ARTICLE IN PRESS

Accident Analysis and Prevention xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Full length article

The impact of environmental factors on cycling speed on shared paths

Soufiane Boufous[a,*], Julie Hatfield[b], Raphael Grzebieta[b]

[a] School of Aviation, Transport and Road Safety (TARS) Research, The University of New South Wales, Sydney, Australia
[b] Transport and Road Safety (TARS) Research, The University of New South Wales, Sydney, Australia

ARTICLE INFO

Keywords:
Shared path
Cycling
Speed
Safety

ABSTRACT

Background: Despite the importance of cycling speed on shared paths to the amenity and safety of users, few studies have systematically measured it, nor examined circumstances surrounding it.

Methods: Speed was measured for 5421 riders who were observed cycling on shared paths across 12 metropolitan and regional locations in Sydney, Australia. Multivariate regression analysis was carried out to examine rider and environmental factors that contribute to riders cycling above the median speed.

Results: The study found that observed riders travelled at a median speed of 16 km/h (mean 18.4 km/h). Nearly 80% of riders travelled at 20 km/h or less and 7.8% at speeds of more than 30 km/h. Riders were significantly less likely to cycle above the median speed on shared paths that had an average volume of over 20 pedestrians/hour. Riders were significantly more likely to travel above the median speed on paths that had a centreline (OR: 1.71, 95% CI: 1.41–2.07), on wider paths (over 3.5 m) (OR: 1.34, 95% CI: 1.12–1.59) and on paths with visual segregation between cyclists and pedestrians. Visual segregation, where cycling and walking areas are differentiated by the type of material or by paint colour used, was the strongest predictor of travelling above median speed on shared paths (OR: 3.9, 95% CI: 3.1–4.8).

Conclusions: The findings suggest that riders adjust their speeds to accommodate pedestrians and path conditions. Path characteristics that support separation from pedestrians may allow relatively higher speeds, and associated amenity, without substantial loss of safety.

1. Introduction

Active transport is increasingly encouraged worldwide due the health, societal, environmental and economic benefits attributed to walking and cycling (Gordon-Larsen et al., 2009; Bassett et al., 2008; Maibacha et al., 2009). Broad public policies, including the provision of appropriate infrastructure, have been developed by governments to support these activities whilst maintaining the safety of pedestrians and cyclists. In various countries, shared paths are frequently used to meet demand for cycling facilities that are separate from motorised traffic when space or resources are deemed inadequate for a bicycle-only path.

However, there are increasing concerns about the safety offered by shared paths (Poulos et al., 2015; De Rome et al., 2015). About half of crashes experienced by bicycle riders on shared paths are due to falls off the bicycle mainly as result of loss of control or collision with an object, while a smaller proportion (1 in 6) are collisions with pedestrians (Chong et al., 2010; Poulos et al., 2015; De Rome et al., 2015). A considerable proportion of crashes associated with shared paths are bicycle–bicycle collisions or collisions with motor vehicles [MV] at intersections (Chong et al., 2010; Poulos et al., 2015; De Rome et al., 2015). It is important to note that falls may be due to cyclist swerving to avoid pedestrians or other cyclists.

Cycling speed is likely to be a key factor in the likelihood and severity of crashes on shared paths. It is generally recognised in the road safety literature that crash likelihood and severity increase with vehicle speeds (Aarts and Van Schagen, 2006), and the same should apply to all types of bicycle crashes occurring on shared paths. For collisions between cyclists and pedestrians, the wide difference in speed may result in serious injuries to the pedestrian (Chong et al., 2010; Short et al., 2007).

While previous observational studies have examined conflicts between cyclists and pedestrians and between cyclists and motorised traffic (Haworth et al., 2014; Grzebieta et al., 2011), few studies have systematically measured cycling speed on shared paths, nor examined the different approaches to managing it. Moreover, little is known about the environmental, situational, and personal factors that may influence cycling speed, to assist with targeting interventions. This study aims to address these knowledge gaps by measuring cycling speeds on shared paths in Sydney metropolitan and regional areas and investigating the factors that contribute to variations in speed.

