Safe Roads for Cyclists: An Investigation of Australian and Dutch Approaches

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Key Findings

- Austroads cycling guidelines do not coincide with best practice principles
- Non-compliant cycling facilities in Melbourne impact safety and network continuity
- Connecting cycling infrastructure would increase cyclist safety and amenity

Abstract

In countries with high cycle mode share, separated infrastructure and low speeds are fundamental to creating a safe cycling environment. The Dutch approach to cycling design is an exemplar of best practice accredited with contributing to the success of high cycle mode share in The Netherlands. The aim of this study was to assess the Australian approach to bicycle infrastructure against the Dutch principles, and investigate conditions on the road. This pilot study used a mixed method approach and was conducted in two parts: 1) a desk-based comparison of the cycling-related road design guidelines in The Netherlands and Australia and, 2) case studies of two primary access routes to a major commuter destination in suburban Melbourne (Monash University). Key differences between the Australian and Dutch approaches were identified from the respective design guidelines for shared-priority local streets, mid-block sections on arterial roads, and at intersections. The Dutch approach requires physical separation between bicycles and cars in most cases, whereas Australian guidelines focus on the details of design rather than an overarching principle of separation. On road, the case study routes were only partially compliant with Australian guidelines with considerable gaps along the route. Potential changes to the Australian guidelines in relation to the Dutch approach and further research are presented.

Keywords

cycling, infrastructure guidelines, Australia, Dutch best practice, safety

Introduction

Globally cities are facing issues with mobility and vehicle congestion as increasing urbanisation impacts safe and efficient travel (Li and Faghri, 2014). Decades of prioritising road space to motor vehicles has led to ‘induced demand’, an economic theory which explains how increased supply leads to increased demand (i.e. more roads leads to more people driving; Næss et al, 2012). This has contributed to a range of negative unintended consequences (e.g. vehicle congestion, extended travel times, vehicle emissions etc). Internationally, cities are shifting their transport focus from the movement of motor vehicles, to the movement of people. Bicycle transport can provide an attractive means of moving people, particularly over short trips (up to 8km) or as a part of longer multi-modal trips. It enables more flexible use of the road, relieves traffic congestion, improves urban mobility, and can deliver public health benefits.

Benefits of cycling for transport are well-documented (Oja et al, 2011) however, Australia’s uptake of cycling as a transport mode is low when compared with northern European countries including The Netherlands, Denmark and Germany (Pucher and Buehler, 2008; Pucher et al, 2011). The nation-wide proportion of commute trips made by bicycle remained stagnant between 2011 (1.2%) and 2016 (1.1%) (ABS 2017). A wide range of barriers are postulated to contribute to the low modal share of cycling, including perceived risk, trip distance, inconvenience and Australia’s historic affinity for the private motor vehicle. However, two key factors facilitating ridership in successful cycling countries is the provision of a connected network of separated cycling infrastructure (Pucher and Buehler 2008; Marques et al, 2015) and low speed limits (e.g. 30kph) (Wooldridge et al, 2016).

Internationally, there is evidence supporting the effectiveness of enhanced cycling infrastructure in generating increased ridership. New on-road separated bicycle lanes enhanced comfort for both cyclists and motorists in Portland, Oregon, USA (Monsere et al, 2012). In Seville, Spain, an overhaul of the city’s bicycle infrastructure between 2006 and 2011 led to significant benefits (Marques et al, 2015). In Australia, studies of specific, local treatments concur; Heesch et al.

(2016) reported accelerating growth of seasonally-adjusted monthly bicycle counts (88 to 178) following the opening of Brisbane's V1 Veloway. However, action is needed at a network level with a positive correlation reported between cycling levels and policy, program and infrastructure interventions, highlighting a comprehensive network to increase ridership compared with localised treatments (Buehler and Dill, 2016, Pucher et al, 2010).

In Australia, while local treatments continue to be implemented, connected, networked cycling infrastructure provisions are lacking. Current provisions along roads in midblock sections and at intersections present risk to cyclists and compromise comfort and convenience. Such deficiencies violate key principles supporting cycling participation (Pucher et al, 2011; Mulvaney et al, 2015; Stevenson et al, 2015). This is in part confounded by the governance structures that oversee infrastructure in Australia.

Strategic Context and Cycling Planning Authorities

All road infrastructure in Australia comes under the governance of the National Road Safety Strategy 2011-2020 (Australian Transport Council, 2016), modelled on the Safe System approach. This approach recognises that people will make mistakes when using the road, and that our bodies can only withstand a finite amount of force before suffering injury or death. The road transport system must aim to minimise crash occurrence and severity through four key pillars: safe roads, safe speeds, safe vehicles and safe people. Alongside the NRSS, the National Cycling Strategy 2011-2016 was overseen by the Australian Bicycle Council (ABC). Following a 2017 review, the ABC is to be re-formed as a Cycling and Walking in Australia/New Zealand (CWANZ) working group, with no immediate aim for a replacement strategy (ABC, 2017).

