Cycling Facility Selection Decision Support Tool & User Guide

Issue 1.0

Prepared for:

A report outlining the technical foundation of, and a multi-step approach for selecting cycling facility types in the City of Ottawa.

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1 INTRODUCTION

1.1 Overview

The City of Ottawa has an extensive and well-used cycling network consisting of both on and off-road facilities. In addition, there is an active cycling community using these facilities that promotes the benefits and use of this network. As such, the City continually strives to improve both the safety of these facilities and the level of comfort experienced by its users.

Awareness of the continuing need for such efforts was highlighted by the July 2009 incident in which 5 cyclists were struck from behind by a motor vehicle while riding single file in a marked cycling lane within the traveled way of a road. This incident highlights the significant vulnerability of bicyclists in such environments, particularly when higher vehicle speeds are involved. The fact that this incident occurred in a marked cycle lane also triggered heightened interest in the potential for new, physically segregated[1] cycling facilities.

1.2 Goals and objectives

In September 2010, the City of Ottawa engaged Delphi-MRC to carry out a Cycling Safety Study. The following project tasks were carried out:

1. Cycling safety assessments at 10 existing cycling facilities (including road segments and intersections) at locations selected by City staff. This effort consisted of a review of geometric and operational data at each site, a detailed engineering study that included extensive field reviews, a diagnostic phase, and finally the development of short-term improvements and longer term solutions for each site.

2. To research the issue of relative safety performance of various types of cycling facilities and develop application criteria to identify opportunities and requirements for the use of cycle facilities that segregate cyclists from motor vehicle traffic.

The first objective has been completed and documented in a separate report entitled “Ottawa Cycling Safety Study” that has been submitted to the City.

The second objective is the focus of this report.

[1] We use the terms “segregated” and “separated” interchangeably in this report. Both indicate a facility that has some level of physical separation between cycling and motor vehicle traffic. The segregation may take a variety of forms, from a simple lane separator within the traveled way in the form of raised curbs, concrete barriers, or other means through to a facility that is outside of the traveled way such as a cycle path or multi-use path.

2 WHY SEGREGATED FACILITIES?

2.1 Overview

Research clearly shows that one of the most effective measures for improving overall cyclist safety within a road network is increasing the number of cyclists using the system. While it is necessary to ensure that existing facilities of current cyclists perform appropriately from a safety standpoint, cycling facility planners and designers also need to provide additional routes and facilities that encourage new or less experienced cyclists. This can only be accomplished if new cyclists feel comfortable using the facilities, and an emerging option that is becoming increasingly important in this respect is the appropriate deployment of segregated cycle facilities.

2.2 Segregated versus non-segregated facilities

Direct comparison of the relative safety of bicycle facilities proves to be a difficult task. Separate bicycle paths may appear to be "safer" than bicycle lanes but may result in more conflicts at intersection and driveway locations, especially if the path is physically removed from the roadway in such a way that motorists may not be expecting cyclists at the junction of the path with the driveway or intersection.

Similarly, bicycle lanes may result in more orderly and predictable behavior between motorists and cyclists along a road segment, but may lead to conflicts at intersections if cycle lane traffic must re-integrate with motorized vehicles as they jointly traverse the intersection and its influence area. Much of the safety performance seems to depend on the design of bicycle facilities and the context of the road environment on which they are applied. The New Zealand Land Transport Safety Authority makes note of this in their Cycle Network and Route Planning Guide as a general consideration for providing either roads or paths:

> One choice is not inherently safer than another; both can be hazardous and both require high-quality design to achieve safety.[2]

Research on this issue is far from conclusive. Findings can be contradictory and many studies seem to exhibit shortcomings in data analysis, basic definitions, (i.e. what are considered on-road and off-road facilities) statistical robustness, and often - a preconceived bias that seemingly favors one type of facility over another. Further, much of the research has been conducted outside of North America where the rules of the road and the nature of transportation systems and policies are substantially different than those experienced on this continent.

2.3 Difficulties in quantifying bicycle safety

The National Cooperative Highway Research Program (NCHRP) Report 552: Guidelines for Analysis of Investments in Bicycle Facilities[3] provides an excellent discussion regarding the challenges associated with evaluating and comparing studies that attempt to determine relative safety levels of various bicycle facilities:

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[2] Land Transport Safety Authority, New Zealand. "Cycle Network and Route Planning Guide." Wellington, New Zealand, 2004.

[3] Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP). *Guidelines for Analysis of Investments in Bicycle Facilities*, Report 552. Washington. 2006.

> The prevailing argument is that enhanced facilities – bike lanes, bikeways and special intersection modifications – improve cyclist safety. This claim, however, is the source of a rich controversy within the literature as evidenced by the debate between Forester[4] and Pucher[5]. Part of the controversy around this topic is fueled by differences between what cyclists state they prefer (i.e. their perception) and what studies with collision data actually reveal.
>
> It is widely acknowledged that increased perception of safety is important to encourage cycling as a means of transportation and recreation. Subsequently, providing separated bicycle facilities along roadways is mentioned as a key ingredient to increased perception of safety…
>
> Existing literature on the safety of bicycle facilities usually considers one of three outcome measures: the number of fatalities, the number of crashes, and perceived levels of comfort for the cyclists. Key explanatory variables behind these measures are myriad and complex to identify. For example, the overwhelming majority of bicycle crashes resulting in fatalities are caused by collisions with motor vehicles. Less severe crashes tend to occur at intersections or at locations where motor vehicles and bicycles come in contact with each other; it is further suggested that crashes are caused by differing expectations between auto drivers and bicyclists. However, there is increasing evidence to suggest that some bicycle crashes do not involve any other party; this is especially true for children.
>
> The degree to which perception of safety translates into actual increased safety however is still debated. It proves difficult to translate perceived measures of safety into quantifiable or economic estimates. Additional confounding factors are that prevailing guidelines recommend a variety of solutions.
>
> In the end, bicycle safety data are difficult to analyze, mostly because bicycle trip data (and thus accident probability per trip) are hard to uncover. As more research and conclusive findings become available, it will likely be possible to understand the safety benefits of bicycle facilities in more detail – at such time, a model could then be developed and incorporated into the guidelines[6].

The NCHRP report touches on the fact that comprehensive bicycle trip data is very difficult to determine; one must have an accurate estimate of the volume of cyclists on each route/facility in order to determine exposure (cyclist kilometers travelled) and subsequently cyclist collision rates. Furthermore, many cyclist collisions go unreported. This is particularly true for “single bicycle” collisions and those that do not result in significant injury or property damage. The rate of unreported bicycle collisions may vary significantly between different types of bicycle facilities, again making it difficult to compare “safety” directly.

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[4] Forester, John. “The Bicycle Transportation Controversy.” Transportation Quarterly, Vol. 55, No. 2, Spring 2001. Eno Transportation Foundation Inc., Washington, DC, 2001.

[5] Pucher, John. “Cycling Safety on Bikeways vs. Roads.” Transportation Quarterly, Vol. 55, No. 4, Fall 2001 (pp 9-22). Eno Transportation Foundation Inc., Washington, DC, 2001.

[6] Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP). *Guidelines for Analysis of Investments in Bicycle Facilities*, Report 552. Washington. 2006.

2.4 Accommodating different types of cyclists

In addition to safety considerations, the level of comfort is an important component to the success of a cycling network[7]. Every cyclist possesses a different level of skill, confidence, and experience. As a result, many cyclists have different needs and often prefer different types of facilities.

This need to provide a variety of bicycle facilities on a variety of types of roads in order to provide an effective cycling network appealing to all users is reflected in the AASHTO Guide for the Development of Bicycle Facilities:

> No one type of bicycle facility or highway design suits every bicyclist and no designated bicycle facility can overcome a lack of bicycle operator skill. Within any given transportation corridor, bicyclists may be provided with more than one option to meet the travel and access needs of all potential users.[8]

Below, we discuss typical breakdowns of skill level and trip purpose used to help designers address the distinct needs of cyclists within their network environment.

2.4.1 Cycling skill levels

Most literature classifies cyclists into one of three distinct skill categories. The following definitions are presented in the AASHTO Guide for the Development of Bicycle Facilities[9] and is generally representative of the types of skill stratification considered in the design of such facilities:

1. Child cyclists – they do not travel as fast as adult cyclists but still require access to key destinations within their community such as schools and recreational facilities. Residential streets with low motor vehicle speeds and separate paths are preferred as children tend not to recognize risk in the same way most adults do. In addition, children have a limited understanding of the rules of the road and how best to interact safely with motor vehicle traffic.

2. Basic/novice cyclists – less confident adult riders using their bicycles for transportation purposes but prefer to avoid roads with fast and busy motor vehicle traffic unless there is ample roadway width to allow easy passing. They consider riding on neighborhood streets and separate paths to be more comfortable and prefer designated facilities such as bike lanes or wide shoulder lanes when riding on busier streets.

3. Advanced/experienced cyclists – generally use their bicycles as they would a motor vehicle. They are riding for convenience and speed and want direct access to destinations with a minimal detour and delay.

[7] Information Technology Centre for Transport and Infrastructure (CROW). *Traffic Engineering Design Manual for Bicycle Traffic*. The Netherlands. June 2007 (English version).
[8] American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Development of Bicycle Facilities*. Washington. 1999.
[9] Ibid.

2.4.2 Cycling trip purpose

Although less of a factor in the decision process to determine if a facility should be segregated or not, some level of consideration should still be given to the reason for the cycling trip. Typically, the trip purpose is related to the characteristics of the route (i.e. is it close by, comfortable to use, direct/indirect), and is a function of how well the route links land uses or trip generators / attractors (i.e. a residential area and an employment area).

The literature stratifies cycling trip purpose in several ways. The City of Ottawa[10] uses two categories: utilitarian (i.e. commuting or school trips) and recreational. Other agencies typically have more categories and an example is provided in the following:

1. Commuting/utilitarian – getting to a destination efficiently
2. Neighborhood – leisurely riding to shops, school, or near home
3. Recreation/touring – for enjoyment, sightseeing, and exercise
4. Sport – for competition and training

Generally speaking, we would expect that a cyclist making a trip to work (utilitarian) and having more advanced skill, will be more likely to use a more direct on-road facility. Conversely, we would expect a recreational or neighbourhood trip made by a less experienced cyclist to feel more comfortable on a segregated facility or on a low volume, low speed roadway.

2.5 Facility segregation: a key factor

Although safety is an important component to measuring the performance of a cycling facility system the level of comfort of a range of users is also important. Creating cycling facility designs that balance the competing needs of these two components is further complicated by the requirement to accommodate both differing user skill levels and trip purposes.

One important design option that can help achieve the necessary balance is the separation of cycle facilities from those of motorized traffic – a technique referred to in this report as segregation. A variety of segregation alternatives exist, ranging from separate cycle lanes delineated by typical lane separator pavement markings, to similar facilities with varying widths of painted buffer, through to cycle lanes that are separated from the motor vehicle lanes with a physical, non-mountable structure of some kind (i.e. raised curb, concrete barrier, etc.).

We begin our exploration of the segregation of cycle facilities from motor vehicle traffic with a review of what is currently being done in other jurisdictions both in North America, Europe and Australasia.

[10] City of Ottawa Cycling Plan. Bikeway Planning and Design Guidelines: Technical Appendix No. 1. Ottawa. January 2008.

3 CYCLE FACILITY SEGREGATION: STATE OF RESEARCH AND PRACTICE

3.1 Overview

A carefully focused literature and research-in-progress review was carried out to provide an examination of the current state of practice with respect to cycling facility segregation. Recent research on cycling safety and implementation guidance was reviewed from the following jurisdictions:

- Netherlands
- United States
- Australia
- New Zealand
- Denmark
- United Kingdom
- Germany

The findings flowing from our literature search for each of these jurisdictions is provided in the Sections that follow.

3.2 Netherlands

3.2.1 Background

We began our literature review with documentation from the Netherlands as they have a very successful cycling network throughout the country and appear to have the most advanced level of guidance with respect to cycling facility design. One of the key organizations behind this success is the national Information and Technology Centre for Transport and Infrastructure (CROW[11]), a non-profit organization disseminating knowledge. They work with all levels of government, civil engineers, and transport agencies to transfer knowledge in the form of guidelines, recommendations, training courses and conferences. Their first design manual associated with cycling infrastructure was published thirteen years ago in 1994 – titled Sign Up For The Bike: Design Manual for a Cycle-Friendly Infrastructure[12]. The most recent update to this document is the Traffic Engineering Design Manual for Bicycle Traffic[13] and is the focus of our discussion below.

3.2.2 Cycling network success

The success of the Dutch cycling system is well known around the world and represents a model to follow for any agency. Their success is due in part to how they overcame the convenience of the automobile as a travel mode and developed their cycling infrastructure to be safe, convenient and direct. The CROW document touches on this issue:

[11] The organization's original name was Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek (CROW), or in English, Dutch Centre for Research and Contract Standardization in Civil and Traffic Engineering. The name was changed in 2004.

[12] Dutch Centre for Research and Contract Standardization in Civil and Traffic Engineering. *Sign Up For The Bike: Design Manual for a Cycle-Friendly Infrastructure*. The Netherlands. 1994.

[13] Information Technology Centre for Transport and Infrastructure (CROW). *Traffic Engineering Design Manual for Bicycle Traffic*. The Netherlands. June 2007 (English version).

> "…various studies have shown that good quality cycling infrastructure actually leads to a higher proportion of bicycles in the modal split.[14]"

and that:

> "…generating large scale bicycle use by means of a high quality network requires patience and continuous attention in policy[15]."

It goes on to explain that bicycle trips are most effective for short journeys (under 5 km). Therefore generating significant cycling demand depends largely on effective land use and transport planning policies. Cyclists often opt for a different means of travel when directness, safety, and comfort are not ideal.

In the Netherlands, the basic principle behind their successful cycling network is an appropriate balance between *function* (goals and expected use), *form* (type of facility provided) and *use* (interaction with other modes, speed and volumes). The five main requirements for bicycle-friendly infrastructure are defined as:

1. *Cohesion*; connection of origins/destinations and other modes of transport, completeness of routes and networks

2. *Directness*; provision of the shortest, quickest, and most convenient routes

3. *Attractiveness*; perception and "social safety"

4. *Safety*; speed and volume of vehicles and the risk and severity of collisions, appropriate separation of vehicle types, minimizing conflicts with other vehicles, obstacles

5. *Comfort*; mental and physical exertion, ease of wayfinding, nuisance, and minimizing shortcomings in the cycling network

3.2.3 Facility types

The use of segregated facilities is first mentioned in Chapter 5 of this document where seven of the most typical cycling facility types are discussed. Each facility type deployed in the Netherlands is defined below. It should be noted that this discussion focuses on roadway sections and a separate discussion is provided on intersections later in the document.

1. *Solitary/isolated cycle tracks* – two-way facilities solely intended for cyclists with alignments independent of any roads (typically termed "bikeways" in Canada). These may be shared with pedestrians (also known as "multi-use trails" in Canada)

2. *Separate cycle tracks* – a cycle path parallel to but physically separated from an adjacent roadway minimizing passing conflicts between motorists and cyclists. Conflicts at intersections of roadways and cycle tracks can be problematic and adequate sightlines must be provided.

[14] Ibid.
[15] Ibid.

3. *Cycle street* – major cycle routes that are deliberately removed from busy mobility-oriented roads because they are neither safe nor attractive for cyclists. They are generally provided on parallel routes through residential communities.

4. *Cycle lane* - a delineated space for cyclists on the roadway characterized by sufficient width, a red color, and the bicycle symbol. "Critical reaction strips" (buffers ≥ 0.5 m) are recommended between cycle lanes and parking lanes if there is a requirement to maintain parking, however designers should ensure a cycle track would not be a better solution.