* Corresponding author.
E-mail addresses: Soufiane@unsw.edu.au (S. Boufous), J.hatfield@unsw.edu (J. Hatfield), R.Grzebieta@unsw.edu.au (R. Grzebieta).

http://dx.doi.org/10.1016/j.aap.2017.09.017
Received 4 August 2017; Received in revised form 17 September 2017; Accepted 17 September 2017
0001-4575/

2. Materials and methods

2.1. Approach

This paper reports on one component of a larger study that examined various issues related to shared path safety including behaviour of, and interactions between, various shared path users. The paper focuses on cycling speed. Nonetheless, interactions played a central role in the methodology, as described below.

Within observation zones at twelve shared paths in metropolitan Sydney and regional New South Wales (NSW), interactions between randomly selected bicyle riders and other path users (pedestrians, bicycle riders, or others) were observed, and details associated with these interactions recorded. Cycling speed was measured by video-recording cyclists passing through a 4 m "speed-measurement stretch" at one end of each observation zone.

2.2. Site selection

Ten shared path locations in metropolitan Sydney and two shared path locations in Wollongong (a regional centre 90 km south of Sydney) were selected with the aim of examining key path characteristics. Three Sydney sites were narrow (less than 2.5 m), four were of medium width (2.5–3.5 m), and three were wide (more than 3.5 m). One Wollongong site was narrow and the other was wide. Eight Sydney locations and one Wollongong location had a centreline. Seven locations (all in Sydney) were judged a priori to serve primarily commuting purposes at their peak time of usage. Table 1 summarises the sites and their characteristics.

Two Sydney locations involved "visual segregation" of bicycle riders and pedestrians. That is, cycling and walking areas were differentiated by the type of material or by paint colour. These paths are distinct from "separated" paths where cycling and walking areas are physically separated by a barrier such as a grass median strip, railings, kerbs, or walls. It is noted that the terms "segregated" and "separated" are used inconsistently in the literature.

2.3. Site set-up and equipment

At each location, an "observation zone" of approximately 30 m was selected – to allow good visibility for observers and for videoing. At one end of each observation zone a 4 m "speed measurement stretch" (SMS) was marked out by drawing lines in chalk on the path. Video equipment (GoPro Hero 3 Black Edition camera) was set up centred on the SMS and at a minimum of 1.5 m back from the path-edge to capture the view of bicycle tyres crossing the lines in the SMS for speed measurement. A second camera was positioned at the same end of the observation zone to capture the entire observation zone. A pair of observers stood beside the video equipment to make observations of interactions between randomly selected bicycle riders and the other path users. The standard observation zone set-up is depicted in Fig. 1.

2.4. Procedures

Ethical approval for the study was obtained from the UNSW Human Research Ethics Committee. Anyone who approached the observers was offered a Participant Information Statement and given an explanation of the research.

Observations were conducted from 16 October 2013 to 21 December 2013. Observations were conducted on three weekdays (on Wednesdays, Thursdays and Fridays) and one weekend day (Saturday) at each site (except for one location, where only 2 weekday sessions were conducted due to inclement weather). On weekdays sessions were during the morning peak (07:30–09:30) and the afternoon peak (16:30–18:30), while Saturday sessions were from 10:00–12:00 and from 13:00–16:00.

The first cyclist to enter the observation zone from either end (Fig. 1) when the previous set of observations was complete was the "trigger cyclist" participant. If the trigger cyclists would not interact with another path user in the observation zone, then only the trigger cyclist was observed. If the trigger cyclist interacted with one or more other path users in the observation zone then an interaction partner was selected for observation in the following priority order:

1 The first pedestrian passed or met by the trigger cyclist.
2 The first other cyclist passed or met by the trigger cyclist (if no pedestrian would be passed or met).
3 The first user other than a pedestrian or cyclist passed or met by the trigger cyclist (if no pedestrian or cyclist passed or met).

2.5. Analysis

The time taken to cover the 4 m speed measurement stretch was employed to calculate speed. Information about the frame rate of the cameras allowed calculation of the time taken to cover this 4 m interval. The observation zone video was used to obtain counts of each user type passing through the observation zone for 2.5 h at each site (30 mins during a morning peak and 30 min during an evening peak on each of 2 weekdays, and 30 mins during a Saturday). This is to measure the general level of path use (Atkins, 2012).