National road design guidelines are incorporated into the *Austroads Guides to Road Design* volumes, which aim to apply a Safe System approach to road design through Safe Roads. The *Cycling aspects of Austroads guides* document (Austroads, 2017) brings together cycling-specific components from all Austroads volumes and is the primary resource for practitioners designing bicycle infrastructure in Australia (VicRoads, 2017a; Bicycle Network, 2015). It is not well-explored, however, how this volume correlates with the overarching Safe System principles, or with international best practice.

State road authorities and municipalities produce additional standards for their jurisdictions. In Victoria, VicRoads publishes supplementary bicycle infrastructure guidelines in their Traffic Engineering Manual (VicRoads, 2016a; VicRoads, 2016b) and municipalities (local government) define objectives within their respective transport strategies. This multi-layered approach creates difficulties for infrastructure planners and designers when seeking an optimal design solution for a given project, especially when connecting a route across municipalities.

Dutch Design Approach

Internationally, the Dutch approach is recognised as best practice in cycling provision (Pucher and Buehler, 2008; Portland Bureau of Transportation, 2010). Cyclist fatality rates in the Netherlands the lowest in the world, estimated at 1.0 per 100 million kilometres cycled, compared to 1.1 in Denmark, 2.5 in the United Kingdom and 4.7 in the United States of America (Buehler and Pucher, 2017), hence the Dutch *Design manual for bicycle traffic* (CROW, 2007) was used as the best practice reference.

The Dutch design approach is underpinned by five requirements for cyclist amenity (CROW, 2007). These are repeated throughout the manual to inform all infrastructure design choices:

- Safety: bicycle infrastructure uses separation to protect vulnerable cyclists
- Cohesion: the network is connected and links key destinations

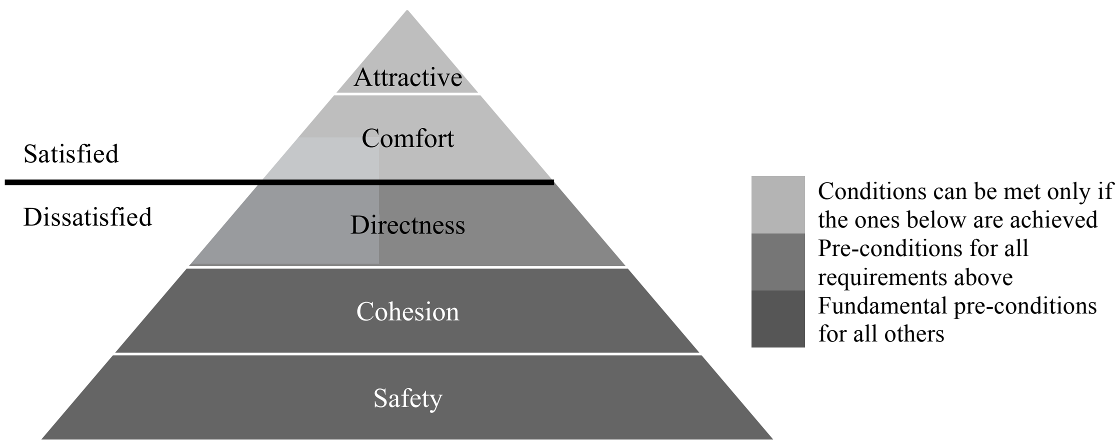

Figure 1. Dutch requirements for cycling amenity (Adapted from: Scheltema, 2012)

- Directness: the network provides a route which is direct in both space and time
- Comfort: the network makes cycling less complex and require less exertion
- Attractiveness: network provisions address individual barriers to cycling

Scheltema (2012) used Maslow's hierarchy as a model to structure these principles as a hierarchy that requires each stage to be fulfilled before amenities are satisfactory for cycling (Figure 1). With safety, cohesion and directness the minimum requirements.

Study Aims

This study comprised two primary aims:

1. To assess how Australian design guidelines for cycling infrastructure compare with international best practice and the overarching Safe System principles, and
2. To identify areas for improvement in physical infrastructure to align with Australian guidelines and international best practice principles.

Methods

A mixed method approach was used, including:

1. A desk-based analysis to compare infrastructure guidelines, addressing aim 1, and
2. A case study component, utilising on-road naturalistic observations and subsequent infrastructure assessment, addressing aim 2.

Component 2) considered on-road infrastructure connecting to Monash University's Clayton Campus, a major destination in the bicycle network in the south-eastern suburbs of Melbourne. A 2016 online travel mode survey found that around 4% of students accessed the University by bicycle (Sift Research, 2017). On a weekday in March 2017, 465 cyclists were counted entering the University between 8am and 11am (Monash University, 2017).

Comparison of Cycling Infrastructure Guidelines

This component of the study sought to highlight the general areas in which cycling components of Australian cycling infrastructure design guidelines do and do not meet international best practice.

