Australian Cycling Conference 2010

Proceedings of the Second Australian Cycling Conference

Australian Cycling Conference
and The University of Adelaide

THE UNIVERSITY OF ADELAIDE AUSTRALIA

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Australian Cycling Conference
and
The University of Adelaide
Adelaide SA 5005, Australia

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Preface

The *Australian Cycling Conference 2010* is the most recent in a series of annual conferences designed to showcase the very latest in cycling research, planning and practice. The conference series commenced in 2005 as *Thinking on Two Wheels* and has been held each January to coincide with the Tour Down Under cycle race. The *Australian Cycling Conference 2010* was held at the University of Adelaide on 18–19 January 2010.

The *Australian Cycling Conference 2010* is of national significance as it is the only forum in Australia to have as a core aim advancing and promoting the development of rigorous research into cycling. The *Conference* also actively encourages academics, policy makers, practitioners (government and private sector) and community organisations to exchange knowledge about cycling in all its forms. Cycling spans institutional boundaries drawing experts from the government, community and private sectors and it ranges across disciplinary boundaries bringing together researchers and professionals from transport, engineering, health, geography, urban planning, sociology and the environmental and spatial sciences.

Associate Professor Ineke Spape from Breda University of Applied Sciences (NHTV) and SOAB Consultants, Netherlands, was the invited Guest Speaker at the 2010 *Conference*. Ineke specialises in walking and cycle planning and she has provided expertise to cities such as London, Cape Town, Quito (Ecuador) and New York. At this year's cycling conference, Ineke introduced the concept of a Bicycle Oriented Society and discussed the lessons Australia might learn from the Dutch experience – both the pitfalls to be avoided and practices that could be embraced.

Professor Ian Lowe, President of the Australian Conservation Foundation, emeritus professor at Griffith University drew on his capacity as prolific science researcher, policy analyst and cyclist and presented a diverse range of evidence to point to the necessity of cycling when creating a sustainable future.

Speakers at the 2010 conference came from New Zealand, United Kingdom, Australia and the Netherlands and they spoke on a diverse range of themes. These included presentations on the current status of utility cycling in different localities and amongst different groups and the mechanisms – e.g. programs and infrastructure – being put in place to encourage more people to cycle. Several presenters offered critical analyses of existing cycling infrastructure – signage, roundabouts, cycle-lanes – and, drawing on international examples, provided suggestions on how things might be done differently. Two speakers discussed methods for researching cyclist preferences and cyclist on-road behaviour while another cluster of presenters reflected on representations of cyclists: in the media; amongst existing and potential cyclists; and in the knowledge we produce about cycling. A handful of papers turned attention to issues of funding, technological changes, cycle design and cycle planning as a tool in engineering education. The diversity of cycling interests was on display with a set of papers on evaluating environmental impacts of mountain biking trails and techniques for mapping mountain bike trails.

The 2010 conference also included roundtable discussions. The conference evaluation revealed that this aspect of the program was highly valued. Roundtable participants had the opportunity to each contribute ideas and then explore aspects of cycling based on their knowledge of cycling issues and their experiences as cyclists. Roundtable topics were those which gained prominence during the conference. Roundtables also provided a balance to listening to conference speakers and an opportunity to form cycling knowledge networks across Australia.

The editors have included both refereed and non-refereed papers in this volume to provide an enduring record of the range of work presented at the *2010 Conference*. The status of each paper as refereed or non-refereed has been indicated in the footer at the bottom of the first page of each paper.

All refereed papers have been subject to an independent double blind referee process. Each refereed paper has been reviewed by *at least* two, and in several cases three, experts in the field: generally including one national and one international reviewer. Four of the papers presented at the conference were subsequently published in a special issue of the journal *Road and Transport Research* while another was published in the on-line open access journal *BMC Public Health.* Prior publication has been acknowledged on the first page of the relevant papers. The editors would like to thank these journals and the authors for allowing us to reprint the papers in full in this volume.