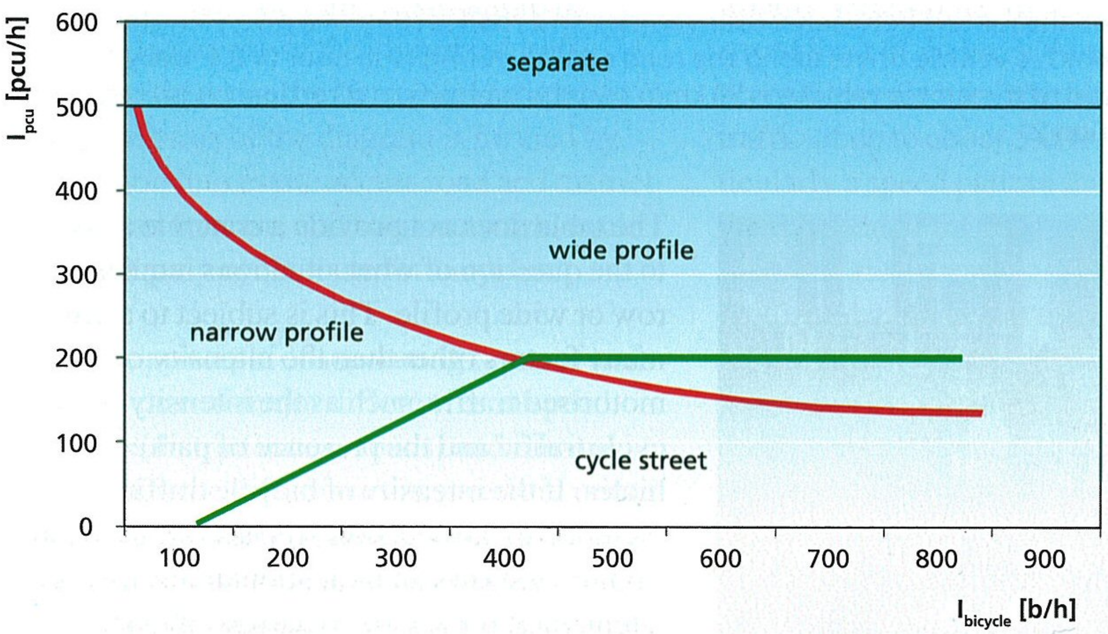
5. *Suggestion lane* – similar to a cycle lane, except not painted red in colour. They are preferably accompanied by parking bans but allow periodic loading and unloading.

6. *Parallel road* – parallel roads next to arterial roads and freeways are often residential local roads appropriate for cycle lanes or suggestion lanes. While they are often one-way streets, cyclist movements in both directions should be accommodated and conflicts with parked vehicles should be accounted for.

7. *Combined traffic* – roads which carry both motorists and cyclists with no separation or delineation between modes. Generally these are found on low-speed residential streets. They may be "narrow profile" whereby motorists must follow cyclists if there is oncoming traffic, or "wide profile" whereby motorists can overtake cyclists without encroaching upon the path of oncoming traffic.

Research has been carried out by CROW with respect to the most appropriate facility type, given site conditions. The science behind the Netherland's facility selection guidance is technically based and practical. It is based on the premise of cycle-vehicle "encounters" or conflicts, and therefore metrics such as cycle volume, vehicle volume and operating speeds are necessary inputs to the decision process. This research has resulted in a set of guidelines to aid practitioners and is illustrated in Figure 1.

Figure 1: Netherlands – facility selection nomograph[16]



The CROW document cautions the reader that the boundaries between the facility types in this diagram are not well defined. This is based on the fact that there may be more than one appropriate solution on a section of road. Again, there is a need for flexibility as the decision-maker needs to balance the function and form of the roadway, and meeting the safety and comfort needs of the cyclist.

3.2.4 Facilities on road segments in urban areas

Generally, in urban road segments fulfilling mobility functions (i.e. arterials) are compatible with specific bicycle facilities. Conversely, road segments fulfilling access functions (i.e. local roads) are more appropriate for combined motorized traffic and cyclists due to the lower operating speeds. However, some flexibility does exist in this general principle. Also, while it may be possible to safely mix cyclists with motorists due to lower speeds, more provisions may be required from the viewpoint of comfort so as to encourage more riders. Another facility selection guideline developed by CROW that is specific to urban roadways is provided in Figure 2.

[16] Ibid.

Figure 2: Netherlands – Urban facility options[17]

Road category	Max. speed of motorised traffic (km/h)		Motorised traffic intensity (pcu/day)	Cycle network category: basic network ($I_{bicycle}$ > work 750/day)	Cycle network category: cycle route ($I_{bicycle}$ 500-2500/day)	Cycle network category: main cycle route ($I_{bicycle}$ > 2000/day)
	n/a		0	solitary track	solitary track	solitary track
Estate acces roead	walking pace or 30 km/h		1 - 2.500	combined traffic	combined traffic	cycle street or cycle lane (with right of way)
			2.000 - 5.000	combined traffic	combined traffic	cycle street or cycle lane (with right of way)
			> 4.000	cycle lane or cycle track	cycle lane or cycle track	cycle street or cycle lane (with right of way)
District acces road	50 km/h	2x1 lanes	irrelevant	cycle lane or cycle track	cycle track or parallel road	cycle track or parallel road
		2x2 lanes		cycle track or parallel road	cycle track or parallel road	cycle track or parallel road
	70 km/h			cycle track,moped/cycle track or parallel road	cycle track,moped/cycle track or parallel road	cycle track,moped/cycle track or parallel road

Based on the guidance illustrated above, there is often more than one appropriate solution for implementing a cycle facility on an urban road. This is reflected by the overlap in vehicle and cyclist intensities.

Other, more specific guidance includes the following:

- For urban roadways that serve both a mobility role (in terms of network function and traffic volumes) and an access role (in terms of adjacent buildings and amenities) are also discussed. In these cases, some form of cycle facility separation is advisable.

- On roadways where on-street parking is provided, guidance suggests that locations with more than 20% of a road's length is used for parking, it is advisable to provide a marked parking lane or parking bays to maintain a straight-riding path for cyclists. Under these conditions, the travel width available for motorized traffic should be limited.

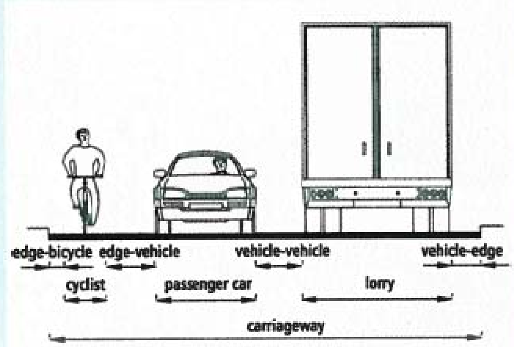
Figure 3 provides an interesting recommendation for width requirements between various combinations of cyclists, curbs, parked and moving vehicles. It is noted that these vehicle dimensions, and the resulting required space between cyclists and parked vehicles, may be significantly different in Canada.

[17] Ibid.

Figure 3: Netherlands – Facility width guidelines[18]

Dimensional segments and indicative use

In order to compile a profile, designers can use dimensional segments and indicative use. Indicative use means the indicative combination on a road section, a combination of a car and two cyclists, for example. Dimensional segments are the dimensions required for a specific user in the cross section profile. The dimensional segments that apply to an estate access road are shown below.



The value of the cyclist/edge dimensional segment refers to the minimum distance a cyclist wants to keep from the kerb. If the cyclist passes cars parked on the right, the value of this dimensional segment is about twice as high. Almost all motorised traffic will overtake bicycle traffic when the value of the cyclist/vehicle dimensional segment is 0.85 m or more and, in addition, the width of the vehicle is left. If the cyclist/vehicle distance is smaller, motorists will hesitate: some overtake, others stay behind the cyclist. This is then a critical profile, which leads to a dangerous, unwanted situation. The remaining width next to the cyclist should, therefore, be restricted in such a way as to make it clear that every motorist has to remain behind the cyclist. The cyclist/moving vehicle dimensional segment is larger than the vehicle/vehicle dimensional segment, because the behaviour of bicycle traffic is harder to predict than that of motorised traffic. When motorists overtake, they take a cyclist's zigzagging into account. Bicycle traffic is also more vulnerable.

Dimensional segment	Required width profile (m)
cyclist[2)]	0.75
car[2)]	1.75
lorry[2+3)]	2.60
cyclist/edge (kerb)[1)]	0.25
cyclist/parked vehicle[1+4)]	0.50
cyclist/cyclist (both riding)	0.50
cyclist/driving vehicle[1+4)]	0.85
vehicle/vehicle (both driving)[2+4)]	0.30
driving vehicle/kerb[2+4)]	0.25

1) value determined on the basis of research
2) source: Recommendations for Traffic Provisions in Built-up Areas (ASVV)
3) in this context, buses are counted as lorries
4) a vehicle refers to: all motor vehicles with at least three wheels

3.2.5 Road segments in rural areas

Outside of built-up areas where speed limits are typically 80 km/h or greater, the guidance in the Netherlands suggests that bicycle traffic should travel off the roadway on a separate cycle track or parallel road. On collector or local roads with speeds 60 km/h or less, it may be appropriate to provide on-road cycle lanes or allow combined traffic. Figure 4 provides a reasonable facility selection guideline for rural areas:

[18] Ibid.

Figure 4: Netherlands – Rural facility options[19]

Function		Speed (km/h)	Intensity (pcu/day)	Bicycle traffic road section function: basis network	Bicycle traffic road section function: (main)cycle route (I_{cycle}> 2,000/day)
Motorised traffic road section function	Estate access road	60	1 - 2.500	combined traffic	cycle street, if I_{pcu} < 500 pcu/day[1)]
			2.000 - 3000	cycle lane or cycle track	cycle track, or perhaps lanes
			> 3000	cycle track	
	District access road	80	irrelevant	cycle/moped track parallel road	

1 Plus any additional requirements in the area of safety

In cases where a cycle track is provided adjacent to a rural road, the space between the cycle track and the roadway is called the *partition verge* and acts as a buffer between cyclists and motorists. It is preferable to have a wide partition verge. Figure 5 provides guidance with respect to minimum and recommended partition verge widths:

Figure 5: Netherlands – Rural facility and verge width guidelines[20]

Road category	Width of partition verg (m): recommended distance	Width of partition verg (m): minimum distance
District acces road	6.00	4.50
Estate acces-road	>1.50	1.50

3.2.6 Summary

The Netherlands have an advanced cycling system and sophisticated policies and guidelines – particularly with respect to the issue of segregation. However, the cycling culture and environment are significantly different than in North America, so a direct adaptation of their facility implementation guidance may not be possible. Nonetheless, some elements may be almost directly useable, while others may require some

[19] Ibid.
[20] Ibid.

modifications. In either case, the basic underlying principles are applicable and appropriate for the Ottawa context.

3.3 United States

3.3.1 Overview

Unlike the Netherlands, in the United States there does not appear to be an extensive history of research, development, and deployment of cycle facilities based on a unified and defensible set of technical principles geared specifically to cyclist needs. Rather, much of the literature and guidance that exists is based on conventional road design principles or practices, but never evaluated comprehensively from the technical standpoint of safety, comfort, and operational criteria.

In the US, there appear to be many implementation opinions but little factual guidance for the purposes of applying segregation principles to cycle facilities. Nonetheless, there is some useful information with respect to current practices, cycling facility safety evaluation and analysis principles and other relevant matters that could be useful in any technical analysis environment related to cycling, and we discuss these beginning below.

3.3.2 AASHTO

The American Association of State Highway Transportation Officials' (AASHTO) Guide for the Development of Bicycle Facilities[21] begins by highlighting the challenges associated with the planning and design of bicycle facilities due to dramatic differences in skill, confidence, and preferences of various types of cyclists. No single type of bicycle facility (or associated highway design) will suit every cyclist and no facility design can overcome a lack of operator skill. It may be appropriate to provide bicycle facility alternatives within the same transportation corridor to meet the needs of all cyclists, and the type of facility provided will influence the level of use and types of users. The Guide notes that:

- Some riders are confident riding anywhere and can negotiate busy and high speed roads that have few, if any, accommodations for cyclists (Type A: advanced or experienced riders).
- Most adult riders are less confident and prefer to use roadways with less traffic and a more comfortable amount of operating space – perhaps with designated space for cyclists – or shared use paths that are away from motor traffic (Type B: basic or less confident adult riders).
- Children may be confident riders and have excellent bicycle handling skills, but lack knowledge and experience in terms of the rules of the road and potential risks (Type C: children).

AASHTO then goes on to classify bicycle facilities in the following manner, including both non-segregated and segregated elements.

[21] American Association of State Highway Transportation Officials (AASHTO). *Guide for the Development of Bicycle Facilities*. Washington. 1999.

- Shared roadway (unsigned) – a roadway shared between motorists and cyclists, with no designated markings or signage. In some cases, a community's existing street system may be adequate and appropriate for bicycle travel and signing/striping may not be necessary. In other cases, streets and highways may be inappropriate for bicycle travel, or it may not be a high bicycle demand corridor, and it would be inappropriate to encourage bicycle travel.

- Shared roadway (signed) – a roadway shared between motorists and cyclists, with no designated markings but with signage (along the route, on a map, etc.) used to either provide continuity to other bicycle facilities or to designate preferred routes through high bicycle demand corridors.

- Bicycle lanes – a designated space for cyclists along a road reinforced with pavement markings and signage. They are intended to delineate right-of-way assignments and to provide more predictable movements by both cyclists and motorists. They are generally placed along streets in corridors with significant cyclist demand and where district needs can be served by them.

- Shared-use path – an exclusive pathway designated for use by cyclists, which may be shared by pedestrians, joggers, inline skaters, etc. Generally these paths should serve corridors not served by streets or highways and be constructed away from the influence of parallel streets. Crossing conflicts should be minimized and the facility must be designed to be consistent with the rules of the road.

The guide emphasizes the need to observe and gather information on existing conditions for bicycle travel when planning facilities in order to identify needs, deficiencies, and safety concerns. AASHTO points out that the use of both new bicycle facilities and alternate routes should be considered. Traffic volumes, speeds, vehicle mix (i.e. presence of trucks and buses), and impediments to cycling (e.g. parking, narrow lanes, driveways, obstacles, poor surfaces, sight distance limitations, etc.) should also be noted. While cyclist volumes are noted as one possible indicator of level of use, the guide points out that this often underestimates demand and the presence of major trip attractors such as residential neighbourhoods, employment centres, schools, parks, shopping centres, recreational facilities, and colleges. Public participation from both bicycle users and non-bicycle users is also noted as an essential component of any cycle facility planning effort.

In selecting an appropriate bicycle facility type for a given location, AASHTO notes that many factors need to be considered, including:

- Skill level of anticipated users
- Turnover, density, and configuration of on-street parking (and loading zones)
- Physical barriers such as waterways, freeways, railroads, gradients, etc.
- Known and potential safety issues
- Directness and convenience
- Connectivity of major trip generators
- Accessibility for maintenance and service vehicles
- Aesthetics
- Personal safety and security

- Frequency of stops and length of expected delays
- Conflicts with other modes
- Pavement surface quality and drainage
- Truck and bus traffic
- Traffic volumes and speeds
- Bridges (width, grades, surface, railings, expansion joints)
- Intersections
- Costs and funding levels
- Applicable laws and regulations

3.3.3 FHWA BIKESAFE Safety Countermeasure Selection System

Development of the BIKESAFE Bicycle Countermeasure Selection System (2006) was sponsored by the Federal Highway Administration (FHWA)[22]. Although this tool is not specifically designed to aid in a facility selection process, it does provide practitioners with the latest information available for improving the safety and mobility of those who bicycle.

The "crash analysis" component of this system provides the most relevant information in terms of identifying risks and safety concerns and helping to address cyclist needs at these locations. Once a high-risk location has been identified, this expert system uses one of two distinct entities – performance objectives and crash types – to help planners select appropriate safety countermeasures.

Performance objectives represent the underlying goal of cycle facility improvements. As outlined in the matrix below in Figure 6, objectives are related to groups of countermeasures, each of which contains more specific countermeasures and application guidelines for designers to explore.

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[22] Federal Highway Administration (FHWA). *BIKESAFE: Bicycle Countermeasure Selection System.* Report No. FHWA-SA-05-006. Washington. 2006.

Figure 6: US – FHWA's BIKESAFE safety objectives and countermeasures [23]

Objective	Shared Roadway	On-Road Bike Facilities	Intersection Treatments	Maintenance	Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement	Support Facilities and Programs
1. Provide safe on-street facilities/space for bicyclists.	•	•		•	•		•	•	•
2. Provide off-road paths or trails for bicyclists.				•		•	•	•	•
3. Provide and maintain quality surfaces for bicyclists.	•			•			•	•	
4. Provide safe intersections for bicyclists.	•		•		•	•	•	•	
5. Improve motorist behavior/ compliance with traffic laws.	•		•	•	•		•	•	•
6. Improve bicyclist behavior/ compliance with traffic laws.	•	•	•	•	•	•	•	•	•
7. Encourage and promote bicycling.	•	•		•		•	•	•	•

In lieu of performance objectives, prevalent crash types can be used and the matrix illustrated in Figure 7 relates each crash type to groups of countermeasures and ultimately application guidelines for a number of specific countermeasures that the designer may explore.