Comparison of infrastructure guidelines is made using two key sources:

Australian approach: *Cycling aspects of Austroads guides* document (Austroads, 2017)

Best practice approach: Dutch *Design manual for bicycle traffic* (CROW, 2007).

For brevity, only selected road types and bicycle infrastructure treatments were considered. Selection of road types was informed by the study locality (around Monash University) to compliment the case study component. Specific road types included in this component are: local streets (default urban speed limit, 50kph); access roads (50kph); arterial roads (60, 70, 80kph); and intersections between these road types.

Selected infrastructure types included mid-block treatments (exclusive bicycle lanes), intersection provisions (approach and departure bicycle lanes), and shared car/bicycle priority on local streets (LATM – Local Area Traffic Management techniques). These types were selected due to being prevalent in the study locality.

Infrastructure types not considered in this comparison include, but are not limited to; roundabouts, off-road shared paths, shared bicycle/bus lanes and grade-separated crossings.

On-Road Naturalistic Case Studies

The major cycling routes into the University were investigated. Ten key routes were selected using the Monash City Council *Walking and cycling map*, which is publicly available for cycle trip planning in the area. The routes vary in length from 1.7-3.3 km and are indicated on the locality map (Figure 2). Several alternative routes were excluded due to high traffic speeds (70-80kph) and a lack of cycling infrastructure provision.

An author (JD) collected naturalistic observations by undertaking a saddle survey – cycling each of the routes and recording front-facing video footage with a handlebar-mounted camera. The camera also recorded GPS data, hence capturing the rider's speed and precise location. Where a bicycle lane was provided, its width was measured during the survey. Following the survey the author recorded lived-experience notes, detailing the relevant comfort of cycling through each location.

Two of the selected routes were isolated for temporal-snapshot case study analysis. These lie on a Strategic Cycling Corridor (SCC) (VicRoads, 2017b), have been the subject of earlier work (Reid and Rose, 2013; Safe System Solutions, 2015; Safe System Solutions, 2017) and vary considerably in relation to speed, traffic volume and composition. This enabled current deficiencies and potential upgrades to be highlighted on distinctly different road types. Case Study routes are marked as solid lines on Figure 2.

Case study 1

This route is 2.1 km long with varied speed zones (50kph, 60kph) and varied road cross section along its length (4 lane divided arterial road, 2 lane undivided collector street). This route has key intersections with the Monash Freeway interchange and Ferntree Gully Road. Published AADT data (VicRoads, 2017c) was obtained for arterial roads traversed on this route. Inbound and outbound routes were assessed individually.