The editors, on behalf of the organising committee, would like to thank the organisations and companies who sponsored the *Australian Cycling Conference 2010*. These include Adelaide City Council, Bicycle Institute of South Australia, City of Charles Sturt, infraPlan, Planning Institute of Australia (SA Division), Sustainable Transport Consultants, Tonkin Consulting and Traffic Calming Australia. We would also like to say a special thank you to Hub Traffic and Transport for the significant in-kind and financial support provided to the conference and preparation of the conference proceedings. Finally, we would like to thank the University of Adelaide for its ongoing support of the *Australian Cycling Conference* series. In 2010, this involved financial assistance for the visit of guest speaker Ineke Spape and in-kind support in the form of providing meeting and conference facilities as well as administrative and academic services.

Jennifer Bonham and Peter Lumb

Editors

Representations of cycling in metropolitan newspapers – Changes over time and differences between Sydney and Melbourne, Australia

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Abstract

Background: Cycling is important for health, transport, environmental and economic reasons. Newspaper reporting of cycling reflects and can influence public and policymaker attitudes towards resource allocation for cycling and cycling infrastructure, yet such coverage has not been systematically examined.

Methods: The Factiva electronic news archive was searched for articles referring to cycling published in four major metropolitan newspapers – two in Sydney and two in Melbourne, Australia, in the years from 1998 until 2008. After excluding articles not about cycling, there were 61 articles published in 1998, 45 in 1999, 51 in 2003, 82 in 2007 and 87 in 2008. Each article was coded for positive or negative orientation, and for framing of cyclists and cycling. Inter-rater reliability was calculated on a sample of 30 articles.

Results: Over the past decade there has been an increase in the reporting of cycling in the major newspapers in Sydney and Melbourne (from 106 in 1998–1999 to 169 stories in 2007–2008), with a significant increase in reporting of cycling in Melbourne, from 49 to 103 stories (p=0.04). Recent reporting of cycling was generally positive (47% of articles, compared with 30% of articles which were negative) and focused on benefits such as health and the environment. Three quarters of negative stories involved injury or death of a cyclist. The Sydney based *The Daily Telegraph* reported the most negative stories (n=60). We found positive framing of 'cycling' was more widespread than negative, whereas framing of 'cyclists' was more negative than positive.

Conclusions: Quantity of reporting of cycling varies over time and by newspaper, and even between newspapers in different cities owned by the same media company. News coverage appears to reflect developments in the different cities, with increases in positive reporting of cycling in Melbourne following increases in cycling in that city. Negative cycling newspaper stories may deter people from considering cycling as a transport option, but real physical or political improvements to the cycling environment may be necessary before coverage becomes more positive.

Background

Cycling is the fourth most popular recreation in Australia, with bicycles increasingly used as transport across the country (Bauman et al. 2008). About a million new bicycles are sold in Australia each year, and cycling is a form of regular physical activity that is accessible to people of all ages and confers substantial health benefits (Bauman et al. 2008).

This paper has been subject to peer review. It has been published previously in BMC Public Health 2010, 10:371

Despite its popularity, the growth of cycling for recreation and transport is potentially limited by the availability of infrastructure that enables it to be performed easily and safely. Of interest to advocates of cycling, therefore, are the perceptions of the public and of policy makers towards this activity, because of the bearing these perspectives have on the planning and investments needed to support cycling. Researching the portrayal of cycling in the media can shed light on the climate of beliefs and values in which policies that support or hinder cycling are made. News media coverage has particular salience because it can shape public understandings of issues and influence policy and behaviours (McCombs and Shaw 1972; Kitzinger 2007).

The limited research undertaken on the news reporting of cycling has identified both positive and negative framings of cycling that have shifted across time within different societies. Following the emergence of the bicycle in the mid 19th century, the media drew attention to the wonder and amazement that was generated by this new machine. Early users of the bicycle were also viewed in some quarters with scorn, with some newspapers portraying cyclists as hoodlums of ill manner.

