarding geometry and visibility etc. In particular, risk factors relating to driveways apply to driveways with adjacent on-street parking that complies with the recommended minimum parking setbacks from driveways – as outlined in the Cycle network guidance section on separated cycleways at driveways.

Along a separated cycleway there may also exist locations of potential conflict between cyclists and pedestrians. These include pedestrian crossing points that traverse the cycleway, bus stops and shared areas where footpaths and separated cycleways are merged. Crashes between a cyclist and a pedestrian are generally less significant than crashes between a cyclist and a motor vehicle, and thus have not been considered in this tool. However, it is assumed that such locations with potential conflict between cyclists and pedestrians will be designed according to best practice guidance.

4.1.1 Residential driveways (base case)

The risk of a conflict involving cycling in the with-flow direction on a separated cycleway at a residential driveway with no adjacent parking has been taken as the base case and assigned a risk factor of 1. The other conflict location scenarios reference this directly or with one or two degrees of separation.

International studies that compare with-flow and contraflow cycling suggest that cycling in the contraflow direction is approximately three times riskier than cycling in the with-flow direction at an intersection between a cycleway and a side road (see Figure 7). It has been assumed that a similar ratio between risk of with-flow and contraflow cycling would apply at driveways. Thus a risk factor of 3 has been applied to residential driveways for separated cycleways that involve contraflow cycling, where there is no adjacent on-street parking.

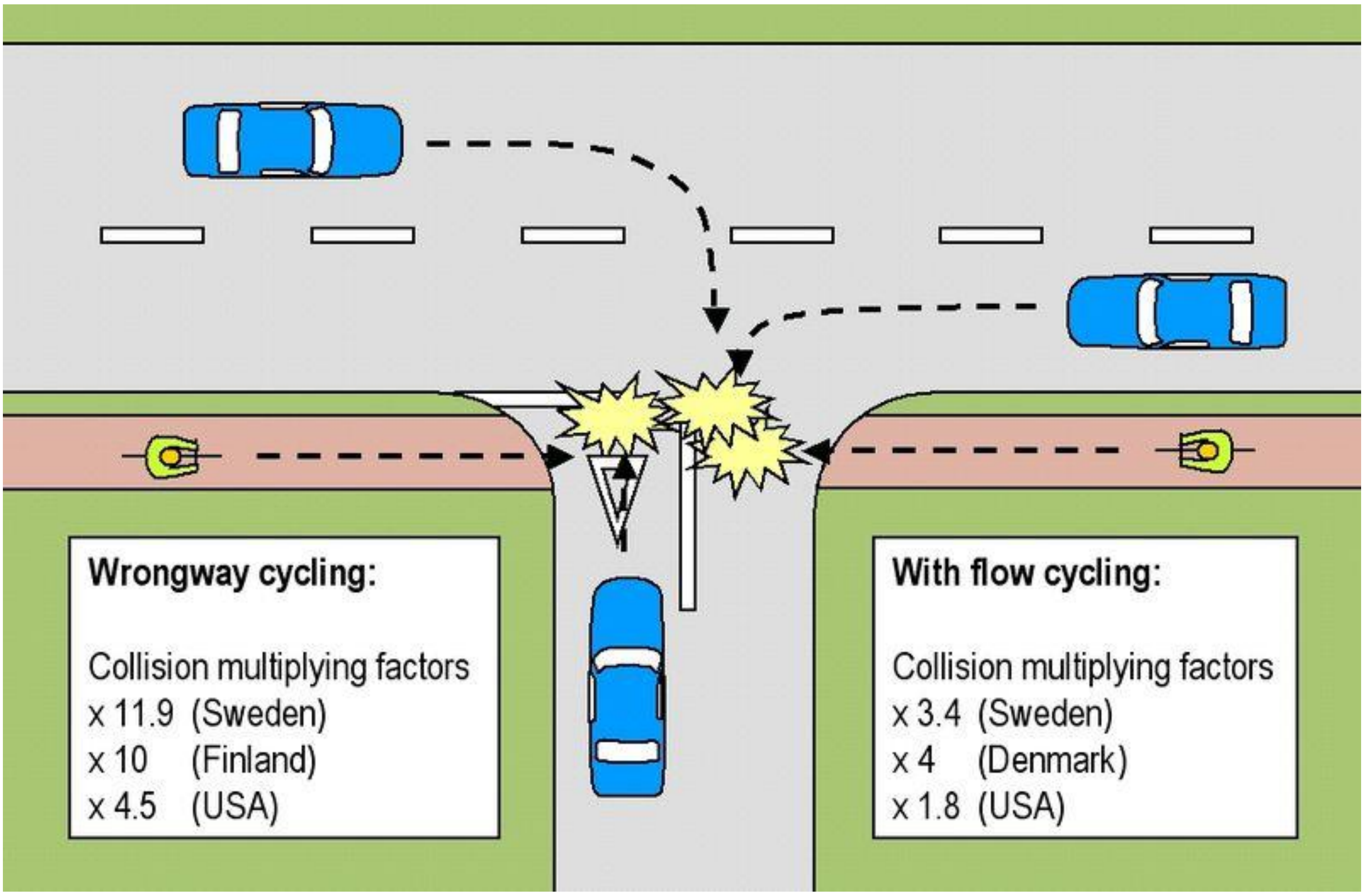

Figure 7: With-flow versus contraflow cycling[2]