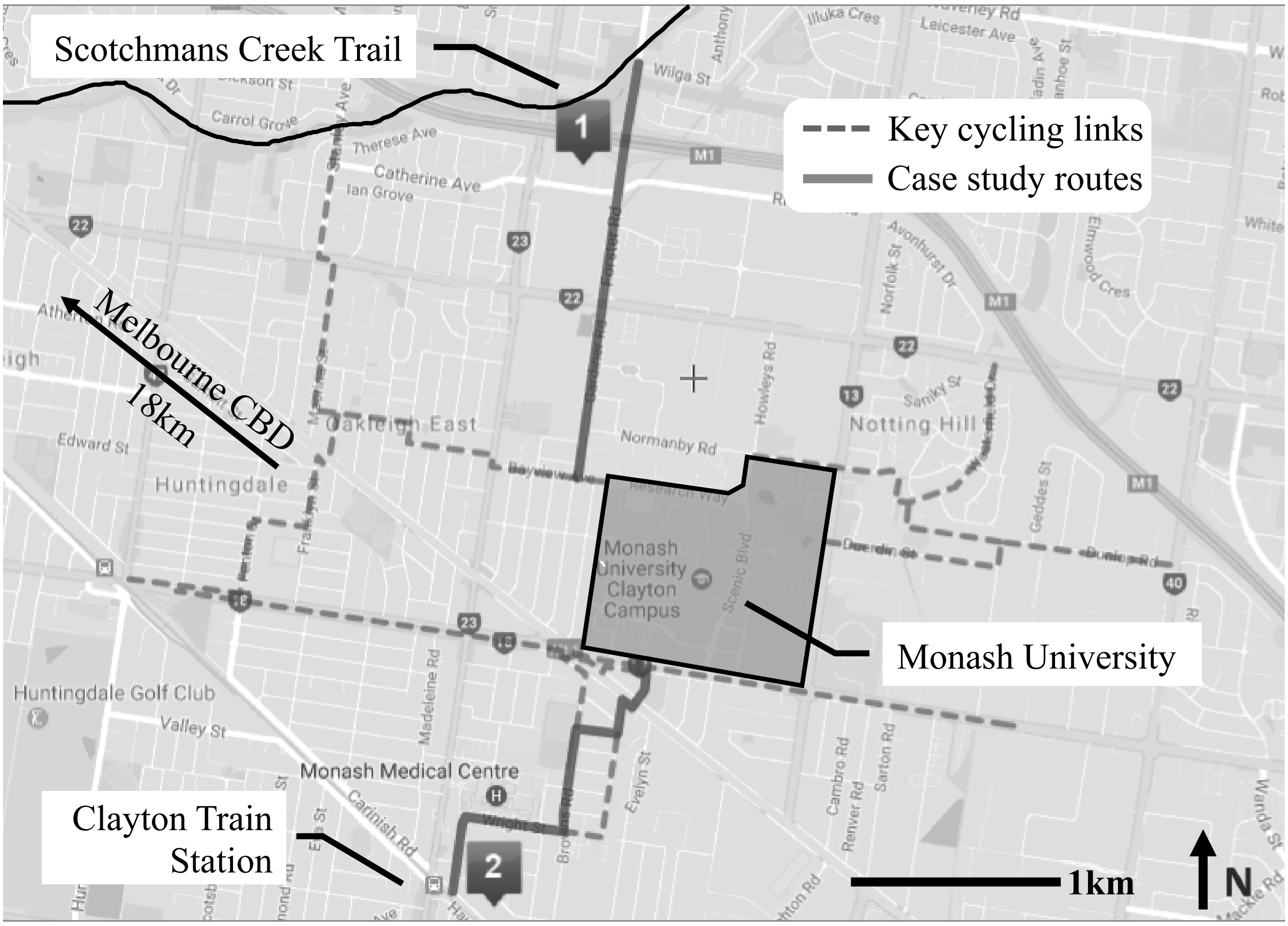

Figure 2. Locality map identifying case study routes and major destinations
(Source: Scribble Maps, 2017)

Case study 2

This route is 2.1km long and links Clayton train station with the University via local roads (50kph, 40kph). Key intersections include Princes Highway and Wellington Rd. AADT data was not available for the roads on this route, however traffic volumes are estimated to be considerably lower than Case Study 1.

Case study road segment classification

Both routes were classified into segments (in Figures 3 and 4) according to the current infrastructure types, then each segment coded by their compliance with Austroads:

Boxed: compliant with Austroads guidelines, although in some cases CROW recommended an alternate treatment.

Dashed: partially compliant with Austroads.

Solid: non-compliant with Austroads. Upgrade works required for compliance with Austroads and best practice guidelines.

Criterion used to assess road segments include: approximate traffic volume (where available), speed limit, road cross-sectional configuration, and presence or absence of adjacent car parking. Finally, segments were assessed against the CROW manual to identify the best practice infrastructure treatment for that location.

Results

Comparison of Australian and Dutch guidelines

A system level approach was used to identify the overarching Austroads principles for providing a safe and continuous bicycle network and assess these against the Dutch approach detailed in the CROW manual. Of the road types assessed, Austroads design guidelines for physical infrastructure were found to be consistent with the Dutch manual in several areas. Both documents recommend on-road bicycle lanes in similar situations, and both suggest off-road kerb-separated cycle tracks in other scenarios.

Network considerations

Austroads identifies the importance of a network in linking major destinations via desire lines but the topic is covered briefly. The five Dutch main requirements are reproduced with limited detail in the introductory chapter. Network connectivity is mentioned briefly in guidelines for mid-block and intersection treatments, but does not regulate design.

The CROW manual takes a movement and place approach and dedicates an entire chapter to network planning. It states that network significance should inform site-specific design in all cases and includes detailed network modelling techniques to advise policy and decision-making. The five main requirements are used to assess both specific designs and wider network characteristics.

Local streets

Local streets form significant links within bicycle networks due to their separation from high speed and high traffic routes. Both manuals recommend either wide lanes which allow motor vehicles to pass cyclists, or narrow lanes which force drivers to travel behind cyclists.

Austroads does not give detailed guidelines for local streets. Instead, it targets a 40kph speed limit and suggests LATM treatments to meet this goal while protecting cyclist amenity. It is important to note that in most local streets in Victoria, the current default speed limit is actually 50kph. Bicycle-friendly speed bumps are recommended and horizontal speed control measures are discouraged as they create a squeeze point for cyclists. Austroads does not account for unregulated kerbside parking.

CROW has similar goals for this road type, with a 30kph speed limit and shared priority between bicycles and cars. A parking lane or indented parking bays should be delineated if parking is allowed along greater than 20 percent of the road length. A critical reaction strip is recommended between the parking and traffic lanes, to prevent cyclists being hit by opening car doors.

Mid-block treatments on arterial roads

50kph roads: Austroads stipulates that separation of bicycle and motor vehicle traffic should occur when the design speed differential is greater than 20kph. However, no detail is given for provisions on 50kph roads. CROW considers a 50kph road as a major district access road, requiring bicycle lanes on roads with one traffic lane each way (2x1) and a separated "cycle track" on roads with two traffic lanes each way (2x2).