The 1890s have been described as the ‘golden era’ of cycling (Hammond 1971). As bicycles became cheaper and more user-friendly, interest grew to the point where entire sections of newspapers were dedicated to bicycle news. According to Hammond (Hammond 1971), the economic benefits generated by bicycle advertising swiftly transformed both press and public attitudes:

> *Bicycle interests allocated thousands of dollars annually to instruct the public about the lightness, swiftness, strength and beauty of their product… In return, by running editorials and regular columns on the wheel, plus special articles by bicycle enthusiasts and medical men, the press and magazines made cycling an increasingly more discussed and respectable activity.*

In the early 20th century, media reporting of cycling declined as the motor car became more popular even though the actual number of cyclists continued to grow. News reporting focused more on cycling as sport and less on its utilitarian values (Horton 2007). Some researchers have also noted that in car-centric societies, images of cyclists are dominated by negative representations. According to Bogdanowicz (2004):

> *Where the bicycle is featured in UK newsprint it’s frequently characterised as a mode of transport for eccentrics or ‘tree-huggers’. Columns or programmes about “Lycra clad fascists” and “Lycra nazis” are re-cycled on a regular basis by newspaper columnists and radio shock-jocks.*

Bogdanowicz (2004) and Horton (2007) argue that there has been an emergence in recent years of biases against cycling in the news media due to the economic and cultural dominance of the automotive industry and their advertising power within the news media. More positive reporting of cycling, however, has also been documented. Fincham, for example, reports that many positive stories have an ‘emphasis on the health benefits of cycling coupled with the perception of freedom that is associated with cycling’ (Fincham 2007).

Because of the importance of cycling, in health, transport, environmental and economic terms, further research about the way that this has been framed in news media in recent years is needed. The news media, and newspapers particularly, warrant investigation because they are a primary source of information that can reflect and reinforce community attitudes. The news media also play an important agenda setting function, by influencing what people think about (McCombs and Shaw 1972) and attitudes to issues (Kitzinger 2007). The higher up the news agenda an issue is, the more likely it is to be seen as important by the public (McCombs and Shaw 1972). Thus the prominence and type of news coverage cycling receives is likely to be shaping public understandings of cyclists and cycling and is of importance to the uptake of cycling and to public policy support for cycling.

This study aims to investigate how cycling and cyclists have been represented in Australian newspapers over the past decade. It examines the frequency of cycling related news stories in major metropolitan newspapers, the way cycling and cyclists are framed by news stories, and variations in the representations of cycling over time, by type of newspaper, and by geographical location.

Methods

Our study draws on social construction of reality theory which explains how individuals use news texts and other information to make sense of the world and uses content analysis to examine the nature of newspaper coverage of cycling and the dominant frames (Kitzinger 2007; Krippendorff 1980) used to portray cycling and cyclists. Initial frames were identified from a focus group study on perceptions of cyclists (Lippman 1922), however coding allowed for new frames to be identified in the newspaper sample. This study was designed to discover how the two separate but related constructs of 'cycling' and 'cyclists' are portrayed in the news and whether there are differences between Sydney and Melbourne newspapers.

Sample

The news coverage analysed was limited to newspaper articles from *The Sydney Morning Herald*, *The Daily Telegraph* (Sydney), *The Age* (Melbourne) and the *Herald Sun* (Melbourne). These are the major newspapers in the two largest cities in Australia, with a potential reach of almost half the Australian population. *The Sydney Morning Herald* and *The Age* are broadsheet newspapers and both published by Fairfax Media. The two tabloid newspapers, *The Daily Telegraph* (Sydney), and the *Herald Sun* (Melbourne), are owned by News Ltd.

The Factiva electronic news archive was searched for articles referring to cycling [search terms Rst=(AGEE OR HERSUN OR DAITEL OR SMHH) AND hd=(cycling OR cyclist OR bicycl* OR bike)] published in selected publications in the years 1998, 1999, 2003, 2007, 2008. These years were selected to cover a decade, and to provide a data point in the middle to allow examination of any trend. This search generated 104 articles in 1998, 73 in 1999, 88 in 2003, 121 in 2007 and 120 in 2008. After viewing the articles, a number were removed as they did not meet eligibility criteria (for example, they were stories about motorbikes, stationary exercise bikes, non-news items). Opinion pieces were excluded as we aimed to focus on news and features, rather than the often extreme views presented in opinion pieces. Editorials, sports news, letters to the editor and news in brief items were also excluded. After exclusions the samples for each year were 61 articles in 1998, 45 in 1999, 51 in 2003, 82 in 2007 and 87 in 2008.