In addition to relevant descriptive analysis, particularly of cyclists' speed on shared paths (mean with 95% confidence intervals, median, minimum and maximum speeds), multivariate regression analysis was carried out to examine factors that contribute to riders cycling above the median speed. Independent factors examined at the univariate level include path characteristics (primary path use, path width, path centreline, visual segregation and pedestrian traffic volume), environmental factors (Weekday vs Weekend, Am vs Pm and interaction with a pedestrian) as well as characteristics and behaviours of the rider (age, gender, rider companions and use of potential distractor, such as mobile

Table 1
Locations for field observations showing key characteristics.

	Location	Width	Centreline	Visual segregation	Primary commuter use
1	Spit Bridge	Narrow	No	No	Yes
2	St Leonards Park, North Sydney	Narrow	No	No	Yes
3	Marine Parade, Manly	Narrow	Yes	No	No
4	Grand Pacific Drive, Wollongong	Narrow	Yes	No	No
5	Naremburn Cycleway, Naremburn	Medium	Yes	No	Yes
6	Victoria Road, Rozelle	Medium	Yes	No	Yes
7	Wansey Road, Randwick	Medium	Yes	No	Yes
8	Anzac Parade, Moore Park	Medium	Yes	No	No
9	Naremburn cycleway, Artarmon	Wide	Yes	Yes	Yes
10	Anzac Bridge, Pyrmont	Wide	Yes	No	Yes
11	Prince Alfred Park, Surry Hills	Wide	Yes	Yes	No
12	Cliff Road, Wollongong	Wide	No	No	No

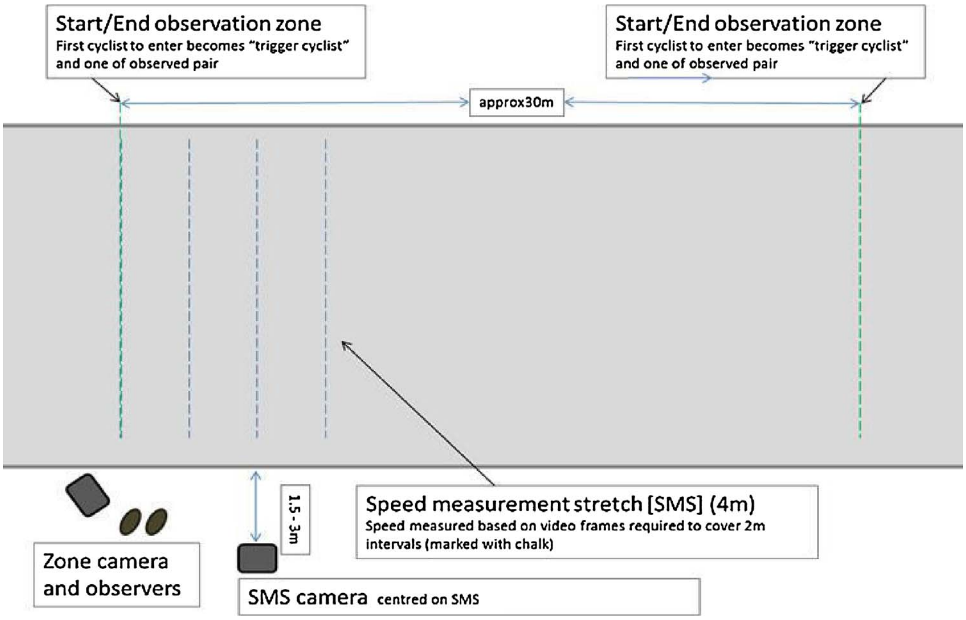

Fig. 1. Schematic illustration of observation site set-up.

phone or music listening device).

Variables that were significantly associated with the outcome measure in univariate analysis (with $p < 0.2$ as the conventional level to screen independent variables for multivariate modelling) were included in a multivariate regression model. Backward stepwise regression was then used to determine the factors that contributed to riders cycling above the median speed. That is, a full model was first used and variables were then eliminated from the model in an iterative process. The final model, which contained only independent variables that significantly contributed to cycling above the median speed, was reached when no more variables could be eliminated. All analyses in the report were carried out using SAS, 9.4.