60kph roads: Exclusive bicycle lanes are generally recommended by Austroads on 60kph roads, including additional width allowance for a bike lane adjacent to a parking lane. Both documents stipulate a lane width requirement of between 1.2-2.5m. CROW specifies lanes narrower than 1.2m pose significant safety risks to cyclists and recommends a kerb-separated, dedicated cycle track. Bicycle lanes alongside parallel motor vehicle parking are not recommended.

70 and 80kph roads: Recommendations differ significantly on high-speed arterial roads. Austroads allows on-road cycling provisions without separation, whereas CROW stipulates that on-road bicycle infrastructure is not permissible for speeds of 70kph and above. Austroads recommends an on-road bicycle lane with desirable minimum width of 2m but also permits a wide kerbside traffic lane with desirable minimum width of 4.5m. CROW requires high-speed roads to have either a separated cycle track adjacent to the road, or a service road on the same alignment.

Intersections

There are several important distinctions about intersection road user hierarchy between the Australian and Dutch approaches.

Austroads guidelines primarily consider cyclist safety at intersections, listing a range of key concerns: squeeze points; left-turning vehicle conflicts; areas where motor vehicles converge or diverge; lack of continuity in protected infrastructure and, gaining position to turn right. The Dutch approach begins with safety and extends to include all five requirements for cyclist amenity with detailed intersection treatments. A roundabout is almost always the preferred intersection type with signalised intersections only suitable for high traffic volumes (10,000-30,000 motor vehicles/day), providing inferior safety outcomes to roundabouts.

Signalised: Austroads provides a range of intersection layout plans to mitigate safety concerns. Both documents recommend bicycle lanes on approach to a signalised intersection. The notable difference is a physical kerb barrier separating cyclists and motorists in the Dutch treatment.

Unsignalised: Both guidelines show bicycle lane continuation through an unsignalised T-intersection. Solid linemarking changes to dashed across the intersection, and pavement colour may be applied. Alternatively, CROW details a separated cycle track, skewed away from the major leg across an intersection, allowing vehicle stacking space on the minor leg.

On-Road Naturalistic Case Studies

Case Study 1: Link from major off-road cycling corridor to the University

Figure 3 shows the segment classifications along Case Study 1 and Table 1 details compliance with Australian and Dutch guidelines. Of the 4.3km surveyed, half (51%) was not compliant with Austroads standards. Five segments were Austroads compliant and provisions at three intersections were non-compliant.

On six non-compliant segments, cyclists must share the lane with high-speed traffic or ride on the footpath (illegal in Victoria) (segments 4, 14; 6, 12; 8, 9). Cycle travel was classified as comfortable in bicycle lanes. In segments where conditions positioned cyclists alongside parked cars, caution was taken to ride outside the car door zone (segments 5, 11).

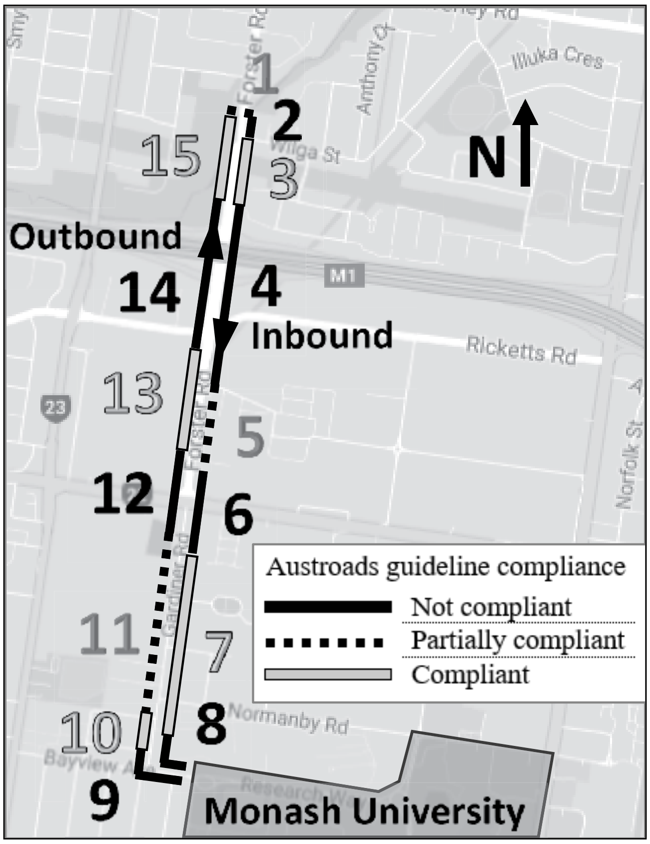

Figure 3. Case Study 1 classification
(Source: Google Maps, 2017)