Inter-rater reliability

One coder reviewed all downloaded articles, and coded all eligible articles according to the coding frame. A second coder (BS) reviewed a random sample of 30 (approximately 10%) of these articles. Inter-rater reliability was assessed using Cohen's Kappa.

Analysis

To determine the change in the proportion of articles about cycling in each newspaper over time, and to assess change in the proportion of articles that were positive or negative about cycling in each city, articles from 1998 and 1999 were treated as one period, as were articles from 2007 and 2008 . The chi-square statistic was used to test whether the proportions were significantly different over the 10 year period. Because the total number of framings of cycling and cyclists within articles was greater than the number of articles, the analysis of the frequency and proportion of different framings was undertaken separately for each of the five data collection years.

Results

Inter-rater agreement on coding was good, with a Cohen's Kappa of 0.77 for identification of the positive and negative frames of cycling and cyclists within articles.

Trends in news coverage of cycling

There was an overall increase in the frequency of newspaper stories about cycling in Melbourne and Sydney from 1998–1999 (n=106) to 2007–2008 (n=169) and slightly more frequent reporting of cycling in Melbourne (54.3%) than in Sydney (45.7%). Over the 10-year period the number of cycling-related stories significantly increased from 49 to 103 stories in Melbourne ($\chi^2 = 6.37$, p=0.04) (refer Table 1.1). The total number of all articles published by these four newspapers in our study years increased from about 130,000 in 1998 to about 145,000 in 2008.

Table 1.1 Number and percent of news stories per year concerning cycling by city and newspaper, 1998–2008

	Sydney						**Melbourne**						
Year	**Daily Telegraph**		**Sunday Morning Herald**		**All**		**Herald Sun**		**The Age**		**All**		**Total**
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
1998–1999	45	42.5	12	11.3	57	53.8	36	34.0	13	12.3	49	46.2	**106**
2003	19	37.3	7	13.7	26	51.0	15	29.4	10	19.6	25	49.0	**51**
2007–2008	40	23.7	26	15.4	66	39.1	56	33.1	47	27.8	103	61.0	**169**
Total	**104**	**31.9**	**45**	**13.8**	**149**	**45.7**	**107**	**32.8**	**70**	**21.5**	**177**	**54.3**	**326**

Due to the greater increase in cycling news stories in Melbourne than Sydney, there was a decline in the relative proportion of items that were published in Sydney newspapers in the study period. As shown in Table 1.1, this was due to less reporting of cycling by *The Daily Telegraph* (with a small increase in *The Sydney Morning Herald*). There was double the number of articles about cycling in 2007–2008 in Melbourne in *The Age* compared to earlier periods.

Table 1.2 shows that there was an increase in stories about cycling that were classified as positive over the last decade, with the largest increase in the last few years. This pattern is mirrored by a decrease in overall negative stories. There was no change in the frequency of neutral stories. Overall, there were slightly more positive news stories about cycling than negative stories.

Table 1.2 Number and percent of positive and negative reporting of cycling by city and over time

	Positive (*n* = 128)		**Negative (*n* = 118)**	
	n	*%*	*n*	*%*
City				
Melbourne	81	45.8	51	28.8
Sydney	47	31.5	67	45.0
	χ^2=6.86, p<.01		χ^2=9.14, p<.01	
Year				
1998–1999	32	30.2	48	45.3
2003	17	33.3	19	37.3
2007–2008	79	46.8	51	30.2
	χ^2=8.38, p=.02		χ^2=6.47, p=.04	

When individual newspapers were examined, *The Daily Telegraph* in Sydney had the lowest proportion of positive cycling stories (18.3%), and *The Sydney Morning Herald* had the highest (62.2%), a significant difference ($\chi^2 = 38.59$, $p<0.01$). In the *Herald Sun* 38.3% of stories about cycling were positive compared with 57.1% in *The Age*. When the total number of cycling stories was considered, there were more than twice as many cycling stories in *The Daily Telegraph* (n=104) as in *The Sydney Morning Herald* (n=45).

The tabloid newspapers had more negative stories about cycling than the broadsheet newspapers. *The Daily Telegraph* in Sydney had the highest proportion of negative cycling stories (57.7%, n=60), more than four times that of *The Sydney Morning Herald* (15.6%, n=7). The *Herald Sun* in Melbourne (n=36) with 33.6% negative cycling stories, had a higher proportion of negative cycling stories than *The Age* (21.4%, n=15).