3. Results

Speed was measured for 5421 riders who were observed cycling on shared paths across the 12 locations over the study period. Across all locations, the average cycling speed through the speed measurement stretches was 18.4 km/h and the median was 16 km/h. Speed varied by location (Table 2). Minimum speed ranged between 4.2 km/h and 8 km/h. Maximum speed ranged between 23.0 km/h and 43.2 km/h, with higher speed levels observed on wide, primarily commuter paths. Nearly 80% of cyclists travelled at 20 km/h or less (over the speed measurement stretch). Only a small proportion travelled at 10 km/h or lower (3.5%) and 7.8% at more than 30 km/h.

Speed varied depending on rider and shared path characteristics (Table 3). For instance, on shared paths with visual segregation over 1 in 5 cyclists travelled at speeds over 30 km/h compared to less than 1 in 20 on paths without visual segregation. Similarly, on wide paths (over 3.5 m) 15.5% of cyclists rode at speeds over 30 km/h compared to 2.5% on narrower paths. Just over 60% of female cyclists travelled at a speed of between 10 and 16 km/h compared to 45% of males. Older cyclists tended to ride at lower speed levels compared to younger cyclists. Higher speed levels were more likely to be observed during mornings and weekdays compared to afternoons and weekends respectively. No major difference in speed levels was observed depending on whether riders were accompanied or using a potential distractor (e.g. a mobile phone or music player).

Multivariate logistic regression analyses were conducted to examine contributors to cycling at more than the median speed of 16 km/h over the speed measurement stretches of the observed shared paths (Table 4). Riders were twice more likely to cycle above the median speed on wider paths (over 3.5 m) (OR: 2.05, 95% CI: 1.75–2.4) and almost four times more likely to cycle above the median speed on visually segregated paths (OR: 3.87, 95% CI: 3.09–4.84). They were also more likely to cycle above the median speed on paths with a centreline compared to those without (OR: 2.09, 95% CI: 1.73–2.52). Generally, the odds of riders travelling above the median speed decreased as the average number of pedestrians per hour (pedestrian/h) passing through the shared path observation zones increased. For instance, riders were

Table 2
Average speed of all observed riders by location.

Location	N	Mean (95% CI)	SD	Median	Minimum	Maximum
Spit Bridge	421	16.8 (16.4–17.3)	4.7	15.5	4.9	38.4
St Leonards Park, North Sydney	219	16.1 (15.7–16.6)	3.1	15.5	4.8	26.6
Marine Parade, Manly	185	14.7 (14.2–15.2)	3.5	14.9	4.5	24.7
Grand Pacific Drive, Wollongong	211	18.4 (17.7–19.1)	5.1	16	8.0	34.6
Naremburn Cycleway, Naremburn	579	20.1 (19.7–20.6)	5.6	16.6	4.8	34.6
Victoria Road, Rozelle	363	16.3 (15.8–16.9)	5.0	15.3	7.0	34.6
Wansey Road, Randwick	403	14.2 (14.0–14.5)	2.7	14.6	4.7	23.0
Anzac Parade, Moore Park	819	18.2 (17.9–18.5)	4.6	16	7.3	43.2
Naremburn cycleway, Artarmon	602	22.7 (22.1–23.3)	7.5	17.1	8.0	38.4
Anzac Bridge, Pyrmont	699	19.1 (18.5–19.7)	7.9	16.2	7.2	43.2
Prince Alfred Park, Surry Hills	472	21.3 (20.6–22.0)	7.4	16.8	4.7	43.2
Cliff Road, Wollongong	448	16.6 (16.2–17.0)	4.3	15.7	4.2	34.6
All locations	5421	18.4 (18.3–18.6)	6.2	16	4.2	43.2

Table 3
Speed level by various rider and environmental factors.