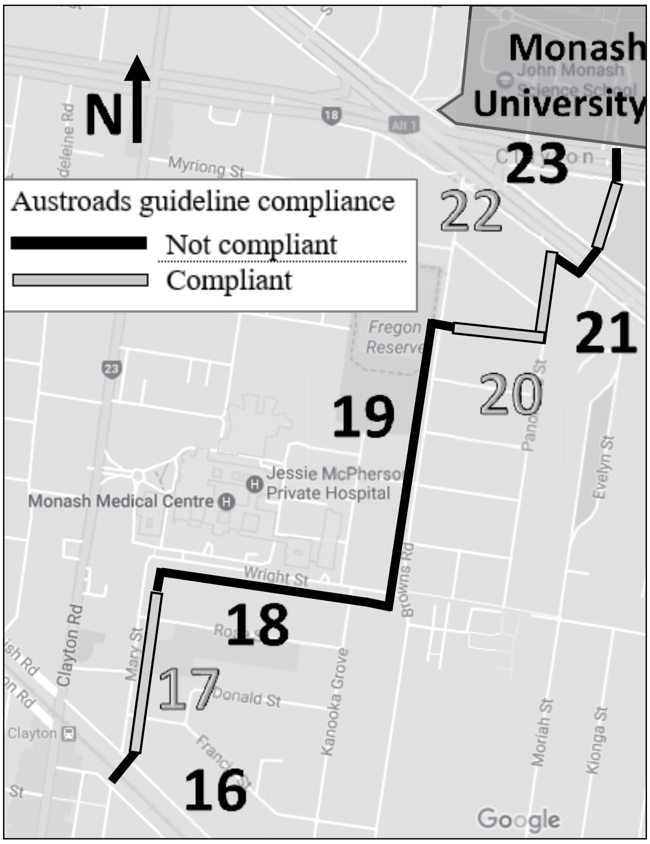

Figure 4. Case Study 2 classification
(Source: Google Maps, 2017)

Two intersections were noted points of perceived low safety. 1) Monash Freeway, due to confusion caused by unclear/lack of signage (segments 4, 14). 2) Ferntree Gully Rd, due to concern for vehicle conflicts (segment 6) and while queuing among traffic and when leaving the hold line after the traffic signal turned green (segment 12).

Case Study 2: Local streets from Clayton train station to the University bus interchange

Of the 2.0 km surveyed, the majority of the route was not compliant with Austroads standards (60%). No segments were partially compliant (Figure 4). There is currently no dedicated bicycle infrastructure along on this route. Segments 17, 20 and 22 are deemed compliant as shared-priority local roads with low speeds and low traffic volumes.

Safety outcomes are not met on Segment 18 due to frequent short-term parking movements and the narrow cross-section with a high potential for conflicts.

Segment 19 was not compliant due to potential high traffic volumes. Intersections between local road segments are generally non-compliant due to lack of shared priority markings. Speed bumps were effective in slowing traffic, and the narrow road width appeared to discourage unsafe overtaking manoeuvres.

There are currently no cycling provisions at the two major intersections (segments 16, 21). Within Segment 23, cyclists share a signalised crossing with high volumes of pedestrians. Perceived safety was low along segments 16 and 21 due to the lack of crossing facilities. These points are major barriers along this route.

Discussion

The differences in philosophy between the Dutch approach and the Australian approach for positioning cyclists on the road reflects differing historical, cultural and political factors underpinning current road safety practices in the two countries. These differences were explored by Pucher and Buehler (2008) who reported that The Netherlands are set apart through right of way legislation, cyclist and motorist education programs and cycling promotion efforts, alongside measures to de-incentivise motorised transport. Key elements of the Australian approach are contrasted below. In addition, the inclusion of the case studies extends this study beyond a theoretical review to practice and identifies some of the gaps between best practice (Dutch), approved practice (Austroads) and reality (on-road).

Table 1. Case Study 1 Mid-block and intersection connectivity

Seg.		Length (m)	Speed (kph)	AADT (vpd)	Current provisions	Austroads		Dutch (CROW)	
						Exclusive lane	Cycle track	Exclusive lane	Cycle track
1	• • •	20	60	-	No bike priority	-	-	-	-
2	▬	120		2600	None	++	+	+	++
3	▭	130			2.5m exclusive lane	++ ▭	+	+	++
4	▬	615		5400	None	++	+	+	++
5	• • •	165			1.4m bicycle lane, 2.2m adjacent parking lane	++	+	+	++
6	▬	310		-	None	++	x	++	x
7	▭	630	50	-	1.8m exclusive lane	++ ▭	+	++	+
8	▬	185		-	None	+	++	+	++
9	▬	215		-	None	++	x	++	x
10	▭	185			1.8m exclusive lane	++ ▭	+	++	+
11	• • •	425		-	2.2m shared parking lane	++	+	++	+
12	▬	280	60	5400	None	++	x	++	+
13	▭	295			1.6m exclusive lane	++	+	+	++
14	▬	500			None	++	+	+	++
15	▭	260	60	2600	2.2m exclusive lane	++ ▭	+	+	++