Of the negative cycling stories (n=122), almost three quarters (73%) were about injury or death to cyclists. The next most common topic was the bad behaviour of the cyclist (20.5% of negative stories). There was variation among the newspapers in how they reported negative cycling stories. There was more frequent reporting of death and injury in the tabloid newspapers (80% of the negative articles in *The Daily Telegraph* and 70.3% in the *Herald Sun*) compared to the broadsheet newspapers (60% of the negative articles in *The Sydney Morning Herald* and 65% in *The Age*).

News Angles

The most common news angle was injury to cyclist(s) (13.2% of articles), followed by death of cyclist(s) (10.7%) (see Table 1.3). About 10% of the news angles were about moves to support cycling or expressions of support for cycling. This 'support for cycling' news angle became more frequent over time (from 0 in 1998 to 23 in 2008). However, stories about people objecting to cycling or moves to facilitate cycling also rose over time (from 1 in 1998 to 9 in 2008). Cyclists committing misdemeanors on and off the road was the fourth most common news angle (7.4%), however this kind of story fell from 10 in 1998 to 1 in 2008. There were few (4.6%) stories about celebrities riding bicycles, but these became more frequent over time. There were also very few stories about cycle tourism (3.4%), but again these became more frequent. The angle 'cyclists kill pedestrians' appeared to peak around specific events: for example 8 of the 10 stories of this kind appear in the 2007 sample. In a similar fashion, drivers who were charged with killing cyclists gained extra news media attention (with a peak of eight stories of this kind in 2003).

Table 1.3 News angles* by type from 1998 to 2008

	1998	1999	2003	2007	2008	Total	% of total
Injured cyclist(s)	13	9	7	6	8	43	13.2
Killed cyclist(s)	10	1	0	14	10	35	10.7
Supporting cycling	0	0	3	7	23	33	10.1
Misbehaving	10	2	7	4	1	24	7.4
Cycling event	4	2	6	8	1	21	6.4
Driver punished for collision with cyclist	2	4	8	3	0	17	5.2
Celebrity cycling	1	2	2	4	6	15	4.6
Impeding cycling	1	0	1	4	9	15	4.6
Bike facilities improved	3	4	2	5	1	15	4.6
Cycle tourism	1	1	1	3	5	11	3.4
Cyclist kills pedestrian	0	1	1	8	0	10	3.1
Stealing bikes	3	2	1	0	2	8	2.5
Other	13	17	12	16	21	79	24.2
Total	**61**	**45**	**51**	**82**	**87**	**326**	**100**

* The news angle of a story is the aspect of an issue which triggers the news coverage. It is usually shown in the headline and/or the first paragraph.

Framing of cycling

As shown in Table 1.4, the dominant framing of cycling was that cycling is dangerous to cyclists (161 instances, present in 49.4% of cycling articles). One in ten stories also carried the frame that cycling is dangerous to non-cyclists. However, the framing analysis detected that overall there were many more instances of positive framing of cycling than negative (510 vs 308). Analysis of change in the framing over time showed that all positive frames were trending upwards especially ‘deserves more support’ and ‘popular’. While there were fewer instances of negative framing of cycling, all negative framings, except risk to cyclists, were also found to be increasing.

Table 1.4 Positive and negative frames of cycling in news stories*

Positive frames	n	%	Negative frames	n	%
Deserves more support	90	27.6	Risk (to cyclists)	161	49.4
Popular	73	22.4	Risk (to non-cyclists)	32	9.8
Quality of life benefits	57	17.5	Negative urban impact	25	7.7
Environmental benefits	51	15.6	Difficult	25	7.7
Promotes health	45	13.8	Unpopular	17	5.2
Fun	43	13.2	Costly	16	4.9
Convenient	38	11.7	Other	32	9.8
Economical	34	10.4			
Other	79	24			

*n = 326, each story may contain more than one frame

The dominant positive frame was that cycling ‘deserves more support’ (present in 27.6% of articles) (Table 1.4). This frame is evoked by words and phrases which portray cycling as deserving of community or government support or neglected by society. The frame of cycling being ‘popular’ was the next most frequently found frame (present in 22.4% of articles), followed by improving ‘quality of life’ (17.5%) , offers ‘environmental benefits’ (15.6%), ‘promotes health’ (13.8%), is ‘fun’ (13.2%), ‘convenient’ (11.7%) and ‘economical’ (10.4%).