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[23] Ibid.

Figure 7: US – FHWA's BIKESAFE crash group and countermeasures[24]

Crash Group	Shared Roadway	On-Road Bike Facilities	Intersection Treatments	Maintenance	Traffic Calming	Trails/Shared-Use Paths	Markings, Signs, Signals	Education and Enforcement
1. Motorist failed to yield – signalized intersection	•		•		•	•	•	•
2. Motorist failed to yield – non-signalized intersection	•		•		•	•	•	•
3. Bicyclist failed to yield – signalized intersection	•		•		•	•	•	•
4. Bicyclist failed to yield – non-signalized intersection	•		•		•	•	•	•
5. Motorist drove out – midblock	•					•	•	•
6. Bicyclist rode out – midblock	•				•	•	•	•
7. Motorist turned or merged left into path of bicyclist	•	•	•		•	•	•	•
8. Motorist turned or merged right into path of bicyclist	•	•	•		•	•	•	•
9. Bicyclist turned or merged left into path of motorist	•		•	•	•	•	•	•
10. Bicyclist turned or merged right into path of motorist	•	•	•	•	•	•	•	•
11. Motorist overtaking bicyclist	•	•		•	•	•	•	•
12. Bicyclist overtaking motorist	•	•		•		•	•	•
13. Non-motor vehicle crashes	•			•		•	•	•

BIKESAFE also outlines a fairly comprehensive program of bicyclist safety improvements, which recognizes that while some bicycle collisions are associated with deficient roadway designs, bicyclists and motorists often contribute through a disregard or lack of understanding of laws and safe driving/riding behaviour. The consequences of these crashes are often exacerbated by speeding, failing to yield, etc. and the following education, enforcement, and engineering measures are recommended to help reduce both the frequency and severity of collisions:

- Shared roadway accommodations, such as provision of roadway surface improvements or lighting where needed.

[24] Ibid.

- Provision of bicyclist facilities, such as bike lanes, wide curb lanes and separate trails.
- Provision of intersection treatments, such as curb radii revisions and sight distance improvements.
- Maintenance of roadways and trails.
- Use of traffic calming treatments, such as mini circles and speed control measures.
- Adequate signs, signals, and markings, particularly as they pertain to intersections and share-the-road philosophies.
- Programs to enforce existing traffic laws and ordinances for motorists (e.g., obeying speed limits, yielding to approaching bicyclists when turning, traffic signal compliance, obeying drunk-driving laws) and bicyclists (e.g., riding in the same direction with traffic, obeying traffic signals and signs).
- Encouraging bicyclists to use reflective clothing and appropriate lighting when riding at night.
- Encouraging and educating bicyclists in proper helmet use.
- Education programs provided to motorists and bicyclists.
- Providing support facilities, such as bicycle parking and events, such as ride-to-work days or fundraisers to support bicycling.

3.3.4 NCHRP Report 552: Guidelines for Analysis of Investments in Bicycle Facilities

The National Cooperative Research Program (NCHRP) Report 552[25] provides a discussion on the North American experience with respect to safety consequences of various types of bicycle facilities. Studies carried out in the United States suggest that there is as much research demonstrating a safety benefit of implementing a particular facility (whether it be segregated or not) as there are findings that no safety relationship actually exists. This synopsis is captured in Report 552 by the following:

> While there is considerable literature suggesting cyclists perceive greater safety with *[cycling]* facilities, the bottom line is that there is little conclusive evidence to suggest this.[26]

The report describes the widely supported research that indicates the number of cyclists in an area has a non-linear (exponential) effect on injury crash rates and that a safety benefit can be realized by encouraging more cyclists to use facilities, a phenomenon which often subsequently reduces the volume of motor vehicle traffic using the roadway. The following excerpts are taken from Appendix F - User Safety Benefits[27]:

[25] Transportation Research Board (TRB), National Cooperative Research Program (NCHRP). *Guidelines for Analysis of Investments in Bicycle Facilities,* Report 552. Washington. 2006.
[26] Ibid.
[27] Ibid.

- There are generally two prevailing opinions among cyclists: that enhanced facilities such as cycle lanes or special intersection provisions improve cyclist safety; the other claims that segregated facilities are the only way to truly improve safety. The literature suggests that this controversy here in North America is due in part to the differences between what cyclists state they prefer (i.e. their perception) and studies of the limited amount of collision data actually reveal.

- Providing separated bicycle facilities along roadways is identified as a key component to the increased perception of safety according to the literature related to quantifying bicycle-related risk.

- Existing literature on the safety of bicycle facilities usually considers one of three outcome measures: the number of fatalities, the number of crashes, and perceived levels of comfort for the cyclist.

- There is still much debate surrounding the perceived safety of a cycling facility and whether that can translate into measurable safety improvements.

In the end, bicycle safety data are difficult to analyze, mostly due to the fact that bicycle trip data (and thus accident probability per trip) are hard to uncover. As more research and conclusive findings become available, a better understanding of cycle facility safety benefits will likely emerge.

3.4 Australia

3.4.1 AUSTROADS

AUSTROADS is the association of Australian and New Zealand road transport and traffic authorities. Their goal is to promote national uniformity and harmony in the implementation of transportation systems and through their work have developed the Guide to Traffic Engineering Practice Part 14 – Bicycles[28]. This document is similar to the CROW document from the Netherlands in that a policy-level emphasis is required between coordinating bicycle planning with transit and land use planning. This guide categorizes cyclists into seven broad groups that must be considered by planners and engineers. The groups include those who are not licensed to drive a motor vehicle and hence have not received formal education regarding the rules of the road:

- Primary school children
- Secondary school children
- Recreational cyclists
- Commuter cyclists
- Utility cyclists
- Touring cyclists
- Sports cyclists

The varying needs and desires of these cyclists suggests that a combination of facility types (on and off-road) in various environments (direct routing on major streets and less direct routing on quieter streets) are appropriate and necessary within a given area or

[28] AUSTROADS. *Guide to Traffic Engineering Practice Part 14 – Bicycles, Second Edition*. Sydney, Australia. 1999.

corridor. In addition, and similar to other guidelines elsewhere, sufficient space and appropriate surfaces should be provided.

The AUSTROADS document departs from other guidelines that use a nomograph, by providing practitioners with a well defined decision tree to identify the appropriateness of a segregated or non-segregated facility. The criteria used in the decicision process is based on technical data including vehicle volumes, operating speed, and the type/skill of cyclists. This particular decision tree is provided in Figure 8, below.

Figure 8: Australia – facility selection decision tree[29]

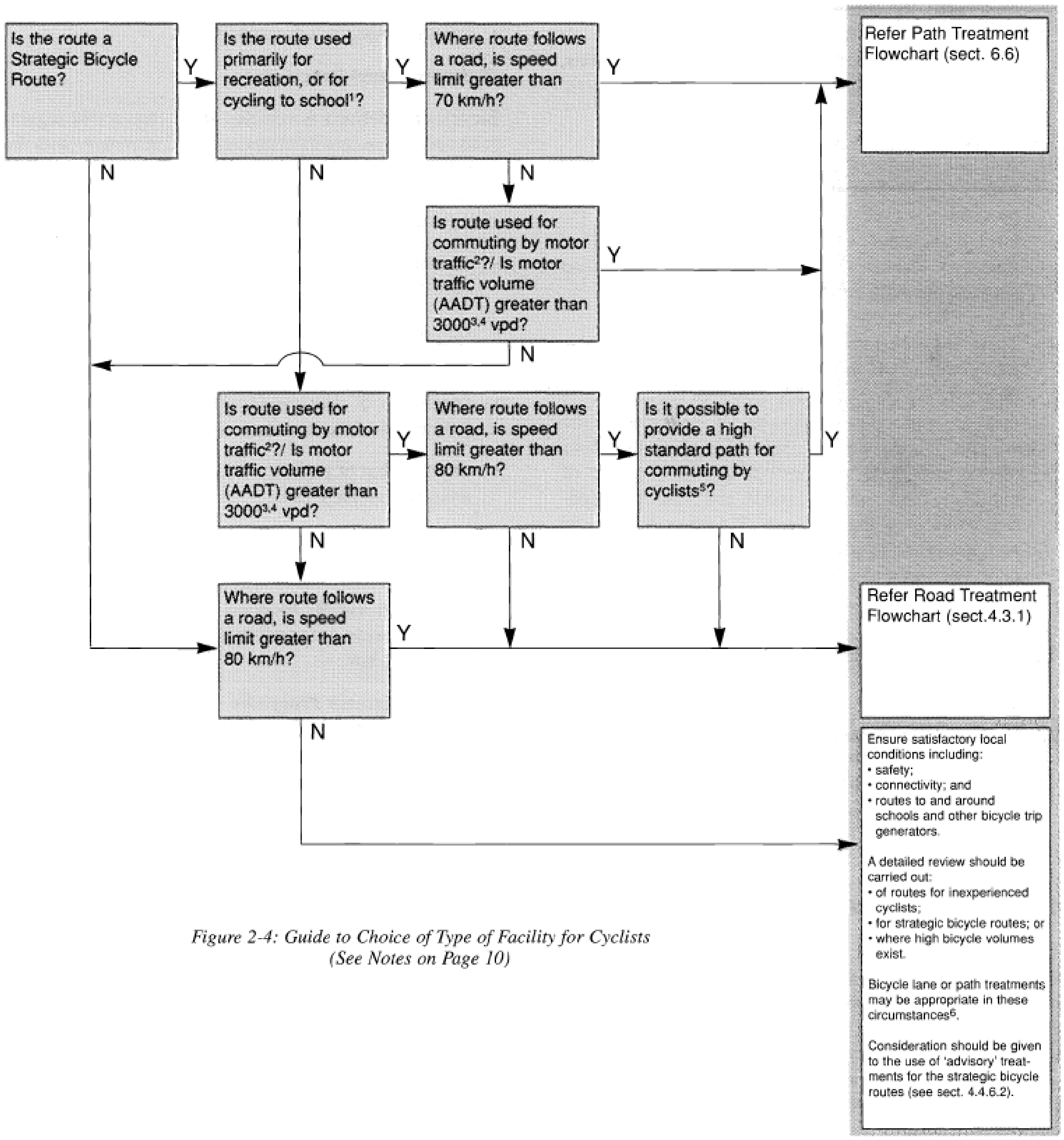


Figure 2-4: Guide to Choice of Type of Facility for Cyclists (See Notes on Page 10)

The above flow chart is based on the following principles:

[29] Ibid.

- A higher level of protection is appropriate if the route is commonly used by inexperienced cyclists.

- Routes commonly used by commuting motor vehicle traffic are commonly associated with aggressive driving conditions which poses significant risk to cyclists.

- A traffic volume of 3,000 vehicles per day is widely regarded as the threshold beyond which provision for cyclists should be made, in terms of road safety concerns and cyclist stress levels. Alternatively, it may be appropriate in the case of multi-lane roads, one-way roads, and roads that experience unusually high or low traffic peaks to consider 200-250 vph in the curb lane as the threshold for making provisions for cyclists.

- The flow chart is not intended to discourage the provision of bicycle lanes including those in low volume, low speed local streets where they may be required as part of a strategic bicycle route or for young and inexperienced cyclists.

Further, this guide comments on various road design criteria for cyclists. Of particular interest is the recommendation to provide clearances between motor vehicle traffic and the bicycle envelope in the following range to provide a level of comfort for cyclists and to account for wind force exerted by heavy vehicles. These guidelines are provided in Figure 9.

Figure 9: Australia – buffer between cycle facilities and vehicle lanes[30]

Speed	**Clearance / Buffer**
60 km/h	1.0 m
80 km/h	1.5 m
100 km/h	2.0 m

It is noted, however, that the inability to achieve these clearances should not preclude the provision of a facility with a lesser clearance unless a suitable alternate route or means of accommodating cyclists exists. The guide suggests that the following factors require careful consideration when choosing appropriate lane and treatment widths:

- Parking conditions
- Motor vehicle speed
- Motor vehicle volume
- Bicycle/parking lane width
- Bicycle volume
- Car lane width
- Percentage of heavy vehicles
- Road alignment

[30] Ibid.

Once a decision has been made to implement an on-road facility or a segregated path, the flow charts shown in Figures 10 and 11, respectively, help to determine the more specific details about these two respective facility types.

Figure 10: Australia – Decision tree for on-road treatments[31]

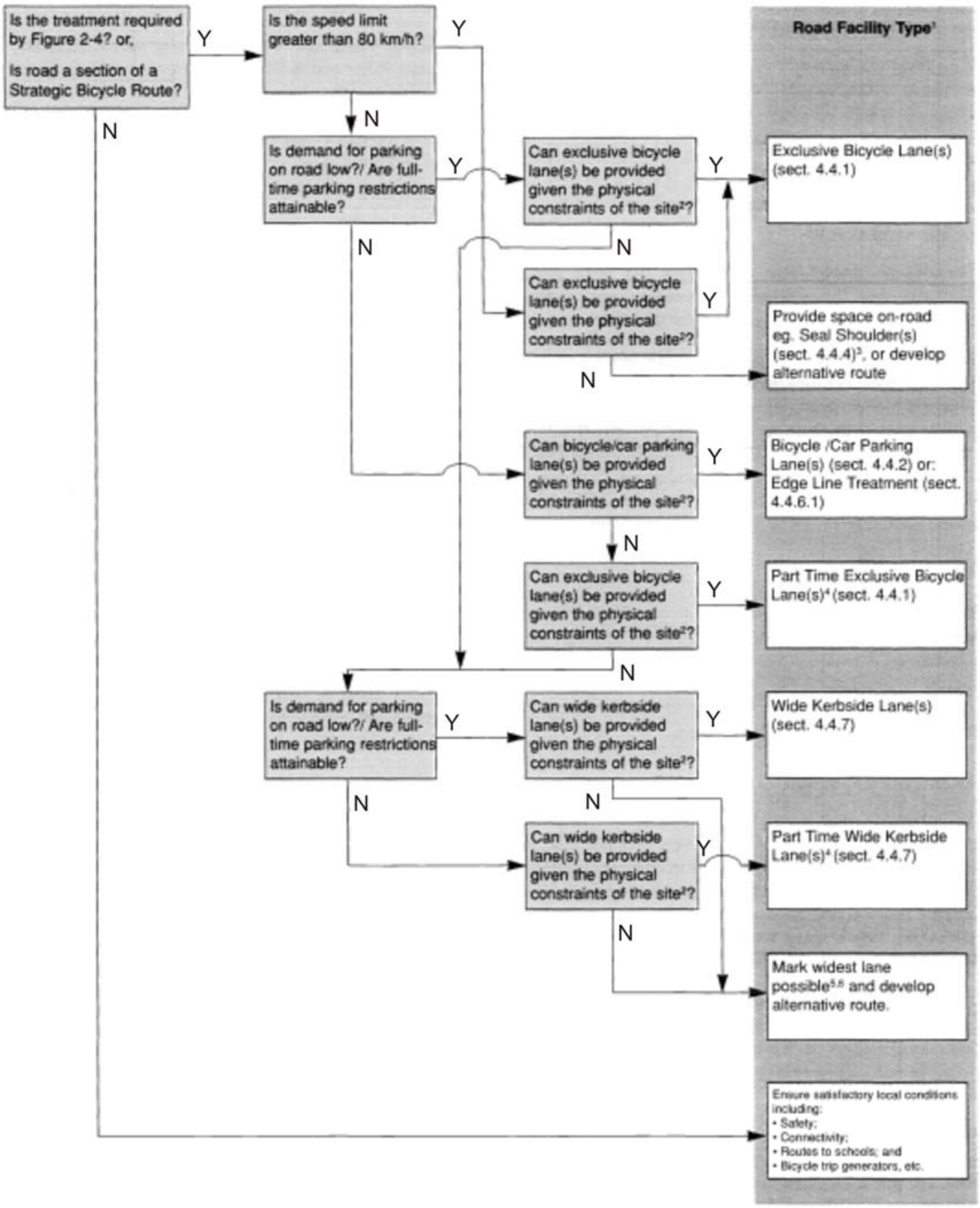


Figure 10 is based on the following criteria:

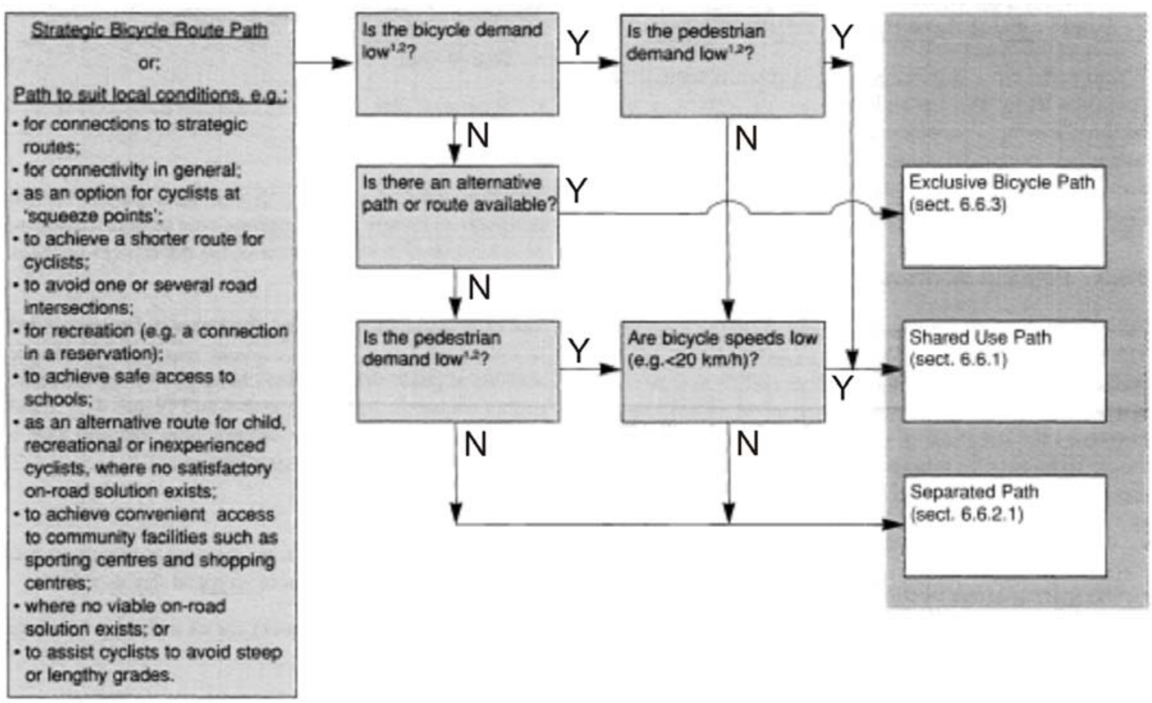
[31] Ibid.

- A cited report by Godefrooij[32] states that where the difference between bicycle and motor traffic speeds is less than 20 km/h, full integration (i.e. sharing the road) may be acceptable. Conversely, segregation is most desirable where the difference between bicycle and motor traffic speeds exceeds 40 km/h. On this basis, wide curb lanes are avoided on roads with speeds in excess of 70-80 km/h as the 85th percentile speed of cyclists under free flow conditions is in the order of 30 km/h.

- The decision tree only identifies the more commonly used on-road facililty types and the less common treatments such as contra-flow cycle lanes or advisory treatments (similar to the application of "sharrows" in North America) are other treatments that may be considered in special circumstances.

Bicycle paths play a critical role in recreational cycling but can also play a critical transportation role where they are used to avoid limitations caused by discontinuous access along roads, excessive gradients, or undesirable traffic conditions. Paths should either lead to specific destinations (commuter paths) or offer a pleasant ride (recreational paths) and the purpose of the path should be based on the potential, likely, and desired use by various types of cyclists. Designs of commuter and recreational paths may be quite different (e.g. design speed, intersection treatments, etc.). If it has been determined that a path facility is appropriate, the decision tree shown in Figure 11 helps to determine the appropriate type of path.

Figure 11: Australia – Decision tree for segregated path[33]



[32] Godefrooij. Criteria for Segregation and Integration of Different Modes of Transport. Prepared for the Conference Velo Mondiale, The Bicycle: Global Perspectives. Montreal, Canada. 1992.
[33] AUSTROADS. Guide to Traffic Engineering Practice Part 14 – Bicycles, Second Edition. Sydney, Australia. 1999.

Figure 11 is based on the following criteria:

- Low demand is described as infrequent use – in the order of 10 users per hour (or less)
- High demand is described as regular use in both directions – in the order of 50 users per hour (or more)
- The volume considerations are intended to limit incidence of conflict between different types of users (e.g. pedestrians and cyclists)

The AUSTROADS guide notes that bicycle symbols for traffic lights should be provided where bicycle paths cross roads at signalized intersections that serve both pedestrians and cyclists, and the signals should be coordinated with the pedestrian crossing phase. The authors also point out that where bicycle paths cross roads at unsignalized intersections, it is generally appropriate to cross close to the intersection, particularly if sightline restrictions exist. They further suggest that typically, warning signs are provided to warn road users of the crossing conflict. An optional yield sign is suggested on the pathway at the street being crossed.

3.4.2 New South Wales

Another prominent Australian cycling document was reviewed as part of our work and is titled New South Wales Bicycle Guidelines[34], published by the Australia Roads and Traffic Authority (RTA) New South Wales. Similar to the CROW and AUSTROADS documents, five key principles for the provision of successful bicycle networks are discussed and include: coherence, directness, safety, attractiveness, and comfort. In support of these over-arching principles, the RTA provides the reader with a facility checklist that covers the common issues from planning through to design.

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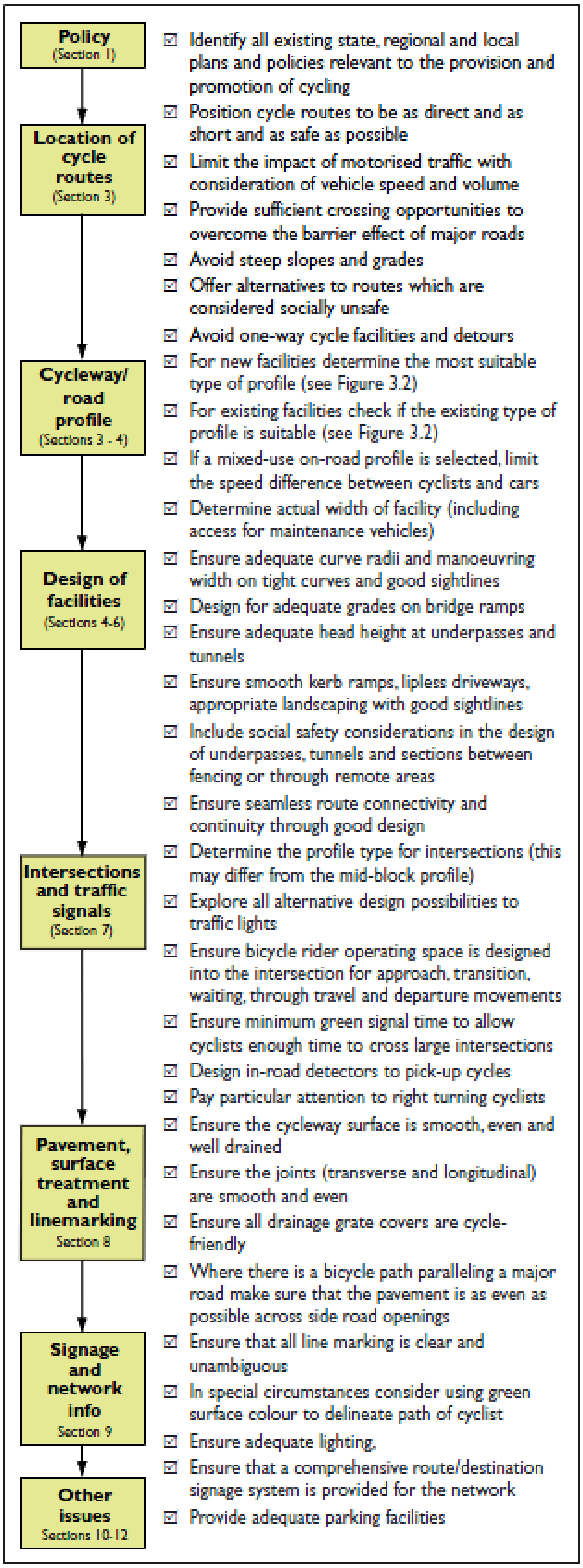
[34] Roads and Traffic Authority New South Wales. *New South Wales Bicycle Guideleines (Version 1.2)*. North Sydney, Australia. 2005.

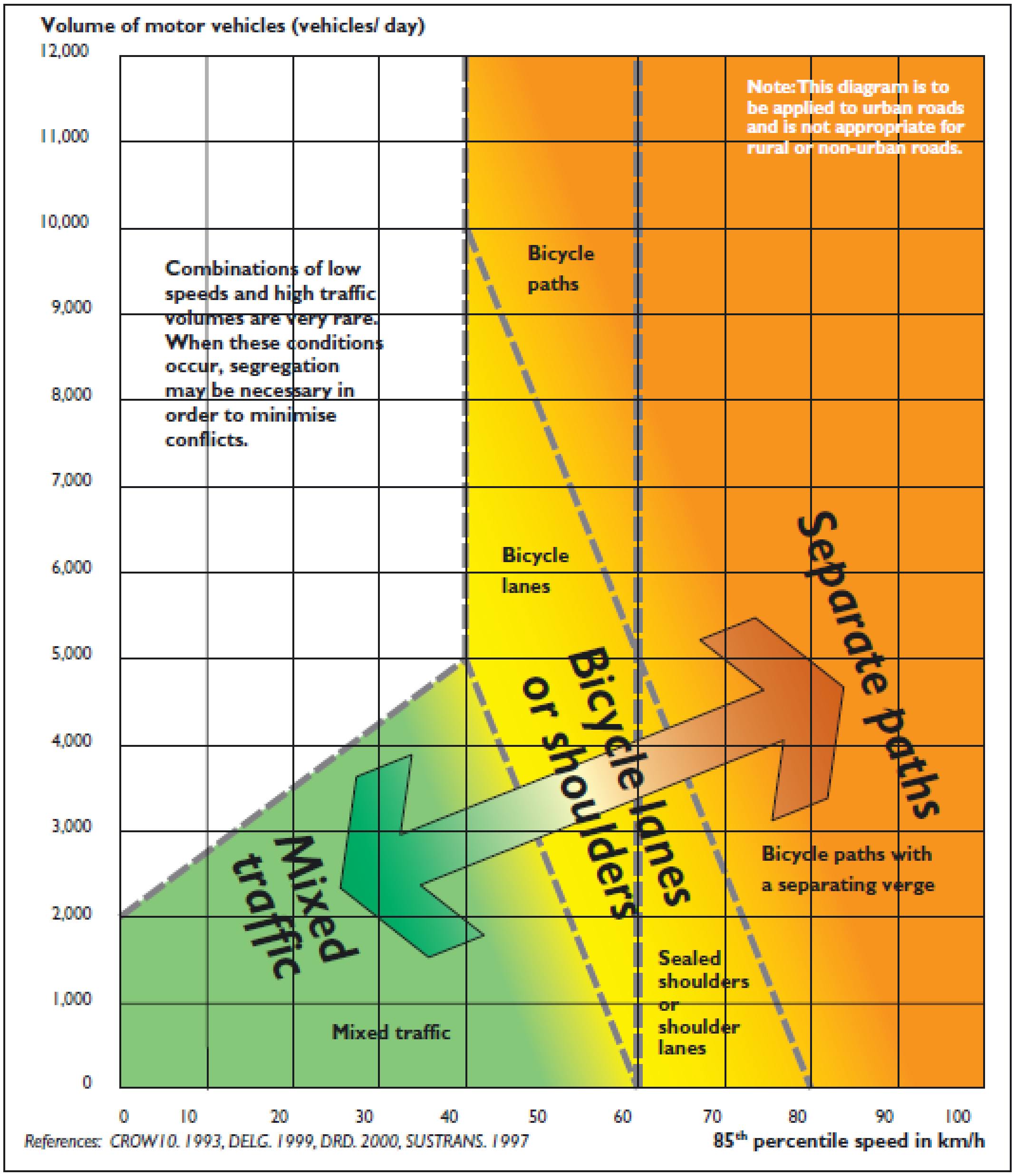
Figure 12: Australia – Bicycle facility design checklist[35]



[35] Ibid.

Specific to the issue of segregation, the guide highlights the relationship between the prevailing traffic speed and volume as an important factor in the decision to provide physically separated facilities, mixed traffic, or something in between. Again, the RTA guidance with respect to facility selection is technically based. The RTA nomograph illustrated in Figure 13 provides an aid to the facility selection process.

Figure 13: Australia – Facility selection nomograph[36]



The guideline recommends, before finalizing a decision on a specific cycling facility type, the practitioner should give careful consideration to the full range of physical and operational parameters, including:

[36] Ibid.

- Function of street within road hierarchies and within the bicycle network
- Width and allocation of space along the street corridor
- Motor vehicle speeds and volumes
- Use by heavy vehicles and busses
- Slopes and grades
- Parking demand
- Collision history
- Location of services and utilities
- Drainage

3.5 New Zealand

The New Zealand Land Transport Safety Authority's Cycle Network and Route Planning Guide[37] begins with an excellent discussion of strategic cycling plans and the relationship with safety. The following key points relate to the Ottawa study:

- Typically, cycling strategic plans aim to increase the number of cycle trips while reducing cyclist injuries. This appears to be realistic as many cities in the world have achieved this result including York in the United Kingdom and Portland in the United States. Therefore, improving cycle safety is an essential part of cycle promotion. The research carried out by Jacobsen supports this notion by providing evidence that higher cycling numbers result in a lower crash risk[38].

- Reducing traffic volumes and speeds may do more to improve cyclist safety than providing cycling facilities, depending on the circumstances[39]. Consequently, a cycling strategic plan needs the support of more general traffic and transport strategies[40].

- The quality of the cycling facilities reflects an agency's commitment to increasing the cycling mode share. Conversely, lower quality facilities, if provided at all, tend to require more skill to negotiate and may not attract new, less confident cyclists.

New Zealand has adopted the same guiding princples for network success (i.e. safety, comfort, directness, cohesion, etc.) and combined them with cyclist skill (child/novice, basic competence, experienced), trip purpose (utility vs. leisure) and trip type (neighbourhood, commuting, sports, recreation, touring). The combination of all these elements guides the practitioner to selecting the best facility that suits the majority of these elements. The decision matrices developed by the Land Transport Authority are provided in Figures 14 and 15.

[37] Land Transport Safety Authority, New Zealand. *Cycle Network and Route Planning Guide*. Wellington, New Zealand. 2004.
[38] Jacobsen, P L. *Safety in Numbers: More walkers and bicyclists, safer walking and bicycling*. In Injury Prevention 9, pp 205—209, 2003.
[39] Institution of Highways and Transportation, Cyclists' Touring Club, Bicycle Association, and Department of Transport. *Cycle friendly infrastructure: Guidelines for planning and design*. Cyclists' Touring Club. Godalming, United Kingdom. 1996.
[40] Koorey, G. *Why a cycling strategy on its own will not increase cycling.* Prepared for the New Zealand Cycling Conference, 2003.