Legend: ++ Optimal outcome; + Potentially suitable outcome; x Unsuitable outcome; - Not available

Table 2. Case Study 2 mid-block and intersection connectivity

Seg.		Length (m)	Speed (kph)	Current provisions	Austroads		Dutch Guidelines
					Mid-block	Intersection	
16	▬	20	60	None Unsignalised	N/A	Separated POS	Raised, separated cycle track crossing
17	▬	320	40	40kph speed	40kph shared	N/A	30kph, shared bicycle/car priority
18	▬	490	50	None Parking lane	40kph shared	Sharrows	30kph, shared bicycle/car priority Separated parking lane
19	▬	495	50*	None	Exclusive lane	Sharrows	Exclusive lane or cycle track
20	▭	350	50*	None	40kph shared	N/A	30kph, shared bicycle/car priority
21	▬	110	80	None	Contra-flow lane	Separated POS	POS or grade separated crossing
22	▭	130	50*	None	40kph shared	N/A	30kph, shared bicycle/car priority
23	▬	80	80	Shared POS	Bike priority	Separated POS	POS or grade separated crossing

Legend: 40 - Posted 40kph; 50* - Default 50kph; POS - Pedestrian Operated Signals; N/A - Not applicable

Comparison of Bicycle Planning Approaches

Bicycle planning in The Netherlands is based on their five main requirements. These principles prioritise cyclists as well as recognising their physical vulnerability.

Australia's current road management approach is built on the four pillars of "Safe System" (safe roads, safe speeds, safe vehicles and safe people). The *National Road Safety Strategy* seeks to reduce the likelihood and severity of road crashes through targeting these four pillars (TIC, 2010). The Safe System approach is predominantly incorporated in Australian design guidelines through safe roads and safe speeds. Safe vehicles requirements offer some protection to cyclists (e.g. Auto Emergency Braking) but this is undermined as motor vehicles currently being rated by the ANCAP tests as 'five star', are rated as marginal in pedestrian protection tests (ANCAP, 2017). Safe people can be targeted through policy and education programs and importantly safe behaviour can be an outcome of responding to inclusive infrastructure.

Safety

At a policy level, the Australian strategic framework has a strong emphasis on safety. However, several aspects of the guidelines for mid-block and intersection bicycle infrastructure did not meet Dutch best practice recommendations. Furthermore, treatments for cyclists on roads assessed in the study locale did not reflect Austroads guidelines or Safe System strategic outcomes.

Pucher and Buehler (2017) compared trends in cyclist fatalities per 100 million km travelled in the Netherlands, Denmark, the United Kingdom and the USA to demonstrate the relative safety of Dutch cycling. Johnson (2010) reported that Australian cycling data is limited and problematic and unlikely to accurately determine a comparable fatality rate. This is a significant gap in Australian data and should be filled to inform and guide widespread reform to improve outcomes for cyclist safety.

Cohesion and directness

The CROW manual targets the network holistically when designing and recommending site-specific treatments. Facilities must link up to provide a holistic route, and provide directness in both space and time. Austroads guidelines were found to have less focus on continuity, with some discussion of spatial route directness but no consideration for time.

Both case study routes were lacking in terms of cohesion and directness. Bicycle facilities are disconnected along the Case Study 1 route, and the Case Study 2 route is not spatially direct. Indirectness has negative impacts on participation and route selection (Buehler and Dill, 2016; Monsere et al, 2012).

Comfort and attractiveness

The Dutch approach seeks to address barriers to cycling by prioritising comfort and attractiveness when planning the bicycle network. At a policy level, Australian strategic documents reproduced these principles, however, they are not applied in the guidelines for specific infrastructure types.

In the case study routes, some segments were intimidating to an experienced cyclist with low perceived safety reported in several instances. It is recognised that user comfort is inherently personal (Monsere et al, 2012), however, it is probable that less experienced cyclists would find the routes less attractive and experience discomfort when using them.

Comparison of On-Road Infrastructure

Local streets

Local streets in The Netherlands have 30kph speed limits, and cyclists share priority with drivers. Austroads has some provision for low-speed, shared priority local streets with 40kph speed limits. However, the 50kph default urban speed limit was identified on most local streets in the study area. Austroads guidelines do not recommend specific cycling treatments for 50kph local streets, despite the importance of speed in protecting vulnerable road users under the Safe System approach.

The Case Study 2 route requires upgrading to meet Austroads principles and fulfil its role as a Strategic Cycling Corridor. Speed limits need to be reduced to 40kph along the entire route to achieve the "safe speeds" target. Car parking should be indented and separated from traffic lanes by a critical reaction strip, to provide a "safe roads" environment. Finally, bicycle priority pavement marking and signage should be installed to increase messages to road users and encourage "safe people" behaviours.