Speed km/h	< =10 km/h	10–16 km/h	16–20 km/h	20–30 km/h	> 30 km/h	Total
Width of the path						
< =3.5 m	117 (3.7%)	1781 (55.7%)	623 (19.5%)	598 (18.7%)	81 (2.5%)	3200
> 3.5 m	75 (3.4%)	812 (36.6%)	571 (25.7%)	419 (18.9%)	344 (15.5%)	2221
Centreline						
Absent	46 (2.9%)	856 (54.9%)	284 (18.2%)	273 (17.5%)	101 (6.5%)	1560
Present	146 (3.8%)	1737(45.0%)	910 (23.6%)	744 (19.3%)	324 (8.4%)	3861
Visual segregation						
No	185 (4.3%)	2349 (54.0%)	855 (19.7%)	763 (17.6%)	195 (4.5%)	4347
Yes	7 (0.7%)	244 (22.7%)	339 (31.6%)	254 (23.7%)	230 (21.4%)	1074
Commuter path						
Absent	90 (4.4%)	1255 (60.7%)	333 (16.1%)	355 (17.2%)	33 (1.6%)	2066
Present	102 (3.0%)	1338 (39.9%)	861 (25.7%)	662 (19.7%)	392 (11.7%)	3355
Pedestrian volume on path (per hour)						
< 20	14 (0.9%)	541 (33.8%)	482 (30.1%)	369 (23.0%)	196 (12.2%)	1602
20–99	83 (4.0%)	1018 (48.7%)	455 (21.7%)	394 (18.8%)	142 (6.8%)	2092
100–199	46 (7.4%)	489 (78.6%)	44 (7.1%)	43 (6.9%)	0 (0.0%)	622
> =200	49 (4.4%)	545 (49.3%)	213 (19.3%)	211 (19.1%)	87 (7.9%)	1105
Gender						
Male	132 (3.0%)	1998 (45.0%)	1033 (23.3%)	881 (19.8%)	395 (8.9%)	4439
Female	60 (6.3%)	584 (60.9%)	156 (16.3%)	129 (13.5%)	30 (3.1%)	959
Age						
20–29	7 (11.3%)	38 (61.3%)	8 (12.9%)	6 (9.7%)	3 (4.8%	62
14–19	52 (2.9%)	811 (45.0%)	407 (22.6%)	393 (21.8%)	140 (7.8%	1803
30–44	78 (3.0%)	1205 (47.0%)	594 (23.2%)	466 (18.2%)	222 (8.7%	2565
45–64	43 (5.0%)	451 (52.5%)	169 (19.7%)	137 (15.9%)	59 (6.9%	859
65+	11 (11.6%)	64 (67.4%)	10 (10.5%)	10 (10.5%)	0 (0.0%)	95
Interaction with pedestrian						
No	104 (3.2%)	1435 (44.0%)	791 (24.3%)	658 (0.2%)	270 (8.3%)	3258
Yes	88 (4.1)%	1158 (53.5%)	403 (18.6%)	359 (16.6%)	155 (7.2%)	2163
Distraction						
No	169 (3.4%)	2387 (47.6%)	1110 (22.1%)	950 (18.9%)	401 (8.0%)	5017
Yes	23 (5.9%)	199 (50.6%)	81 (20.6%)	66 (16.8%)	24 (6.1%)	393
Companion						
Alone	167 (3.3%)	2431 (47.6%)	1139 (23.3%)	963 (18.9%)	402 (7.9%)	5102
With at least 1 companion	25 (8.3%)	152 (50.2%)	50 (16.5%)	53 (17.5%)	23 (7.6%)	303
Weekend						
No	156 (3.2%)	2262 (46.5%)	1102 (22.7%)	936 (19.3%)	406 (8.4%)	4862
Yes	36 (6.4%)	331 (59.2%)	92 (16.5%)	81 (14.5%)	19 (3.4%)	559
Time of the day						
AM	56 (2.2%)	1061 (41.8%)	645 (25.4%)	489 (19.3%)	289 (11.4%)	2540
PM	136 (4.7%)	1532 (53.2%)	549 (19.1%)	528 (18.3%)	136 (4.7%)	2881
Total	192 (3.5%)	2593 (47.8%)	1194 (22.0%)	1017 (18.8%)	425 (7.8%)	5421

less likely to travel above the median speed on shared paths carrying 20–99 pedestrians/h compared to paths carrying less than 20 pedestrians/h (OR: 0.46, 95% CI: 0.39–055). Riders were less likely to travel above the median speed when they interacted with pedestrians compared to when there was no interaction (OR: 0.87, 95% CI: 0.75–0.96), during afternoons compared to mornings (OR: 0.51, 95% CI: 0.45–0.57), on weekends compared to weekdays (OR: 0.52, 95% CI: 0.43–0.64), and if they were females compared to males (OR: 0.46, 95% CI: 0.39–0.55). The odds of riding above the median speed over the speed measurement stretches of the observed shared paths decreased with age, with those aged 65+ years the least likely to do so compared to riders aged 20–29 years (OR: 0.16, 95% CI: 0.10–0.28).