Figure 14: New Zealand – Facility design guidelines matrix[41]

	CYCLIST TYPE	NEIGHBOURHOOD	COMMUTING	SPORTS	RECREATION	TOURING
	Cyclists' possible cycling objectives	To shops, school, or riding near home	To get to their destination efficiently	To be physically challenged	To enjoy themselves and get some exercise	To see and enjoy new places and experiences
NETWORK/ROUTE REQUIREMENTS	CRITERIA					
Safety	Personal security (good lighting etc)	🚲🚲🚲🚲🚲	🚲🚲🚲🚲	🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲
	High degree of safety	🚲🚲🚲🚲🚲	🚲🚲🚲	🚲	🚲🚲🚲🚲🚲	🚲🚲🚲
	Separated from busier/faster urban traffic	🚲🚲🚲🚲🚲	🚲🚲🚲	🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲
	Rural road shoulders or paths	🚲🚲🚲🚲🚲	🚲🚲🚲	🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲
Comfort	Screening from weather and wind	🚲🚲🚲	🚲🚲🚲🚲		🚲🚲🚲	🚲
	High-quality riding surfaces	🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲	🚲🚲🚲
Directness	Direct routes	🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲		🚲🚲🚲
	Minimal delays	🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲	🚲🚲
Coherence	Continuity	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲	🚲🚲🚲🚲🚲
	Sign-posted; recognisable	🚲	🚲🚲🚲	🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲
Attractiveness	Pleasant and interesting routes or destinations	🚲🚲🚲	🚲🚲	🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲
	Physically challenging routes or grades			🚲🚲🚲🚲🚲	🚲🚲	
Complementary facilities	Parking facilities located near destinations	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲	🚲🚲🚲🚲	🚲🚲
	Security of bicycle parking	🚲🚲🚲🚲	🚲🚲🚲🚲🚲	🚲🚲	🚲🚲	🚲🚲🚲🚲🚲
	Showers, baggage lockers		🚲🚲🚲🚲			🚲🚲
	Water, toilets, shelter, shops, phones	🚲	🚲	🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲

Legend: 🚲 minimal benefit, 🚲🚲🚲 moderate benefit, 🚲🚲🚲🚲🚲 most benefit

Table 3.1: The relative importance of network or route criteria to different cyclist groups

[41] Land Transport Safety Authority, New Zealand. Cycle Network and Route Planning Guide. Wellington, New Zealand. 2004.

Figure 15: New Zealand – Facility type suitability by cyclist skill[42]

CYCLE FACILITY OPTION	CHILD/NOVICE	BASIC COMPETENCE	EXPERIENCED
Kerbside cycle lane	🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲
Cycle lane next to parking	🚲	🚲🚲🚲🚲	🚲🚲🚲🚲
Contra-flow cycle lane	🚲	🚲🚲🚲🚲	🚲🚲🚲🚲🚲
Wide kerb side lane	🚲🚲	🚲🚲🚲	🚲🚲🚲🚲
Sealed shoulder	🚲🚲	🚲🚲🚲🚲🚲	🚲🚲🚲🚲🚲🚲
Bus lane	🚲	🚲🚲	🚲🚲🚲🚲
Transit lane	🚲	🚲🚲	🚲🚲🚲🚲
Slow mixed traffic	🚲🚲🚲	🚲🚲🚲🚲	🚲🚲🚲🚲🚲
Paths	🚲🚲🚲🚲🚲	🚲🚲🚲🚲	🚲🚲🚲

Legend: Benefit: 🚲 minimal benefit, 🚲🚲🚲 moderate benefit, 🚲🚲🚲🚲🚲 most benefit

Further facility selection support for urban roads is provided in the form of a nomograph, illustrated in Figure 16. The basis of the nomograph is that comfort and safety is a function of traffic speed and volume – similar to other facility selection nomographs applied elsewhere. The document suggests that cycling facilities identified using this nomograph are expected to yield the broadest appeal.

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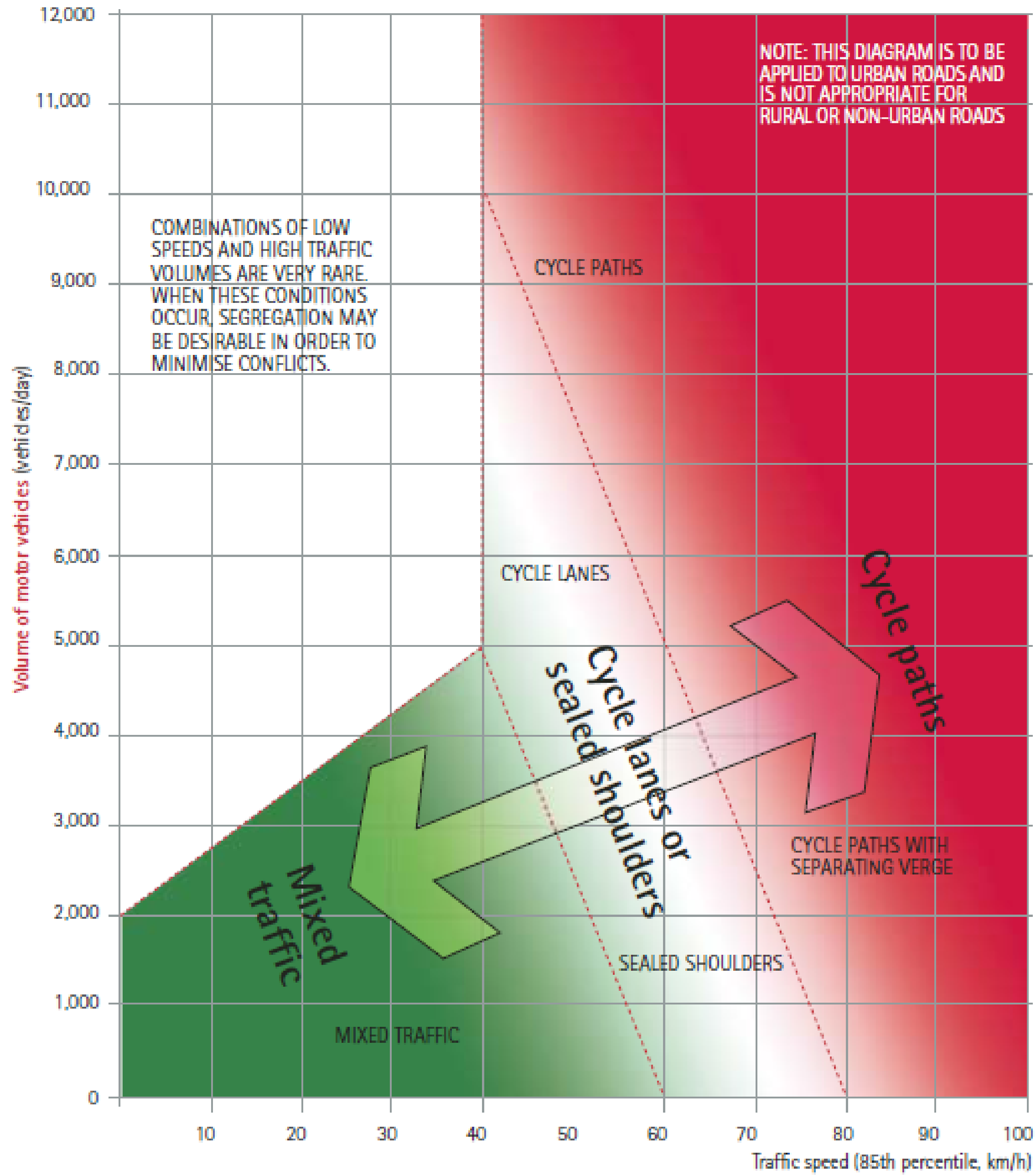
[42] Ibid.

Figure 16: New Zealand – Facility selection nomograph[43]



The publication also discusses various locations where bicycle facilities can be provided, both on and off-road, and discusses the advantages and disadvantages of each. A brief summary is provided below.

[43] Ibid.

- Urban arterial roads: Minor arterials, with lower traffic volumes and speeds, are typically a single lane in each direction and can usually be adapted to provide for cyclists of basic competence both mid-block and at intersections. Major arterial roads are busier and faster, and typically have multiple lanes. They are not appropriate for cyclists of basic competence unless they have more effective separation and facilities to turn [left], such as hook turns. Alternative routes supplement arterial routes (for less competent cyclists) but rarely eliminate the need for cycle provision on the latter.

- Urban streets: Many cyclists undertaking inter-suburban trips prefer quiet routes, especially if they are not confident mixing with busy traffic. Local or collector roads can provide this as long as they form a coherent pattern. Commuter cyclists will use them only if they are as convenient as the most direct route. Careful attention must be paid to busy intersections.

- Urban off-road paths: Generally absent of conflict with motor vehicles, paths are attractive and relatively safe to less confident, novice cyclists. Perception of personal security on these paths however is poor, particularly at night, and they must be frequently light and posted with wayfinding information. Once again, careful attention must be paid to intersections and connections to roads.

- Rural arterial roads: In rural areas, cyclists rarely have an alternative to using the same road system as motorized traffic. Because traffic is fast, a high proportion of cyclist crashes involve death or serious injury. Cyclists benefit from sealed road shoulders; even greater safety benefits are attainable with parallel bicycle paths. Narrow bridges are particularly hazardous.

- Rural secondary roads: Rural secondary roads can provide a coherent route and be an excellent cycling alternative to more heavily used rural arterials.

The authors provide a discussion of major factors that influence whether roads or paths best suit cyclists' needs. Of particular interest are:

- Increased segregation from motor traffic is usually accompanied by increased interference from pedestrians, pets, skateboarders, slower cyclists, etc.

- Both paths and on-road facilities can be hazardous and both require high quality design to achieve safety. Paths tend to be safer between intersections as long as the design is adequate and there are minimal crossing driveways. Cycling through intersections is generally safer from the roadway than from a path. Traffic calming or signals may be required where paths cross busy roads.

- New Zealand law (as in Canada) requires cyclists on paths to yield to vehicles on roads, reducing cyclist level of service.

- Geometric design standards are almost always higher for roads than for paths.

- It is usually easier and less expensive to accommodate the needs of commuter cyclists on roads than paths. Notwithstanding, many commuters make use of well located paths and many leisure cyclists enjoy on-road facilities.

- It is difficult to provide a coherent and direct path system that is as convenient for commuters as the arterial road network.

- Depending on the circumstances, there is usually no clear advantage between roads and paths in terms of safety, conflicts with other users, expense, and maintenance.

- Relative advantages of on-road facilities include: directness, coherence, convenience, efficiency, availability, intersection controls, high levels of surveillance, and are well suited for experienced cyclists.

- Relative advantages of separate paths (between intersections) include: no motor traffic, lower speeds, less stress, attractive environment, additional links beyond the road network, and are well suited for child/novice cyclists.

3.6 Denmark

The Danish Road Directorate's Collection of Cycle Concepts[44] indicates that increased cycle use has been associated with increases in safety – an observation that is consistent with other literature. Figure 17 presents a list of measures described in this document that provide assistance in improving cycle use and safety.

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[44] Danish Road Directorate. *Collection of Cycle Concepts*. Copenhagen, Denmark. 2000.

Figure 17: Denmark – Planning and policy guidelines for improving cycle safety and use[45]

45 Ibid.

This document also presents a facility selection nomograph that offers the following discussion on facility types:

- Mixed traffic: At low car speeds and low volumes of motor vehicles, separation rarely results in safety benefits for cyclists. In fact, separation on roads with many junctions will often result in more bicycle accidents. Traffic calming is often necessary to obtain suitably low speeds in mixed traffic.

- Cycle lane: With speeds of 50 km/h and less, and moderate traffic volumes, cycle lanes may be a solution. Cycle lanes can be recommended on urban roads without shops and with few junctions. Like cycle tracks, cycle lanes can result in more bicycle accidents as the number of intersections and accesses increase.

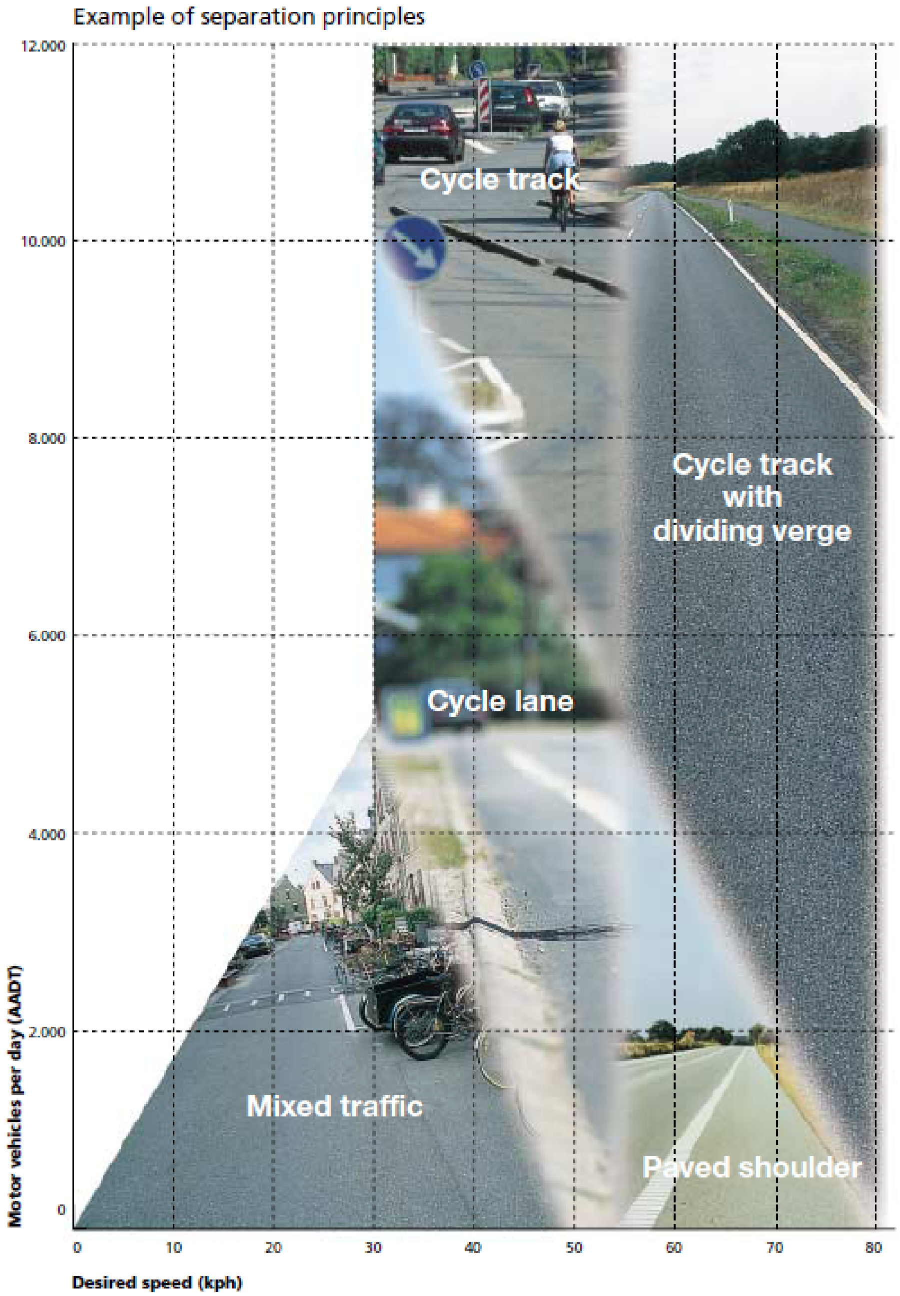
- Cycle track: A physical barrier between cars and bicycles is beneficial even at moderate speeds and traffic volumes. Cycle tracks improve safety, comfort, and perceived risk. Cycle tracks lose many of their advantages with respect to safety and comfort on roads where there are many major and closely spaced intersections. On the other hand, cycle tracks function well on roads with signalized junctions and minor side roads.

- Cycle track with dividing verge: On roads with high speeds, distances between intersections are often greater and improved comfort and less perceived risk can be attained by providing a cycle track with a dividing verge. Dividing verges should not be used on roads with many intersections or at signalized intersections.

- Paved shoulders: If it is necessary to widen the road in order to establish paved shoulders, the construction of cycle tracks should be considered.

The facility selection nomograph is illustrated in Figure 18 on the following page.