The trend for all positive frames was upwards, with the frames of ‘deserves more support’ and ‘popular’ increasing more than other positive frames of cycling. ‘Quality of life’ benefits of cycling showed the next steepest rise, followed by ‘environmental benefits’ and ‘promotes health’. In 1998, positive framing of cycling was dominated by the frames that cycling is ‘popular’ (11.5% of articles), ‘deserves more support’ (11.5%) and ‘fun’ (11.5%). In 1999, the ‘deserves more support’ (17.8%), ‘quality of life’ (13.3%) and ‘environmental benefits’ (11.1%) frames were dominant. In 2003, the dominant positive framings of cycling presented it as ‘fun’ (17.6%), ‘popular’ (15.7%) and ‘convenient’ (13.7%). In 2007, ‘popular’ (30.5%) rose to the top, followed by ‘deserves more support’ (26.8%) and ‘promotes health’ (21.9%). By 2008, the key positives messages were that cycling ‘deserves more support’ (54%), is ‘popular’ (32.2%) and confers ‘environmental benefits’ (32.2%). The year 2008 was distinguished by the presence of the frame of ‘deserves more support’ in more than half of all articles (54%). The ‘promotes health’ frame rose from 4.9% in 1998 to a peak of 21.9% in 2007, falling slightly in 2008 to 16.1% when it was overtaken by ‘environmental benefits’. ‘Environmental benefits’ varied between 6.6% and 11.1% until 2008 when almost one third of articles carried this frame (32.2%).

The dominant negative framing of cycling was that it is a ‘risk to cyclists’ (present in 49.4% of articles) (see Table 1.4). One in ten articles carried the frame that cycling is a ‘risk to non-cyclists’. Framing of cycling as having a ‘negative urban impact’ or being ‘difficult’ was present in 7.7% of articles each, and the frames of cycling as ‘unpopular’ or ‘costly’ were in 5.2% and 4.9% of articles respectively. About 10% of articles carried other negative framings of cycling.

By far the most dominant negative framing of cycling was ‘risk to cyclists’. Although the frequency of this frame fell slightly, this remained by far the most common negative frame. In 1998, cycling was framed negatively as a ‘risk to cyclists’ (57.4% of articles conveyed this frame) and as ‘difficult’ (3.3%) and ‘unpopular’ (3.3%). The frame of ‘risk to non-cyclists’ was present, but only in 1.6% of articles. By 1999, the negative framing of cycling conveyed the message that it is a ‘risk to cyclists’ (55.6%) and the proportion of the ‘risk to non-cyclists’ frame rose to 11.1%. In 2003, the dominant negative framing of cycling was again ‘risk to cyclists’ (43%), with the ‘risk to non-cyclists’ framing declining to just 1.9% of articles. In 2007, the dominant negative framing of cycling was ‘risk to cyclists’ (43.9%), which was followed by ‘risk to non-cyclists’ (14.6%) and ‘negative urban impact’ (11%). In 2008, ‘risk to cyclists’ was still the most widespread negative framing of cyclists (49.4%), while ‘negative urban impact’ rose to 16% and ‘risk to non-cyclists’ to 14.9%. The framing of cycling as having a ‘negative urban impact’ increased the most, from 1.6% in 1998 to 16.1% in 2008.

Framing of cyclists

The analysis detected remarkably few (n=58) instances of positive framings of cyclists (as opposed to cycling) (see Table 1.5). Negative framings of cyclists (n=107) were detected almost twice as often as positive framings of cyclists. The negative frames of cyclists in this sample paint a picture of cyclists as ‘irresponsible lawbreakers’, ‘pariahs’ and ‘dangerous to others’, a message delivered with greater frequency than the positive presentation of cyclists as ‘brave’, ‘harmless’, ‘healthy’ and ‘safety conscious’.