When adjacent parking is present, the risk increases. Parked vehicles obscure intervisibility between drivers turning into driveways and cyclists. Parked vehicles obscure visibility for drivers turning out of driveways to on-road traffic, which adds complication to their manoeuvre and therefore increases the likelihood that they will overlook cycleway users.

This risk has been assumed to be a linear increase with respect to the no parking (equal to zero occupancy) case (i.e. this involves an addition to, not a multiplication of, the no-parking cases for both with and without adjacent parking). The upper limit of risk for locations with 100% parking occupancy will need to be subjected to sensitivity testing. It is expected to be 1.5-2 times that of the zero occupancy case.

It has been assumed that heavy vehicle movements at residential driveways are so rare that they are insignificant and therefore not accounted for.

4.1.2 Non-residential driveways

The unfamiliarity of users at non-residential driveways is expected to increase the likelihood of conflicts. Non-residential driveways are also expected to involve a non-negligible proportion of heavy vehicles which must be accounted for.

Light vehicles

To account for the lack of unfamiliarity at non-residential driveways, the risk factors for conflicts involving light vehicles have been taken as twice that of the corresponding risks at residential driveways for all four combinations involving direction of cyclist travel and parking occupancy. That is, a multiplication factor of 2 has been applied to the row in Figure 6 for the various conflict scenarios relating to residential driveways to produce the next row for conflict scenarios relating to light vehicles at non-residential driveways.

[2] Diagram created by Shane Foran of the Galway Cycling Campaign; see http://www.galwaycycling.org/ and http://www.oocities.org/galwaycyclist/cycletrack.html

Heavy vehicles

In assessing the risk of conflicts involving heavy vehicles at non-residential driveways, two principles are noted:

1. The consequences of crashes involving heavy vehicles and cyclists are much more severe, therefore the risk factors will be higher than for light vehicles.
2. The geometry of heavy vehicles restricts drivers turning left into a driveway from seeing adjacent cyclists travelling in the same (i.e. "with-flow") direction. This means that the proportion of risk between crashes involving with-flow cycling and those involving contraflow cycling is reduced for heavy vehicles compared with light vehicles. Therefore, it is not possible to simply apply a multiplication factor to the conflict scenarios involving residential driveways to derive the risks associated with heavy vehicles at non-residential driveways, as was possible for light vehicles at non-residential driveways.

Combining these two principles, the tool uses a factor of 10 for with-flow heavy vehicle crashes and 15 for heavy vehicle contraflow crashes. Another way of looking at this is that a heavy vehicle crash with cyclists in the with-flow direction at a non-residential driveway is 5 times more risky than a light vehicle crash at the same location and a heavy vehicle crash involving contraflow cycling is 1.5 times more risky than one involving with-flow cycling.

It has been assumed that these risk factors are not augmented by the presence of parking as heavy vehicle drivers are positioned to be able to see over parked vehicles.

4.1.3 Priority-controlled side streets / intersections

For the initial tool development, it has been assumed the risk factors applied at non-residential driveways are also suitable for priority-controlled side streets, for both light and heavy vehicles. The two conflict location types both involve a higher proportion of unfamiliar motorists than residential driveways. Side streets are generally wider (and therefore involve a larger zone of potential conflict) than non-residential driveways, but side streets are also more prominent to users; cyclists in particular are likely to be more cautious at side streets than at driveways as they enter the roadway at side streets.

The tool does not make any distinction between priority-controlled intersections where turning drivers are required to give way to cycleway users and those where cycleway users are required to give way. Here it was identified that too little information and professional understanding is available to determine which operation would be safer, and furthermore that the most important factor is achieving a suitable design that communicates the intended function to users. Therefore, these two methods of assigning priority have been assumed to be equal.

As the risk is calculated as a function of the volume of vehicles that cross the cycle route, no distinction is made between T intersections (i.e. side streets) and X intersections, although it may be investigated whether the latter group has a slightly higher risk due to increased complexity.

4.1.4 Signalised intersections

It has been assumed that signalised intersections are safer for all users than non-signalised intersections as they involve a higher degree of control and less room for user-error, however non-compliance may be an issue at signalised intersections. The tool assumes that the risk at signalised intersections will be **half of that at priority-controlled intersections**, for both light and heavy vehicles.