Mid-block treatments

Guidelines were found to differ in their prescription of on-road versus separated bicycle lanes. The Dutch are absolute in their recommendations for mid-block separation between bicycles and other road users. Cycling on major roads is discouraged through the provision of alternative routes which are more attractive and equally direct.

In contrast, Australian strategies have far less focus on separation. Austroads permits a wide kerbside traffic lane on roads with up to an 80kph speed limit, which bicycles share with motor vehicles with no physical separation, line-marking or signage. This does not comply with safe speeds or safe roads principles.

Bicycle lanes are recommended for a wide range of road types and speeds, and were observed to be the predominant mid-block treatment within the study area. However, research into hospital admissions from on-road cycling crashes revealed that cyclists were traveling in a bike lane in almost a quarter of crashes (Beck et al, 2016). This evidences the idea that some infrastructure types do not achieve the Safe System goal of reducing crash severity.

Accordingly, Austroads guidelines require amendment to encourage physical separation as a first priority. The alternative requirement should be marked, exclusive bicycle lanes with adequate width and buffer from parked cars. Such a focus could align guidelines with Australian safe roads principles.

Intersection treatments

The Dutch approach favours roundabouts to deliver infrastructure which prioritises and eases bicycle transport. Their primary concerns with signalised intersections include cyclist convenience, comfort and directness in time.

The historic approach to major intersection planning in Australia favours signalised intersections over roundabouts, and no roundabouts were observed on major roads within the study area.

Austroads guidelines encourage continuity of bicycle infrastructure at traffic signals, but these treatments were not found in the study locale. Where Forster Rd intersects Ferntree Gully Rd on the Case Study 1 route (segments 6 and 12), mid-block bicycle lanes terminate prior to the intersection, forcing cyclists to mingle with traffic. This situation is found widely across the Australian cycling network (Johnson, 2011; Thompson, 2010) and highlights the shortcomings of past guidelines in meeting safe roads objectives.

Approach and departure bicycle lanes were recently added at an existing intersection in the City of Glen Eira (2010). This demonstrates that some municipalities are willing to reclaim road space from motor vehicles, a stance which is needed across the wider cycling network to protect cyclists and achieve safety targets.

While there are clear socio-political differences in how cycling has been provided for in the Netherlands compared to Australia, the Dutch approach provides a model that can be applied in the Australian environment. Its suitability is already identified as the five fundamental Dutch requirements are named in the preface of Australian policy documents but as yet are not being incorporated into guidelines and practice. For example, a recent review reported that the National Road Safety Strategy 'provides little more than passing references to cyclists…[and offers] few suggestions about how to apply Safe System principles to promote cycling safety in the broader context of the transport system' (Lydon et al, 2015; p5). From this study, it is evident that greater integration of the Dutch approach into the Australian guidelines is an important step towards promoting cycling safety in the transport system in Australia.

Strengths and limitations

The main strength of this study is that it provides a direct comparison between the current Australian guidelines to the Dutch best practice approach, both theoretically and on-road. There are gaps in the way cycling is provided for in Australia and this review provided new insights in terms of both the theory and practice. These insights can help to inform how cycling provisions need to be included in Austroads guidelines and broader road safety policy in Australia.

The main limitation of this study was that we only compared the Australian approach to one international model. Albeit the Dutch approach is a leading example, there are other international approaches (e.g. Denmark, United Kingdom, parts of the United States of America e.g. Portland) that would have offered further insights. Multi-country analysis was beyond the scope of this study but will be explored in future research. Also, the case study routes provide a limited selection of infrastructure provisions across wider Melbourne and Australia. Further research that assessed additional infrastructure types would address this limitation.

Conclusions

The Australian cycling infrastructure planning framework states it has a focus on safety. However, the Dutch best practice approach includes supplementary factors which target other barriers to cycling and improve cyclist amenity. Australian cycling infrastructure design guidelines did not wholly reflect the overlying Safe System principles. Some allowed infrastructure types compromise cyclist safety, as evidenced by crash studies.

Existing bicycle facilities in urban areas often do not comply with current Australian design guidelines. Problems include unsafe or non-existent intersection and mid-block treatments, leading to disconnected routes. Infrastructure upgrades linking discontinuous routes, such as Case Study 1, should be prioritised to increase cyclist amenity and align bicycle networks with the safe roads pillar of the Safe System approach. Local streets lie on major cycling routes for a range of cyclist abilities, such as those in Case Study 2, and should be targeted for speed limit reduction and shared priority measures.

The study of case study routes could be extended temporally to assess the success of future upgrade works in aligning case study routes with Australian guidelines. Further, before-and-after cyclist counts and intercept surveys could identify changes to ridership and perceived safety.

Alternative future research should seek to assess a wider range of routes servicing major destinations. Strategic Cycling Corridors, the target of future funding in Victoria, should be prioritised for assessment.

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