Table 1.5 Positive and negative frames of cyclists in news stories*

Positive frames	N	%	Negative frames	N	%
Brave	24	7.4	Irresponsible lawbreakers	38	11.7
Harmless	7	2.1	Pariahs	14	4.3
Healthy	4	1.2	Danger to others	13	4
Safety conscious	3	0.9	Extremists	10	3.1
Other	20	6.1	Inconvenient	9	2.8
			In the minority	6	1.8
			Badly behaved	4	1.3
			Substance abusers	2	0.6
			Other	11	3.4

*N=326, each story may contain more than one frame

In 1998, one in five (22.9%) cycling articles carried a negative framing of cyclists. These frames were found in 48.9% of articles in 1999, 21.6% in 2003, 33% in 2007 and 38% in 2008. The most dominant frame, ‘irresponsible lawbreakers’, was present in every year (between 5 and 11 instances), with a peak of 11 (13.4%) in 2007. Negative portrayals of cyclists developed from ‘irresponsible lawbreakers’, ‘pariahs’, ‘danger to others’, ‘inconvenient’, ‘badly behaved’ and ‘extremists’ in 1998, to ‘irresponsible lawbreakers’, ‘danger to others’, ‘pariahs’, ‘inconvenient’, ‘extremists’ and ‘in the minority’, in 2008.

The proportion of positive framings of cyclists rose from 11.5% of the 61 articles in 1998 to 26.7% in 1999, slumped in 2003 and 2007 (7.8% and 9.8% respectively), and rose to 31% in 2008. In 1998, cyclists were framed as ‘brave’, ‘safety conscious’ or ‘other’, including ‘charitable’ and ‘campaigners for better transport’. In 1999, the ‘healthy’ frame emerged. In 2008, ‘brave’ was the leading frame (11 uses), followed by ‘harmless’ (5) and ‘safety conscious’ (1). Among the ‘other’ frames found in 2008 were instances of cyclists as ‘image conscious’ and as ‘outraged by restrictions on taking bikes on trains’.

Discussion

Over the past decade there has been an increase in the quantity of newspaper coverage of cycling in the two main newspapers in Sydney and Melbourne, with a significant increase in Melbourne in recent years. More recent reporting of cycling has been generally positive, with the Sydney tabloid paper *The Daily Telegraph* reporting the most negative stories. Negative stories were predominately about death or injury to cyclists. Death and injury to cyclists are the two most common news angles, and are the main ways that cycling draws news media attention.

There were large increases in cycling in Melbourne between 2001 and 2006 (a 42% rise from 14,443 to 20,592 people), reported in the Australian Bureau of Statistics journey to work statistics, compared with modest increases in Sydney (8%, from 11,131 to 12,132 people) (Bauman et al. 2008). This increase in cycling in Melbourne appears to have been followed by positive reporting of cycling in Melbourne. Negative newspaper stories about cycling may deter people from considering cycling as a transport option, but real physical or political improvements to the cycling environment may be necessary before more positive coverage is reported.

Whether the media initiate a widespread change in beliefs and practices in relation to an issue, or react to existing trends (e.g. an upswing in cycling), public health practitioners cannot afford to be passive about news media debates. Most citizens and policy makers learn about health from the media (Lippman 1922; Johnson 1998; Dorfman and Wallack 2005) and media frames and agendas influence public opinion and attitudes (McCombs and Shaw 1972; Entman and Framing 1993). Public health media advocacy, defined as 'the strategic use of news media to advance a public policy initiative, often in the face of opposition' (Chapman 2004) is central to advancing public health (Chapman and Lupton 1994) and has been critical to policy changes which have reduced death and disability from tobacco, firearms, HIV/AIDS and car accidents (Chapman 2001; Dorfman and Wallack 2005).

The results highlight cycling as an under-appreciated, deserving of support, fun and popular activity which generates social, environmental, health and economic benefits. However, many articles also framed cycling as dangerous to cyclists and non-cyclists and, to a lesser extent, as difficult, bad for the urban environment, unpopular and costly. Given the powerfully negative sentiments sometimes circulating in opinion pages and blogs, it is somewhat surprising to find many more instances of positive frames of cycling than negative. This information is tempered by the findings that almost half of all articles include the frame of cycling as a risk to cyclists and that death, injury and danger were the main ways in which cycling attracted news media attention.