There are few models available that can be used to compare signalised intersections with priority intersections, especially with respect to cycling. The most useful comparison comes from the "bicyclist likelihood risk factors" developed by the International Road Assessment Programme as shown in

Table 4-1. The iRAP ratios for signalised / un-signalised taken from these factors are all higher than 0.5, which suggests that the risk of a signalised intersection is more than half of that of an un-signalised intersection for cyclists, however there is not enough background information provided with the iRAP factors to confirm whether these should be adopted in the SCOT risks.

Table 4-1: iRAP bicyclist likelihood risk factors by intersection type[3]

Intersection type	Signalised	Un-signalised	Ratio
4-leg with protected turn lane	35	55	**0.64**
4-leg with no protected turn lane	50	80	**0.63**
3-leg with protected turn lane	30	45	**0.75**
3-leg with no protected turn lane	40	55	**0.73**

4.2 Safety in numbers effects

Research shows that as the volume of cyclists on a cycleway increases, the crash rate per cyclist decreases. This is because motorists are more likely to see cyclists more often and therefore will be more aware of them and more likely to expect to see them. Similarly, but to a lesser degree, the tool assumes that an increase in motor vehicle volume will also reduce the likelihood of a crash per vehicle; this is because cyclists will be more aware of the presence of motorists at locations with high vehicle volumes.

The tool applies an exponent of 0.5 (i.e. the square-root) to motor vehicle volumes, based on the exponents used in crash prediction models for on-road cycling (e.g. Research Reports 289 and 389) which were generally in the range of 0.2-0.5. As these models involve cyclists directly next to the motor vehicles (i.e. not separated by parked vehicles or physical devices) and did not include lower volume roads in the dataset (where non-linear effects are more likely to be identified) the upper end of the range, i.e. 0.5, has been adopted for the tool. It is assumed that the safety in numbers effect will be more sensitive to the cyclist volumes thus an exponent of 0.4 has been applied to the cyclist volumes.

For want of more informed data, the exponents applied to cycle and motor vehicle volumes to represent the safety in numbers effect remains the same for each of the conflict types.

Each conflict location is treated separately in terms of the safety in numbers effect. That is, the safety in numbers factors are applied to the motor vehicle and cyclist volumes at each individual driveway, accessway and intersection. Thus the tool's "safety in numbers" reduction does not account for an improvement in safety where there are numerous occurrences of a particular type of conflict location along a route. To illustrate this, while it may be reasonable to assume that a route with frequent driveways will have fewer crashes per driveway (as cyclists will be more aware of the associated dangers) than a route with very few driveways, the tool does not go to this level of detail.

Appendix A shows how the parking occupancy, heavy vehicle volumes and risk factors are incorporated into the basic safety in numbers risk equation.

4.3 Predictions of actual crash rates

The conversion factor from the tool risk to actual crash rates has been developed based on the case of with-flow cycling at a residential driveway, crash prediction models, mode share statistics and relative safety for on-road versus off-road cycling.

The derivation behind this is detailed further in the SCOT worksheet "actual crash prediction".

5. Conclusions

The separated cycleways option tool (SCOT) has been developed using professional judgement to assess the relative risks of various conflict locations. It provides the industry with a useful interim tool to be used while waiting on more informed experience and evaluation of the risks involved at separated cycleways. Users must continue to apply professional judgement to consideration of the inputs and interpretation of the outputs.

In addition to the further research required to validate the factors used in this tool, the tool could be expanded to include different facility types (e.g. shared paths, one-way cycleways with cycling in the contraflow direction, or comparison with on-road cycling provisions).

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[3] International Road Assessment Programme (iRAP) 2013. Road Attribute Risk Factors: Intersection Type. https://www.google.co.nz/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBsQFjAAahUKEwiGvM6r45XJAhWMRSYKHZBOCAo&url=http%3A%2F%2Fwww.irap.net%2Fabout-irap-3%2Fmethodology%3Fdownload%3D117%3Airap-road-attribute-risk-factors-intersection-type&usg=AFQjCNEHnvqrHU1dd3pEVcVrJN0f8fWynA&sig2=k5QITcxPPQDICFKdMgeY5A&bvm=bv.107467506,d.eWE

Appendix A Formula development

$$Risk = a \times MV^{0.5} \times c^{0.4}$$

a = risk factor for scenario
MV = motor vehicle volume
c = cyclist volume.

- When including effect of heavy vehicles (HV): derive proportioned a and use actual vehicle (i.e. driver) volumes

$$a = \frac{a_{HV} \times HV + a_{LV} LV}{MV}$$

LV = light vehicle volume.

OR

$$a = a_{HV} \%HV + a_{LV} (100\% - \%HV)$$

When including effect of adjacent parking occupancy:

$$a_p = \frac{a_0 + (a_{100} - a_0)}{\%p}$$

a_p = the risk factor at parking occupancy $p\%$.

- Combining effect of HVs and parking

$$a = \frac{(a_{HV_0} + (a_{HV_{100}} - a_{HV_0}))\%HV + (a_{LV_0} + (a_{LV_{100}} - a_{LV_0}))(100\% - \%HV)}{\%p}$$