Figure 18: Denmark – Facility selection nomograph[46]



The following discussion regarding the interaction between cyclists and parked vehicles highlights the following:

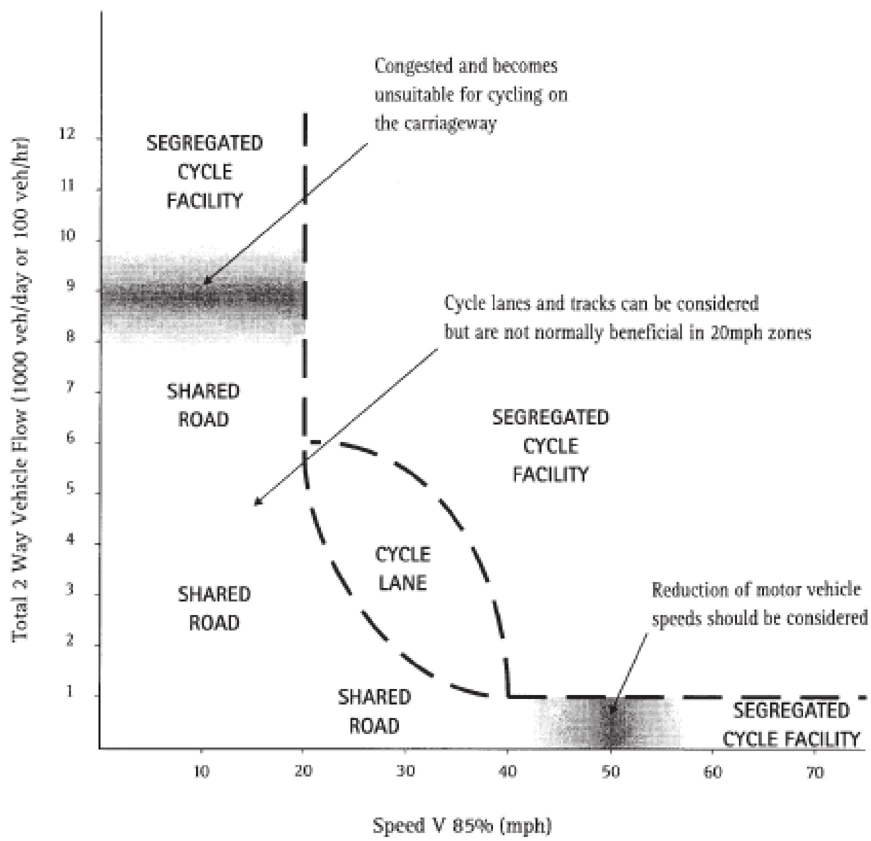
[46] Ibid.

Parking should be prohibited on roads with cycle lanes if there is significant turnover. Where parking is permitted a raised island can be established between the cycle lane and parking lane. Only parallel parking is acceptable on roads with cycle lanes. Angle and perpendicular parking has the potential to increase the risk of collision.[47]

3.7 United Kingdom

Sustrans, a UK organization supporting active and public transportation modes has published The National Cycle Network – Guidelines and Practical Details: Issue 2[48]. This document identifies the need to first assess the need for a segregated facility by using a facility selection nomograph. The concept is similar to other facility selection nomographs by using different boundary criteria to identify one facility type over another. The Sustrans nomograph is illustrated in Figure 19. Generally, the threshold to move to a segregated facility is lower relative to the nomograph developed in the CROW document and reflects the needs of the inexperienced cyclist or family group who will benefit from segregation earlier than the experienced cyclist.

Figure 19: UK – Facility selection nomograph[49]

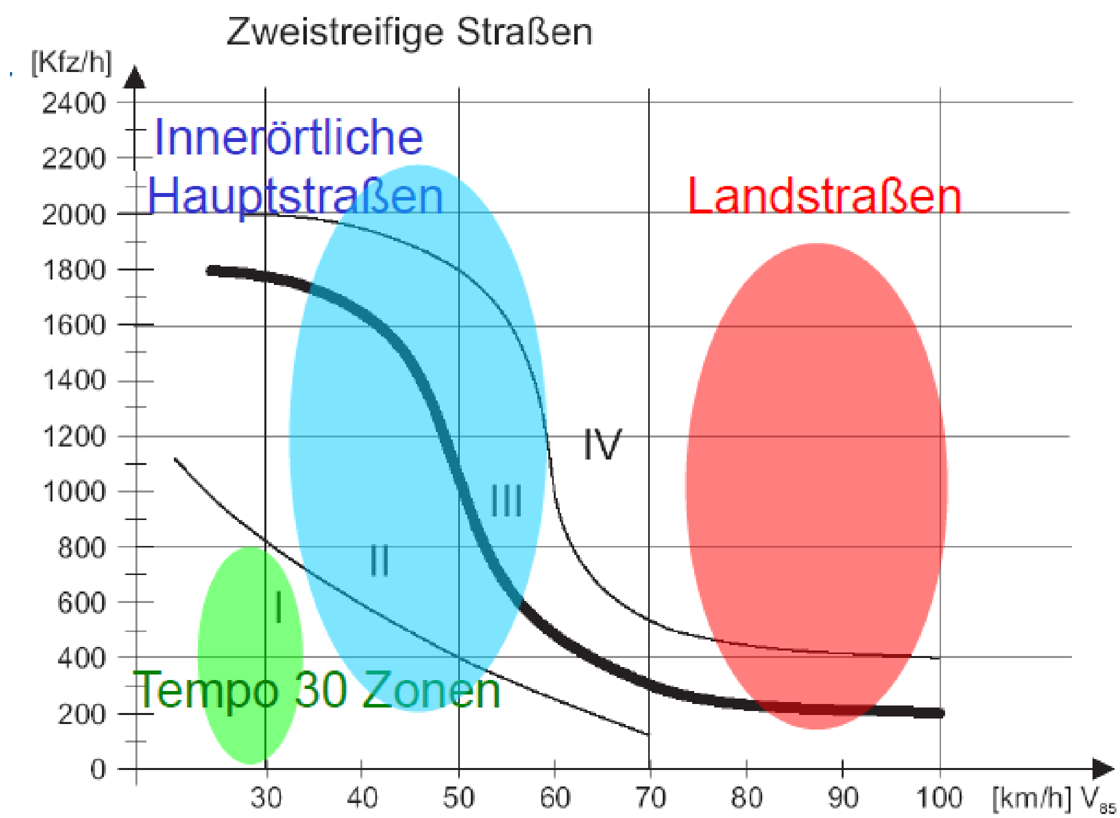


[47] Ibid.
[48] Sustrans. *The National Cycle Network – Guidelines and Practical Details: Issue 2*. Bristol, United Kingdom, 1996.
[49] Ibid.

3.8 Germany

Literature from Germany was also reviewed including Empfehlungen für Radverkehrsanlagen (Recommendations for Bicycle Facilities)[50], published by Forschungsgesellschaft für strassen- und verkehrswesen (Roads and Transport Research Society). While an English translation of this guide could not be obtained, the facility selection nomograph illustrated in Figure 20 is the suggested guidance in this particular document. Similar to other nomographs used in other jurisdictions, it is based on traffic volume – in this case hourly volume - and vehicle speed.

Figure 20: Germany – Facility selection nomograph[51]



I – guiding principle is mixing
II – guiding principle is partial separation
III – separation is preferred
IV – separation is essential

Blue zone – urban major roads
Green zone – 30 km/h speed zones
Red zone - highways

[50] Forschungsgesellschaft für strassen- und verkehrswesen (Roads and Transport Research Society). "Empfehlungen für Radverkehrsanlagen (Recommendations for Bicycle Facilities)." Köln, Germany, 2010.
[51] Ibid.

3.9 A summary of the literature

In table 1, we have provided a concise summary of the principles drawn from the literature review section of this report for ease of reference.

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Table 1: A summary of the literature review

Roadway Characteristic Catergory	Criteria / Thresholds	Heuristics	Source
Motor Vehicle Volume	- Some form of designated bicycle facility is recommended when vehicular volumes exceed 500 vph (Figure 19).	- Generally, mobility-oriented roads (i.e. arterials) require bicycle facilities (cycle lanes or separated facilities) and access-oriented roads (i.e. residential/local) do not, provided speeds are low. Roads that serve both a mobility and access role generally require some form of bicycle facility.	CROW Traffic Engineering Design Manual for Bicycle Traffic (June 2007)
	- Cyclists should be provided with adequate exclusive operating space when traffic volumes exceed 3,000 vpd or 200-250 vph in a single outside lane.	- Provision of bicycle facilities is recommended on motor vehicle commuter routes as this is often associated with aggressive traffic conditions.	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)
	- Traffic volumes are categorized into three groups: - less than 2,000 vpd (low) - 2,000 to 10,000 vpd (moderate) - greater than 10,000 vpd (high)		FHWA Selecting Roadway Design Treatments to Accommodate Bicycles
Motor Vehicle Speeds		- Available roadway width needs to be considered in conjunction with traffic volumes and speed to determine the most appropriate type of facilities and preferred routes. - Bicycle commuters (generally advanced/experienced cyclists) frequently use arterial streets because they are direct, minimize delay, and provide continuity. - Basic/novice cyclists generally prefer more lightly travelled streets.	AASHTO Guide for the Development of Bicycle Facilities (1999)
	- On high-speed (>80 km/h) rural roads, separated bicycle facilities or alternate routes are recommended. A boulevard buffer of 4.5 - 6.0 m is recommended between the roadway and the bicycle facility.		CROW Traffic Engineering Design Manual for Bicycle Traffic (June 2007)
	- Cited research (Godefrooji, 1992) states that where the difference between bicycle and motor vehicle speeds is less than 20 km/h, mixed traffic may be acceptable. Separated bicycle facilities are most desirable when the speed differential exceeds 40 km/h. On this basis, wide curb lanes and cycle lanes are avoided if possible when operating speeds exceed 70 km/h (assuming a typical bicycle operating speed of 30 km/h).	- Incremental clearance or buffer space is recommended between vehicles and the bicycle operating envelope as speeds increase (e.g. 1.0 m at 60 km/h, 1.5 m at 80 km/h, 2.0 m at 100 km/h)	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)
		- Reducing traffic volumes and speeds may do more to improve cyclist safety than providing cycling facilities, depending on the circumstances.	New Zealand Land Transport Authority Cycle Network and Route Planning Guide (2004)
	- Operating speeds are categorized into four groups: - less than 50 km/h - 50 to 65 km/h - 65 to 80 km/h - greater than 80 km/h		FHWA Selecting Roadway Design Treatments to Accommodate Bicycles
Cyclist Volumes		- Cyclist volumes may be used as an indicator of level of use, however may underestimate the potential bicycle demand. - Bicycle trip generators such as residential neighborhoods, employment centres, schools, parks, shopping centres, recreational facilities, colleges, etc. should also be considered to estimate latent bicycle demand and desire lines.	AASHTO Guide for the Development of Bicycle Facilities (1999)
	- Infrequent bicycle use, in the order of 10 users per hour or less, is considered low bicycle demand. - Bicycle demand is considered to be high when there are 50 or so users per hour.	- If a road section forms part of what Ottawa would term a "spine" bicycle route (direct, primary routes between major destinations and areas of the city), preference is directed toward cycle lanes or separated bicycle facilities.	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)

Table 1 continued

Roadway Characteristic Catergory	Criteria / Thresholds	Heuristics	Source
Truck/Bus Use		- Conflicts with bus loading and unloading should be minimized in bicycle facility design. - Greater separation may be required where cyclists must share roadway space with trucks and busses, particularly if operating speeds are high.	AASHTO Guide for the Development of Bicycle Facilities (1999)
	- More than 30 heavy vehicles per hour warrants design consideration to minimize conflict between bicycles and large vehicles		FHWA Selecting Roadway Design Treatments to Accommodate Bicycles
On-Street Parking		- Turnover, density, and configuration of on-street parking can affect cyclist safety - Locations with perpendicular and diagonal parking should be avoided	AASHTO Guide for the Development of Bicycle Facilities (1999)
		- If on-street parking demand is low and parking restrictions appear attainable, cycle lanes are preferred over mixed traffic.	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)
		- Parking should be prohibited on streets with cycle lanes if there is significant turnover. Where parking is permitted, a buffer should be provided between the cycle lane and the parking lane. - Angle and perpendicular parking increases bicycle collision risk significantly.	Danish Road Directorate Collection of Cycle Concepts (2000)
Anticipated Users (Skill level & trip purpose)		- Bicycle facilities near schools, parks, and residential neighborhoods are likely to attract more basic/novice and child cyclists who typically prefer separated facilities.	AASHTO Guide for the Development of Bicycle Facilities (1999)
		- Significant use by children or basic/novice cyclist typically warrants consideration of separated bicycle facilities.	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)
Physical/topographical barriers		- Steep grades, waterways, railroads, freeways, and narrow bridges can impede bicycle movement. - Bicycle facilities should be designed to overcome these types of barriers	AASHTO Guide for the Development of Bicycle Facilities (1999)
Collision Patterns		- Plans for providing bicycle facilities should attempt to resolve existing collision patterns and collision/conflict frequency	AASHTO Guide for the Development of Bicycle Facilities (1999)
Directness		- Particularly for commuter/utilitarian bicycle trips, facilities should correspond with bicycle desire lines and provide a direct, convenient route	AASHTO Guide for the Development of Bicycle Facilities (1999)
Accessibility		- Frequent, convenient access to bicycle facilities should be provided, especially in residential areas and around bicycle traffic generators (schools, office buildings, shopping areas, parks, museums, etc.). Designs should also facilitate access for service, maintenance, and emergency vehicles.	AASHTO Guide for the Development of Bicycle Facilities (1999)
Aesthetics		- Scenery is an important consideration for recreational users. Trees also provide shade and shelter from the elements.	AASHTO Guide for the Development of Bicycle Facilities (1999)

Table 1 continued

Roadway Characteristic Catergory	Criteria / Thresholds	Heuristics	Source
Personal Safety/Security		- Potential for criminal acts against cyclists, particularly along isolated bicycle facilities needs to be considered.	AASHTO Guide for the Development of Bicycle Facilities (1999)
Delay (Stops)		- Cyclists have an inherent desire to maintain momentum and may avoid a route where bicycle facilities are provided or disregard traffic control if delays are frequent or excessive.	AASHTO Guide for the Development of Bicycle Facilities (1999)
Conflicts between modes		- Potential conflicts between different types of users (cyclists/motorists, cyclists/pedestrians, etc.) should be identified and designs should aim to minimize and highlight the presence of conflicts. Intersections and driveways generally result in concentrations of conflicts.	AASHTO Guide for the Development of Bicycle Facilities (1999)
	- Infrequent bicycle use, in the order of 10 users per hour or less, is considered low bicycle demand. - Bicycle demand is considered to be high when there are 50 or so users per hour.	- When designing separated bicycle facilities, bicycle demand and pedestrian demand are both considered in determining the most appropriate configuration (i.e. exclusive to bicycles, mixed-use, or designating exclusive space for cyclists and pedestrians). Bicycle operating speeds are also considered. This is intended to minimize conflict between cyclists and pedestrians.	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)
Maintenance		- Designs which facilitate and simplify maintenance activities improve the safety and use of the facility	AASHTO Guide for the Development of Bicycle Facilities (1999)
Pavement Surface Quality		- Pavements in bicycle travel paths should be free of bumps, potholes, and other irregularities. Utility covers and drainage grates should be flush and traversable, preferably outside of the travel path.	AASHTO Guide for the Development of Bicycle Facilities (1999)
Bridges		- Physical conditions on bridges such as narrower lanes, steep grades, metal grates, expansion joints, and low railings can be challenging for cyclists.	AASHTO Guide for the Development of Bicycle Facilities (1999)
Intersection Conditions		- Bicycle collisions are often concentrated at intersections. The number and size of intersection crossings should be minimized to the extent possible and crossings should be designed to minimize and highlight conflicts. Exclusive bicycle signals should be considered at high-speed, high-volume intersections.	AASHTO Guide for the Development of Bicycle Facilities (1999)
		- Bicycle symbols for traffic signals should be provided where separated facilities cross roads at signalized intersections that serve both pedestrians and cyclists. - Separated facilities that cross side streets at unsignalized intersections should do so adjacent to pedestrian crosswalks. - Proper signage and positive guidance are necessary to clearly indicate motorist/cyclist right-of-way expectations at intersection/driveway conflict areas.	Austroads Guide to Traffic Engineering Practice Part 14 - Bicycles (1999)
Costs/Funding		- Funding availability can limit feasible bicycle facilities at particular locations or limit the extent to which bicycle facilities can be provided. - A lack of funds should not result in poorly designed or inappropriate bicycle facilities.	AASHTO Guide for the Development of Bicycle Facilities (1999)
Provincial and Municipal Laws		- Design of bicycle facilities must not encourage cyclists or motorists to operate in a manner that is inconsistent with established laws and expectations.	AASHTO Guide for the Development of Bicycle Facilities (1999)

4 DEVELOPING A FACILITY SELECTION TOOL

4.1 Three basic principles

Our review of the literature suggests that in choosing the type of cycling facility design that will be deployed in any given situation, there are three basic principles that must be clearly understood:

1. The choice to provide a segregated versus non-segregated facility is not a simple "yes" or "no" decision;
2. The criteria or thresholds used to select one cycling facility type over another need to be flexible to be able to accommodate each unique set of site characteristics that will exist for each design situation; and
3. The final decision to segregate or not to segregate, and the choice of the specific facility type to be deployed, will always be the responsibility of the designer. No quantitative algorithm, warrant, or other selection tool can substitute for the experience and judgement of a qualified engineering designer in such situations. To help designers to properly exercise their judgement, any facility type selection tool must also provide supplementary technical guidance appropriate to a full range of likely design situations.