4. Discussion

The observed average speed of 18.4 km/h found in this study was comparable to that reported in two previous studies carried out in the UK, USA and Australia which found the average speed of cyclists on shared paths to be between 15 km/h and 23 km/h (Virkler and Balasubramanian, 1998; Atkins, 2012). While maximum speeds of 35 km/h and above were observed at 10 locations, including on narrow paths such as Spit Bridge where such speeds would never be appropriate, nearly 80% of observed riders were travelling at 20 km/h or less. It has been suggested that on well designed and maintained shared paths, cyclists can comfortably travel at speeds between 15 and 25 km/h with minimum risk or decrease in amenity to pedestrians (Department of Transport and Main Roads, 2014).

Although a speed limit of 10 km/h for cyclists using shared paths has been suggested based on injury biomechanics survivability assessment for bicycle-pedestrian collisions (Short et al., 2007), the present results suggest there are difficulties of adopting such a limit. Firstly, very few riders travelled at 10 km/h or less. Secondly, while the stability of a bicycle depends on various factors including the skill of the rider, bicycle type and the characteristics of the path (i.e. surface and slope), it is recognised that a bicycle can become unstable at speeds of 11 km/h (Wilson and Papadopoulos, 2004; de Waard et al., 2010). Travelling at less than 10 km/h for any substantial distance undermines the value of cycling as an efficient mode of transport. Thus, a 10 km/h limit is likely to be ignored by bicycle riders, or if it were enforced (which would be difficult) may divert riders onto less safe adjacent roads or deter them from cycling.

In fact, there is little evidence, either in Australia or internationally,

Table 4
Regression analysis of factors that contribute to cyclist riding above the median speed of 16 km/h on shared path.

	Univariate			Multivariate		
	OR	95%	CI	Adjusted OR	95%	CI
Width of the path						
3.5 m or less*	1			1		
More than 3.5 m	2.19	1.96	2.45	1.34	1.12	1.59
Centreline						
Absent*	1			1.00		
Present	1.4	1.3	1.6	1.71	1.41	2.07
Visual segregation						
No*				1		
Yes	4.58	3.93	5.34	3.87	3.09	4.84
Commuter path						
No*	1			1		
Yes	2.48	2.22	2.78	1.1	0.98	1.24
Pedestrian volume on path (per hour)						
< 20	1			1		
20–99	0.48	0.42	0.55	0.66	0.54	0.80
100–199	0.09	0.07	0.11	0.15	0.11	0.20
> =200	0.46	0.39	0.53	0.61	0.45	0.81
Gender						
Male	1			1		
Female	0.45	0.39	0.52	0.42	0.36	0.50
Age						
20–29	1			1		
14–19	0.35	0.20	0.61	0.53	0.29	0.96
30–44	0.92	0.81	1.04	0.77	0.67	0.88
45–64	0.68	0.58	0.80	0.55	0.46	0.66
65 +	0.25	0.15	0.40	0.18	0.10	0.30
Interaction with pedestrian						
No	1			1		
Yes	0.66	0.59	0.74	0.85	0.73	0.98
Weekend						
No	1			1		
Yes	0.52	0.43	0.62	0.52	0.42	0.64
Time of the day						
AM*	1			1		
PM	0.57	0.51	0.64	0.49	0.44	0.56

* Reference category. Significance in Table 4 is determined by 95% CI.

to support imposing any speed limit on shared paths. As in other parts of the world, Australian road rules and guidelines do not recommend a certain speed limit for cyclists on shared paths but mention cycling speed when recommending conditions of construction. Austroads guidelines provide some indication regarding the appropriate path width for various levels of path use and cyclist speed. For instance, the width of 3 m is recommended for shared paths that are mainly recreational with regular use and cyclist speed of 20 km/h (Austroads, 2017). Physical separation of pedestrians and cyclists is recommended on busy shared paths and/or paths used by cyclists travelling at relatively high speed.

On the other hand, advisory speed signing and warning signs on paths with high pedestrian traffic are recommended and used on some shared paths in Australia (Austroads, 2006). It is argued that the actual advisory speed is less important than the fact that the sign indicates a need for cyclists and other faster users to slow down to speeds compatible with those of other users. However, there is no evidence to support the effectiveness or otherwise of advisory speed signing in reducing cycling speed and improving safety and comfort of all users on shared paths.