4.2 Considering site-specific conditions

Through the use of a facility selection tool, such as a nomograph similar to those discussed in Section 3, a practitioner can identify a preferred cycling facility type with relative ease. However, actually implementing the result produced from the nomograph may not be possible in all situations due to such issues as physical constraints, environmental or neighbourhood impacts, or significant costs. In making their final choice of facility type, designers must also consider the site-specific characteristics (i.e. lane widths, access density, etc.) and how they relate to cycling safety and comfort. To help designers do this, we have taken the results of our detailed literature review, as summarized in Table 1, and constructed a set of rules that link specific site conditions to appropriate facility types. These rules are summarized in Appendix B.

4.3 The tool requirements

The facility-type selection tool that we have developed for this purpose in the course of this project is a multi-step process that:

- Addresses the issue of segregated versus non-segregated facilities;
- Is technically reliable and founded on current knowledge and research;
- Provides a consistent framework that is easy to apply and uses readily available data; and
- Allows flexibility during the decision process to account for differences in the physical and operational characteristics of the design context.

We discuss this tool beginning in the immediately following Section.

5 THE FACILITY SELECTION TOOL

5.1 Overview

Based on our discussion in the previous Section, we took the principles gleaned from the literature review, as well as the basic requirements of a facility selection decision tool and developed a process customized for the City of Ottawa context. This process has three elements:

1. An initial pre-selection step using a nomograph to guide the practitioner in selecting an initial facility type;

2. A decision tree process in support of the nomograph that guides the practitioner through the decision making process at a more detailed level - essentially, determining if the pre-selected facility is compatible with the site characteristics; and

3. A process for summarizing the decision and rationale behind a final facility type.

An overview of the tool is provided in Figure 21 on the following page. Figure 22 provides a model “worksheet” that practitioners can use to work through the facility selection process.

5.2 A note to users

In carrying out the facility selection tool, the user must bear the following in mind:

- This tool is intended as an aid to City staff during the planning process to provide a consistent and technical sound process to make decisions.

- The tool has been developed for urban facilities and will address both two-lane, two-way roads as well as multi-lane roads.

- Along a given route the roadway characteristics may vary. As such, the route should be divided into homogenous sections. The tool can then be applied to each homogeneous section of the route. Notwithstanding this principle, if possible, the practitioner should strive to maintain a consistent facility type along a given route to better match the expectations of both cyclists and motorists.

- The tool does not specifically address intersection locations but it does provide guidance with respect to the types of facilities to consider on the approaches to intersections.

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Figure 21: The decision support tool process

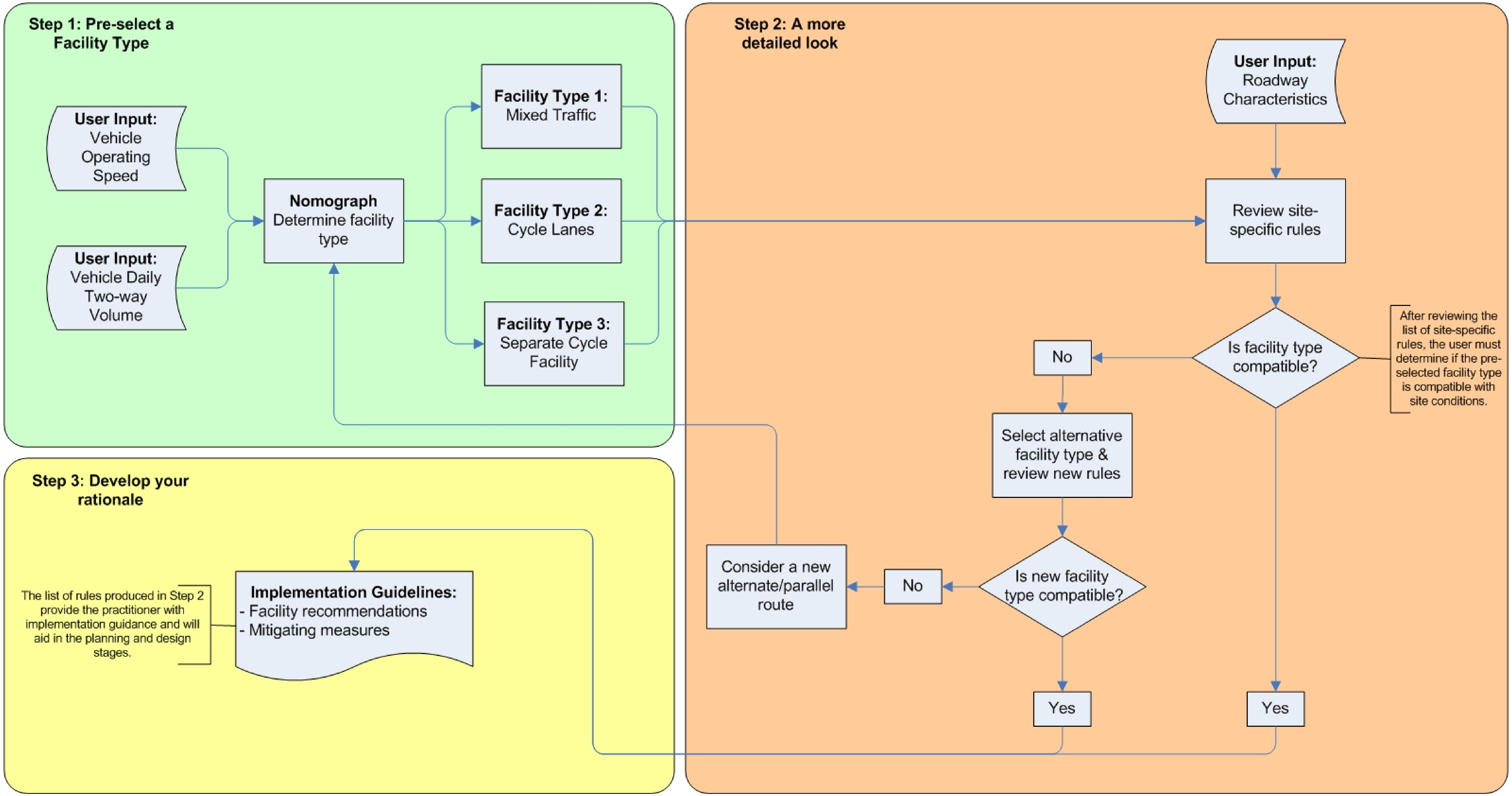
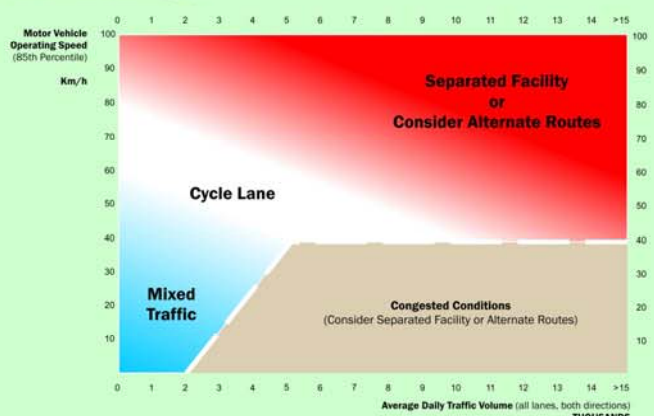


Figure 22: A model worksheet to carry out the facility selection process

Step One
Pre-select the facility type

Street and Section:

Cycle Facility
Pre-selection Nomograph



Traffic Volume:

Date and source:

Motor vehicle operating speed:

Date and source:

Nomograph Result:

Step Two
A more detailed look

Photo

This view shows the following relevant factors:

Describe Your Site:
The Table In Appendix B has descriptors from the following categories:

- Speed
- Volume
- Function
- Vehicle Mix
- On-street parking
- Intersection/access density
- Collision history
- Available space
- User skill
- User density
- Route function
- Project type
- Costs/funding

Check all that apply.

Select Rules:
From the column next to each checkmark, extract each rule.

Photo

This view shows the following relevant factors:

Photo

This view shows the following relevant factors:

Attach additional sheets if more documentary photos and data are required.

Step Three
Develop your rationale

If Step 1 yields a result different than Step 2 or if Step 1 is inconclusive, prepare a rationale for selecting a preferred option.

List the relevant rules:

Document your design considerations to support the rationale.

5.3 Step 1 - Pre-select the facility type

The facility pre-selection in Step 1 of the tool is intended to identify the most appropriate facility type based on two key safety risk factors: vehicle speed and volume. This is supported by the literature and appears appropriate for the Ottawa context. As such, the user is required to have the following information:

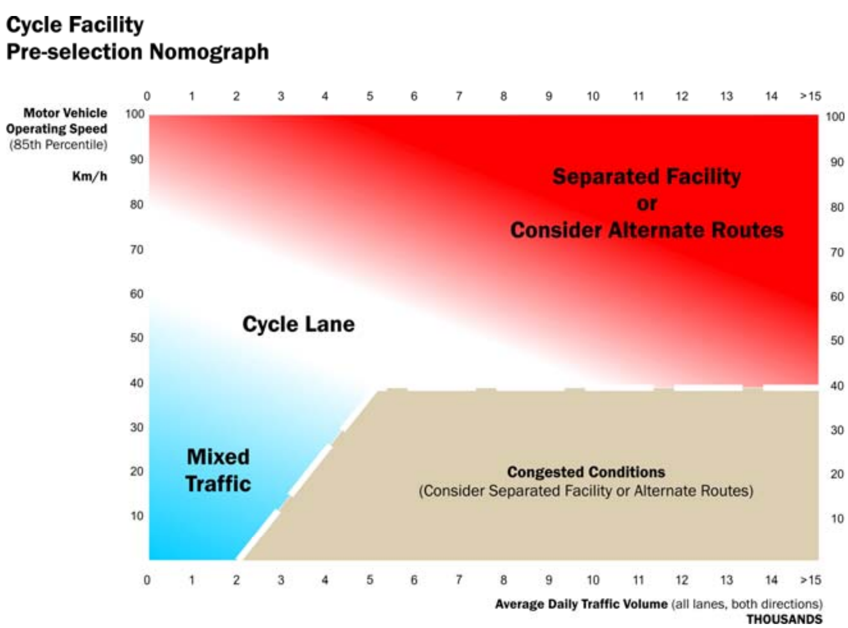
- Motor vehicle traffic volume (vehicles per day, in all lanes in both directions)
- Motor vehicle operating speed (85th percentile speed in km/h).

Based on the combination of motor vehicle volumes and operating speeds that are present along a given segment of roadway, and using the nomograph shown in Figure 23, the user can pre-select a cycling facility type[52]. There are five possible options - identified by the four colour patterns in the nomograph and are described as:

1. Mixed traffic (i.e. regular traffic lanes or wide curb lanes);
2. Cycle lanes or paved shoulders;
3. Separated cycling facility (high volume, low speed); and
4. Separated cycling facility (high volume, high speed); and
5. Consider an alternative route (due to high exposure to risk).

Once a facility type is identified, the user must proceed to Step 2 to complete a more detailed assessment of site-specific conditions.

Figure 23: Step 1 facility pre-selection nomograph



Source: Delphi-MRC, 2011

[52] The nomograph is also provided in Appendix A.

5.4 Step 2 – A more detailed look

After pre-selecting a cycling facility type that appears appropriate – given the speed and volume conditions – the user must then carry out a more detailed review of the site characteristics. This ensures in fact that the pre-selected facility type is compatible with the site conditions. Two things can happen when this step is carried out:

- Other facility types may emerge as being appropriate for the site under review; and

- Specific design considerations will likely be identified to suit the road segment.

As discussed earlier in Section 4.2, our project team has developed a set of facility selection rules from the literature and related them to specific site conditions. They include:

- Speed;
- Volume;
- Roadway function;
- Vehicle mix;
- On-street parking;
- Intersection and access density;
- Collision history;
- Available space;
- User skill level;
- Cycling demand;
- Function of cycle route;
- Type of improvement project; and
- Project cost/funding.

A detailed list of rules associated with these site conditions is contained in Appendix B. This table allows users to select (or check) each roadway characteristic that applies to the particular site. Once all the applicable characteristics are identified, the corresponding rule (i.e. located in the same line of the table) is pulled from the Appendix B table and assembled into a customized list of rules.

5.5 Step 3 – Develop your rationale

Once the customized list of rules for the site under review has been developed in Step2, the practitioner is required to review the list and determine if the rules are compatible with the pre-selected facility type in Step 1. For example, if the result of Step 1 is a “cycle lane” facility type, the user must review the list of rules (developed in Step 2) and determine if site conditions support cycle lanes. If not, the practitioner must consider another facility type that may be more compatible with site conditions.

The expectation is that once the user has completed all the steps in the tool, the user can make a final decision regarding the appropriateness of the facility type for the specific roadway section being evaluated. It is imperative that each decision made during the process is documented. In this way, the tool provides a consistent means of defending and documenting planning decisions.

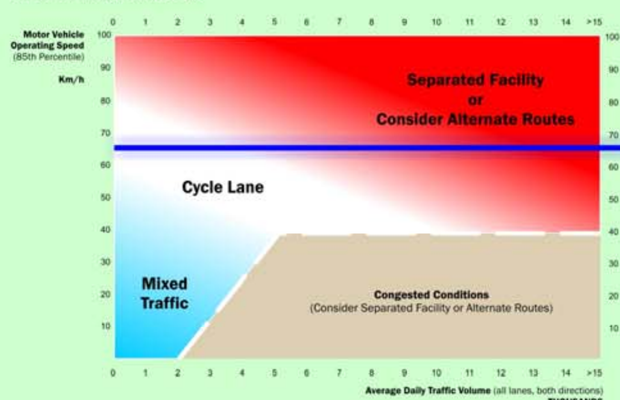
6 WORKED EXAMPLES

Figure 24: Worked Example 1

Step One
Pre-select the facility type

Example A: Maitland Avenue at Highway 417

Cycle Facility Pre-selection Nomograph



Traffic volume: 26,330 (data from City)
Operating speed: 65 km/h (observed)

Result: Consider Alternate Route or Separated Facility

Step Two
A more detailed look

This view shows the following relevant factors:

Speed: Moderate 55-65km/h

Describe Your Site:
The Table in Appendix B has descriptors from the following categories:

- Speed
- Volume
- Function
- Vehicle Mix
- On-street parking
- Intersection/access density
- Collision history
- Available space
- User skill
- User density
- Route function
- Project type
- Costs/funding

Check all that apply.

Select Rules:
From the column next to each checkmark, extract each rule.

This view shows the following relevant factors:

Traffic volume: High
Function: motor vehicle commuter route
Vehicle Mix: trucks
On-street parking: none
Intersection / access density: major intersections with high traffic volume

This view shows the following relevant factors:

Available space: physical barriers; curb-to-curb width is inadequate; sight distance limited
Current bicycle use: low

Step Three
Develop your rationale

If Step 1 yields a result different than Step 2 or if Step 1 is inconclusive, prepare a rationale for selecting a preferred option:

Consider an alternate parallel route to by-pass the "barrier" caused by the Highway 417 and the narrow bridge structure on Maitland Avenue. Explore opportunities to use the east-west NCC path (south of Highway 417) to connect Maitland Avenue to Clyde Avenue.

List the relevant rules:

See Table in Appendix B

Document your design considerations to support the rationale.