The results of this study, particularly those of the multivariate regression analysis, suggest that riders adjust their speeds according to shared paths conditions and to accommodate pedestrians on shared paths. The likelihood of riders to cycle above the median speed (16 km/h) is significantly reduced on shared paths with an average volume of more than 20 pedestrians per hour and when they interact with a pedestrian on a shared path.

The multivariate regression analysis also showed that cyclists were more than 70% more likely to ride above the median speed of 16 km/h on shared paths with a central line. Previous research has shown that centrelines are important in managing traffic flow on shared paths, mainly by encouraging left-hand travel, thus reducing potential conflict between users (Jordan and Leso, 2000). However, it is also possible that the presence of centreline marking gives the shared path the resemblance of a road which leads to cyclists treating it as such and to increase their speed compared to shared paths without a central line.

Other path characteristics that increase the likelihood of riders to cycle above the median speed are path width and the presence of a visual segregation (colour or different type of material) between cyclists and pedestrian. In fact, after adjusting for all relevant rider and environmental factors, visual segregation was the strongest predictor of bicycle speed on shared paths with riders nearly four times more likely to ride over median speed on shared paths with visual segregation compared to paths without. Just over one in five riders cycled at or over the relatively high speed 30 km/h on shared paths with visual segregation compared to only 4.5% on those without. The findings suggest that design of shared paths, including the provision of appropriate width and visual segregation on busy paths, is likely to significantly contribute to managing speed on shared paths as a viable and more practical alternative to imposing speed limits.

Some limitations of the present study must be noted. First, speed measurement is likely to have a margin of error. However, a previous study found a similar method to be well correlated with using radar guns (Thompson et al., 1997). Second, the spatial and temporal overlap of some of the predictor variables with the outcome variable were not perfect, introducing further error. Finally, the findings based on data collected during spring/summer from selected shared paths in Sydney, Australia, may not generalise to other seasons or locations, particularly other countries with different shared path conditions and rules.

The design of shared paths should recognise the need of the main users, namely cyclists and pedestrians. While cyclists prefer separated bicycle lanes or paths, and shared paths might not be the best infrastructure type for commuter cycling (Hatfield and Prabhakharan, 2016), they remain a viable alternative to riding on higher speed roads that don't have any cycling infrastructure. It can also be argued that the provision of shared paths is important from a public health perspective to encourage cycling uptake among young and inexperienced riders who perceive them to be less risky than roads in the absence of alternative infrastructure that is exclusive to cyclists (Tilahun et al., 2007; Garrard et al., 2008).

While there is little evidence in the available police crash or hospital data of high risk of injury to pedestrians on shared paths, perceptions of increased risk of injury on shared paths due to cyclists, particularly among older people, are common. Walkers, particularly older people, are equally encouraged to be active and are entitled to do so without fear of conflict with cyclists riding at high speed. It is therefore important to consider separating users on paths where cyclists are travelling at higher speed and on paths with high volumes of pedestrians and/or cyclists. This is also relevant to many cyclists who prefer more direct travel and may find having to negotiate pedestrians to be a disincentive to cycling to work or for recreation (Hummer et al., 2006).

5. Conclusions

The study shows that the average cycling speed on Sydney's shared paths – 18 km/h, with nearly 80% of cyclists travelling at 20 km/h or less – to be relatively moderate but above that previously suggested for pedestrian safety and amenity. The findings also suggest that riders generally adjust their speeds to accommodate pedestrians and according to path conditions. Appropriate width and other path characteristics that support separation from pedestrians, such as visual segregation, may allow relatively higher speeds, and associated amenity, without substantial loss of safety.

Acknowledgments

This study was funded by Transport for NSW (TfNSW). The authors wish to thank TfNSW staff, particularly Ralston Fernandes, for their support and assistance with the selection and access to various data collection sites.