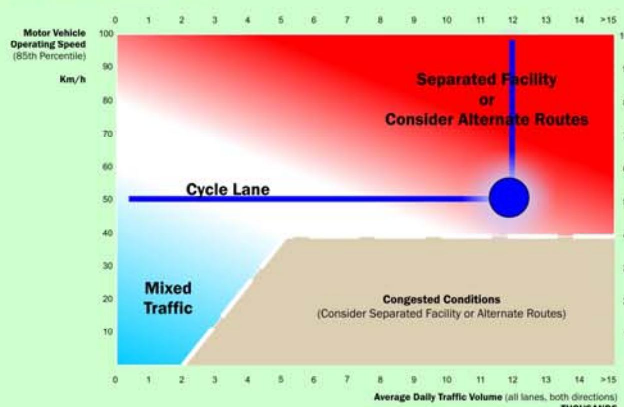
n/a

Figure 25: Worked Example 2

Step One
Pre-select the facility type

Example B: Bank Street
(from Echo Drive to Riverside)

Cycle Facility
Pre-selection Nomograph



Traffic volume: 12,000 vpd
Operating speed: 50 km/h

Result: Could be one of three options:
> cycle lane
> separated facility
> consider alternate routes

Step Two
A more detailed look

This view shows the following relevant factors:

Traffic speed: Low (30 to 50 km/h)
Traffic volume: High (> 10,000)
Function: mobility and access
Vehicle Mix: bus stops, buses, trucks
On-street parking: parallel on-street parking; high demand and turnover
Available space: sufficient curb-to-curb width for motorists and cyclists
Anticipated users: experienced cyclists
Level of bicycle use: high >50/hr

Describe Your Site:
The Table in Appendix B has descriptors from the following categories:

- Speed
- Volume
- Function
- Vehicle Mix
- On-street parking
- Intersection/access density
- Collision history
- Available space
- User skill
- User density
- Route function
- Project type
- Costs/funding

Check all that apply.

Select Rules:
From the column next to each checkmark, extract each rule.

This view shows the following relevant factors:

Function: direct access
Intersection / access density: numerous driveways

Step Three
Develop your rationale

If Step 1 yields a result different than Step 2 or if Step 1 is inconclusive, prepare a rationale for selecting a preferred option:

Bank Street is a north-south spine route. There are limited alternatives to this north-south route due to its location between the Rideau Canal and river. This area of the City is dense and well-established with numerous accesses and side-streets. Therefore, site conditions appear incompatible with a separated facility or an adjacent alternative route. Explore opportunities to implement a cycle lane.

List the relevant rules:

See Table in Appendix B

Document your design considerations to support the rationale.

Given the importance of vehicle parking for local merchants and residents, some form of on-street parking should remain on Bank Street. Explore opportunities to re-configure on-street parking or limit availability of on-street parking. This will make roadway width available for an exclusive space for cyclists – in the form of a cycle lane with an addition buffer if next to parking.

7 CONCLUDING THOUGHTS

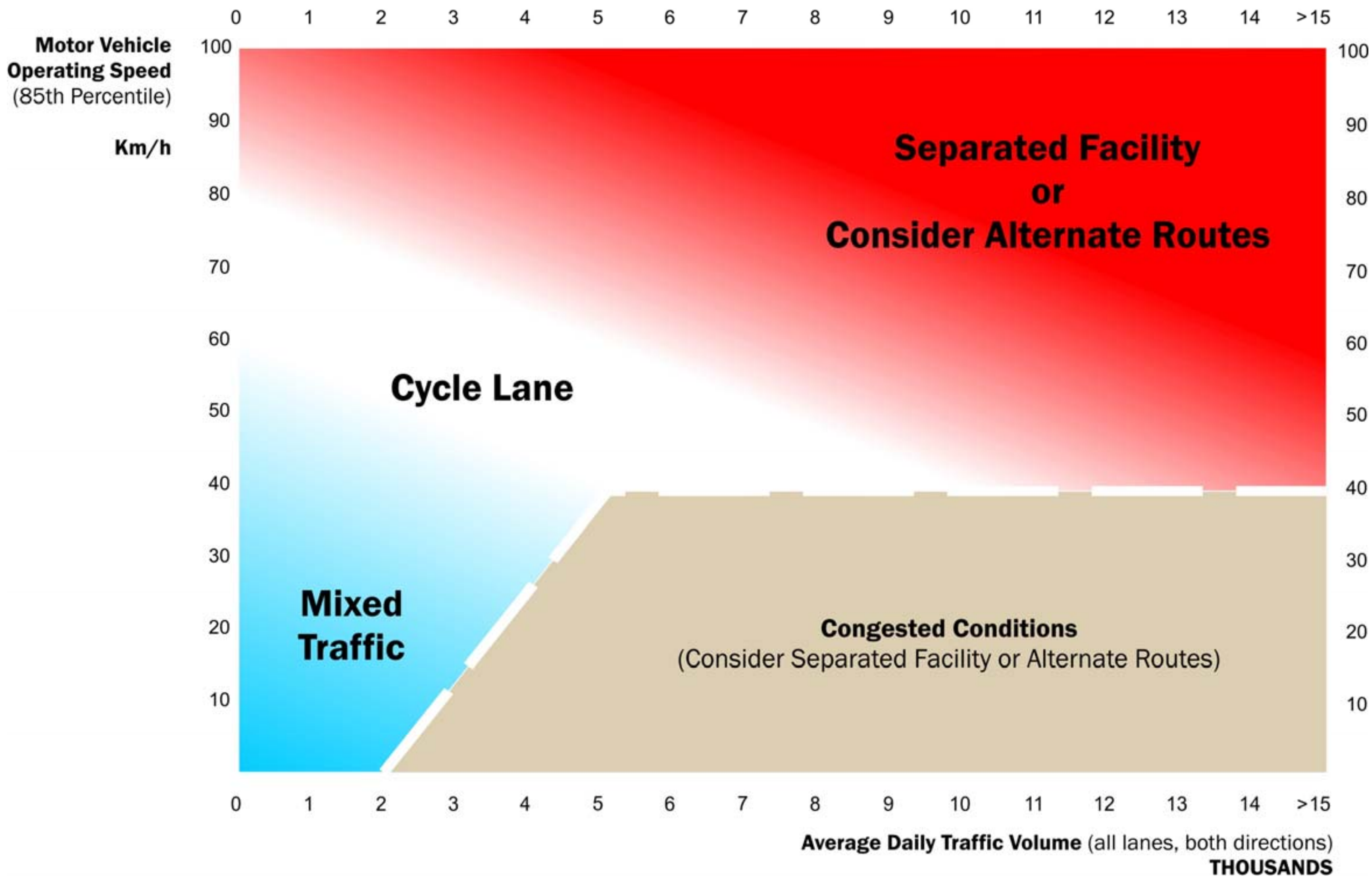
The technical basis for this tool is extensive and similar tools have been deployed elsewhere in Europe and Australasia with success. At its foundation is a consistent framework that is relatively easy to apply, is technically based and allows flexibility to account for the differences in physical and operational characteristics from one site to another. This tool represents a significant departure from the practical experimentation that has taken place across North America on the issue of segregated cycling facilities and changes how we look at facility selection and the principles behind our decisions.

Finally we note, the selection tool does not tell designers when and when not to provide a segregated facility. Rather it provides guidance on the use of a mixture of cycling facility types. Having a mixture of facility types that can be deployed using a consistent methodology is necessary to achieving both safe and comfortable cycling routes. Again, experiences elsewhere suggest that comfort and safety are key elements to a successful cycling network.

Appendix A

Step 1 - Facility Pre-selection Nomograph

Cycle Facility
Pre-selection Nomograph



Appendix B

Step 2 - A More Detailed Look: Site-specific Rules

Roadway Characteristics	Rules / Considerations
Motor vehicle operating speeds (85th percentile)	
Very low (less than 30 km/h)	Bicycles and motor vehicles operate at approximately the same speed. Formal bicycle facilities may not be necessary.
Low (30 to 50 km/h)	Speed differential between bicycles and motor vehicles is within 20 km/h, suggesting integration of the two modes as mixed traffic (in standard or wide curb lanes) may be appropriate.
Moderate (50 to 65 km/h)	Exclusive operating space for both bicycles and motor vehicles, in the form of wide curb lanes, cycle lanes, or separated facilities is recommended. Traffic calming and enforcement may be considered to manage motor vehicle volume and speed.
High (65 to 80 km/h)	Speed differential between bicycles and motor vehicles exceeds 40 km/h, suggesting physical separation of the two modes is most appropriate (i.e.
Very high (greater than 80 km/h)	Typical of rural highways and major urban thoroughfares, separated facilities with a buffer between the roadway and the bicycle facility are most appropriate. Alternatively, a parallel bicycle route should be explored.
Motor vehicle volumes	
Low (two-way daily average volume less than 3,000 vpd)	Mixed traffic may be appropriate if vehicle speeds are also low. Curb lanes should be as wide as possible.
Moderate (two-way daily average volume 3,000 to 10,000 vpd)	Some level of formal bicycle facility (cycle lanes or separated facility) is recommended.
High (two-way daily average volume greater than 10,000 vpd)	Physical separation of motor vehicle and bicycle traffic (i.e. separated facility) may be most appropriate.
Hourly one-way volume in the curb lane exceeds 250 vph	Some level of formal bicycle facility (cycle lanes or separated facility) is recommended.
Function of street/road/highway	
Access (local roads, residential streets)	Mixed traffic may be appropriate if speeds and volumes are low. Curb lanes should be as wide as possible.
Mobility (arterials, major collectors)	Some level of formal bicycle facility (cycle lanes or separated facility) is appropriate.
Both mobility and access (many collectors, other roads and streets)	Some level of formal bicycle facility (cycle lanes or separated facility) is appropriate.
Motor vehicle commuter route	Separated bicycle facilities should be considered to minimize conflicts with aggressive drivers on the roadway.
Vehicle mix	
More than 30 trucks or busses per hour are present in a single outside lane	Separated bicycle facilities may be preferred by many cyclists. If wide curb lanes or cycle lanes are considered, additional width should be provided as a
Bus stops are located frequently along the route	Facilities should be designed to minimize and clearly mark conflict areas between cyclists and busses/pedestrians at stop locations.
On-street parking	
Parallel on-street parking is not permitted	Opportunities to provide wide curb lanes or cycle lanes, as well as their appropriateness should be explored.
Parallel on-street parking is permitted in localized areas along the route	Consistent cycle lanes may prove difficult to provide as available roadway width is likely to change where parking is provided. Wide curb lanes may be an acceptable solution.
Parallel on-street parking is permitted but demand is low	Opportunities to remove, restrict, or relocate parking in favour of providing cycle lanes should be considered.
Parallel on-street parking is permitted but turnover is low	Cycle lanes may be appropriate. Additional buffer space between bicycle and parking lanes should be provided.
Parallel on-street parking is permitted; turnover and demand is high	Separated bicycle facilities or alternate routes may be most appropriate. Cycle lanes are not desirable in this situation due to frequent conflicts with parking
Perpendicular or diagonal parking is permitted	On-road facilities are not appropriate unless parking is reconfigured or removed. Alternate routes or opportunities to provide a separated facility should be
Intersection/access density	
Limited intersection and driveway crossings are present along the route	Separated facilities or cycle lanes are well suited to routes with few driveways and intersections.
Numerous low volume driveways and/or unsignalized intersections are encountered	Wide curb lanes or cycle lanes may be more appropriate than separated facilities as motorists are more likely to be aware of cyclists on the roadway than adjacent to the road.
Numerous high volume driveways and/or unsignalized intersections are present along the route	Separated facilities are generally not preferred in this situation; cycle lanes or wide curb lanes may be more appropriate. Crossings should be designed to minimize conflicts; additional positive guidance/warning measures should be considered to warn cyclists and motorists of conflicts.
Major intersections with high speed and traffic volumes are encountered	Consider provision of cycle lanes, advance stop lines, and exclusive bicycle signal phases at major intersections; consider hook/indirect left turn treatments if there is significant bicycle left turn demand conflicting with through motor vehicle traffic. If a separated facility is being considered, crossings should have bicycle traffic signals with exclusive phases and conflicts should be clearly marked.
Collision history	
Bicycle collisions are relatively frequent along the route	A detailed safety study is recommended. Alternate routes should be considered. Separated facilities may be appropriate to address midblock conflicts. If on-road facilities are considered, the operating/buffer space provided to cyclists should be enhanced.
Bicycle collisions are relatively frequent at specific locations	Localized design improvements should be considered to address contributing factors at high-collision locations (often near intersection and driveway
Noticeable trends emerge from bicycle collisions	Proposed facility and its design should attempt to address noticeable collision trends (refer to the FHWA's BIKESAFE as one potential source of safety countermeasures).
Conflicts exist between cyclists and other modes (i.e. motor vehicles, pedestrians)	Facilities and crossings should be designed to minimize conflict between different types of users and the conflict area should be clearly marked.
Available Space	
Sufficient curb-to-curb width exists to adequately accommodate motorists and cyclists	Redistribute roadway space to accommodate cycle lanes or wide curb lanes by narrowing/eliminating parking lanes, narrowing travel lanes, eliminating unnecessary turn lanes, etc.
Sufficient curb-to-curb width exists, but pinch points are created where turn lanes are developed at intersections	Cycle lanes may be discontinued (with appropriate positive guidance/warning measures) upstream of intersections to encourage cooperative merging of cyclists and motorists into a single traffic lane through intersections. Sharrow markings can be used to denote desirable cyclist path through narrow intersections. Refer to TAC Bikeway Traffic Control Guidelines for Canada for design recommendations.
Physical barriers are created by steep grades, rivers, freeways, railways, narrow bridges, etc.	Separated facilities should be considered to bypass or overcome barriers.
Curb-to-curb width is not adequate to provide adequate operating space for both motorists and cyclists	Provide separated facilities adjacent to the roadway or within independent right-of-way, widen roadway platform to accommodate cycle lanes or wide curb lanes, or examine alternate routes. If on-street parking is present, explore opportunities to eliminate or reduce parking.
Sight distance is limited at intersections, crossing locations, or where cyclists and motor vehicles share limited road space	Improve sightlines by improving roadway geometry or removing/relocating roadside furniture and vegetation; provide adequate space for cyclists either on or off the roadway. Design intersection crossings to minimize and clearly mark conflicts and restrict parking in close proximity to intersections.
Anticipated users (skill, trip purpose)	
Experienced/advanced cyclists (commuters/utilitarian)	This group generally prefers direct, continuous facilities with minimal delay as is generally provided by the arterial road network. Wide curb lanes may be
Basic/novice cyclists (recreational)	This group generally prefers routes on residential, neighborhood streets with light traffic and low speeds. Wide curb lanes, cycle lanes, and separated facilities should be considered.
Child cyclists	This group generally requires separated facilities free of conflicts with motor vehicle traffic. Separated facilities should be considered near schools, parks, and neighborhoods.
Level of bicycle use	
Presently low bicycle volumes (< 10 per hour)	Wide curb lanes may be adequate.
Presently high bicycle volumes (>50 per hour)	Cycle lanes may be appropriate. Provided width should accommodate bicycle volumes during peak periods both mid-block and at intersections.
Significant bicycle traffic generators are nearby	Latent bicycle demand may exist if there are employment centres, neighborhoods, schools, colleges, parks, recreational and shopping facilities along the route. Cycle lanes and separated facilities should be considered to accommodate anticipated levels of cyclists.
Function of route within bicycle facility network	
Parallel bicycle routes already exist with bicycle facilities present	Redundancy of bicycle routes may provide an opportunity to provide different types of bicycle facilities within the same travel corridor, providing options for cyclists with different skill levels and trip purposes.
New route provides a connection between adjacent existing facilities	Facility selection should provide continuity with adjacent bicycle facilities to the extent possible.
New route provides district level access to a neighbourhood, city region, suburb, etc.	Cycle lanes and separated facilities should be considered to encourage cycling for all users.
Type of Roadway Improvement Project	
New construction	Appropriate bicycle facilities should be planned and integrated with design and construction of new roads and communities.
Reconstruction	Major roadway reconstruction provides an opportunity to improve provisions for cyclists through increased roadway width or off-road space with considerable cost savings.
Retrofit	Affordable solutions may be limited to redistributing existing road space.
Costs/Funding	
More than one type of bicycle facility appears appropriate	Benefit/cost analysis of alternatives should be conducted. Refer to NCHRP Report 552 - Guidelines for Analysis of Investments in Bicycle Facilities.
Funding levels are not available to provide preferred type of facility	Consider alternate routes or focus on cost-effective improvements to existing facilities such as improved maintenance, pavement/drainage rehabilitation, and removal of barriers. Poorly designed or constructed facilities may result in increased safety risks for cyclists and are unlikely to encourage additional