References

Aarts, L., Van Schagen, I., 2006. Driving speed and the risk of road crashes: a review. Accid. Anal. Prev. 38 (2), 215–224.
Atkins, 2012. Shared Use Operational Review. Department of Transport, London.
Austroads, 2006. Minimising Pedestrian-Cyclist Conflict on Paths. Pedestrian Cyclist Information Note No 9–Regulation and Enforcement. Publication No. AP–R287/06. Austroads, Canberra.
Austroads, 2017. Guide to Road Design Part 6A: Paths for Walking and Cycling. Publication No. AGRD06A-17. Austroads, Canberra.
Bassett, D., Pucher, J., Buehler, R., Thompson, D., Crouter, S., 2008. Walking, cycling, and obesity rates in Europe, North America, and Australia. J. Phys. Act. Health 5, 795–814.
Chong, S., Poulos, R., Olivier, J., Watson, W.L., Grzebieta, R., 2010. Relative injury severity among vulnerable non-motorised road users: comparative analysis of injury arising from bicycle-motor vehicle and bicycle-pedestrian collisions. Accid. Anal. Prev. 42, 290–296.
De Rome, L., Boufous, S., Georgeson, T., Senserrick, T., Richardson, D., Ivers, R., 2015. Bicycle crashes in different riding environments in the Australian capital territory. Accid. Anal. Prev. 78, 155–164.
de Waard, D., Schepers, P., Ormel, W., Brookhuis, K., 2010. Mobile phone use while cycling: incidence and effects on behaviour and safety. Ergonomics 53, 30–42.
Department of Transport and Main Roads, 2014. Speed Management on Shared Paths. Technical Note130. Department of Transport and main roads, Brisbane.
Garrard, J., Rose, G., Lo, S.K., 2008. Promoting transportation cycling for women: the role of bicycle infrastructure. Prev. Med. 46, 55–59.
Gordon-Larsen, P., Boone-Heinonen, J., Sidney, S., Sternfeld, B., Jacobs, D., Lewis, C., 2009. Active commuting and cardiovascular disease risk: the CARDIA study. Arch. Intern. Med. 169, 1216–1223.
Grzebieta, R.H., McIntosh, A.M., Chong, S., 2011. Pedestrian-cyclist collisions: issues and risk. In: Australasian College of Road Safety Conference. Melbourne, Australia.
Hatfield, J., Prabhakharan, P., 2016. An investigation of behaviour and attitudes relevant to the user safety of pedestrian/cyclist shared paths. Transp. Res. Part F 40, 35–47.
Haworth, N., Schramm, A., Debnath, A.K., 2014. An observational study of conflicts between cyclists and pedestrians in the city centre. J. Australas. Coll. Road Saf. 25 (4), 31–40.
Hummer, J.E., Rouphail, N., Hughes, R.G., Toole, J.L., Patten, R.S., Schneider, R.J., Green, J.S., Hughes, R.G., Fain, S.J., 2006. Evaluation of Safety Design, and Operation of Shared-Use Paths. Report No. FHWA-HRT-05-137. The U.S. Federal Highway Administration, Washington.
Jordan, G., Leso, L., 2000. Power of the line: shared-use path conflict reduction. Transp. Res. Rec.: J. Transp. Res. Board 1705, 16–19.
Maibacha, E., Steg, L., Anablec, J., 2009. Promoting physical activity and reducing climate change: opportunities to replace short car trips with active transportation. Prev. Med. 49, 326–327.
Poulos, R.G., Jb, Hatfield, Rissel, C., Flack, L.K., Murphy, S., Grzebieta, R., McIntosh, A.S., 2015. Characteristics, cycling patterns, and crash and injury experiences at baseline of a cohort of transport and recreational cyclists in New South Wales, Australia. Accid. Anal. Prev. 78, 155–164.
Short, A., Grzebieta, R.H., Arndt, N., 2007. Estimating bicyclist into pedestrian collision speed. Int. J. Crashworthiness 12 (2), 127–135.
Thompson, D.C., Rebolledo, V., Thompson, R.S., Kaufman, A., Rivara, F.P., 1997. Bike speed measurements in a recreational population: validity of self reported speed. Inj. Prev. 3, 43–45.
Tilahun, N.Y., Levinson, D.M., Krizek, K.J., 2007. Trails, lanes, or traffic: valuing bicycle facilities with an adaptive stated preference survey. Transp. Res. Part A: Policy Pract. 41, 287–301.
Virkler, M., Balasubramanian, R., 1998. Flow characteristics on shared Hiking/Biking/Jogging trails. Transp. Res. Rec.: J. Transp. Res. Board 1636, 43–46.
Wilson, D.G., Papadopoulos, J., 2004. Bicycling Science, third ed. MIT Press, Cambridge.