While the proportion of positive framing of 'cyclists' (as opposed to 'cycling') was low, it appears to be rising, with the dominant positive framing of cyclists as 'brave' detected almost four times as frequently in 2008 as in 1998. However, between one-fifth and one-half of the articles carried a negative framing of cyclists in every year studied. While our study shows widespread use of positive framing of cycling, cyclists are portrayed negatively in a substantial subset of coverage (33% on average) and this trend is upwards.

The way that news stories were framed builds a picture of cyclists as irresponsible, law-breaking, dangerous 'others' who behave badly and cause problems for society out of proportion to their numbers. The focus on the label of 'cyclist' tends to connote an image of people who cycle as different from the rest of the population. Perhaps it conjures images of Lycra wearing groups or people wearing fluorescent clothing that is somehow alien to the mainstream, and therefore easier to dismiss or deride. As Koorey (2010) says:

> *When it comes to cycle planning and policy, all parties involved (politicians, policy-makers, practitioners, advocates) should remember that they are providing for **"cycling"**, not "cyclists". The former term is an activity that virtually anyone can do under the right circumstances (and hence should be planned for), whereas the latter often gives connotations of a relatively small bunch of "weird" people who only ever cycle.*

Basford and colleagues' (2002) study of driver attitudes towards cyclists found that drivers saw cyclists as an 'out group', and blamed them accordingly for what was seen as negative behaviour, whilst exonerating members of the 'in group', namely themselves and other drivers. Hence, the practice of stereotyping cyclists within the broader culture finds its way into the news media, just as the news media can legitimise and reinforce such stereotypes. Drivers can also be negatively stereotyped by the type of car they drive; four wheel drive vehicles in urban areas have been identified in collective urban mythology, according to Moran, as 'over-privileged hoggers of road space', while minicab drivers in England are regarded as 'rude, incompetent crooks and potential rapists' (Moran 2005).

The tendency towards negative framing of cyclists may create barriers to cycling for transport for people who do not identify themselves as in this group. Koorey (2010) argues that the majority of people who ride bicycles at least occasionally do not identify themselves as cyclists and for others the term has negative connotations, suggesting that the term 'cyclist' should be avoided in communications promoting cycling to the non-cycling public and motorists. It follows that cycling advocacy should focus more on the benefits of cycling for all, and not focus on the needs of cyclists. Appeals for better cycling infrastructure or policies for the benefit of cyclists may not attract as much public support as cycling changes presented as having benefits for the whole community.

A limitation of the study is that we excluded opinion pieces. They were excluded because they are often written to provoke readers, and do not necessarily reflect popular norms (although do represent some sub-group views). Negative opinion pieces on cyclists in the news have been identified by some cycling advocates as inflaming driver aggression and violence against cyclists. Furthermore, news articles on cycling crashes are more likely to blame and stereotype cyclists as reckless risk-takers rather than develop a more balanced or neutral approach to reporting crashes.

Other limitations include that we did not sample all years (due to resource constraints) or more newspapers. The analysis is restricted to the main Australian cities of Sydney and Melbourne and may not represent newspapers in other capital cities. Excluding sports coverage may have removed a body of positive coverage of cycling. However, cycling for transport and recreation has greater public health importance and was the focus of this study.

Conclusions

This paper is the first internationally to document how cycling is represented in newspapers and to examine changes in newspaper reporting of cycling over time and by capital city newspapers. Coverage appears to reflect developments in cycling in different locations, but specific newspapers still have particular approaches to how they report stories that range widely on the positive-negative spectrum. Unfavourable news reporting of cyclists and cycling may deter people from considering cycling as a transport option, however physical or political improvements to the cycling environment may be necessary before coverage becomes more positive.

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Limitations on the use of the term 'cyclist' to describe people who ride bicycles

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Abstract

This paper presents evidence supporting the contention that the term 'cyclist' is narrowly interpreted as referring mainly to 'serious' sports cyclists by both people who ride bikes and those who do not. Most (over 70%) people who ride bikes at least occasionally do not self identify as *cyclists* and for others the term has negative connotations. This suggests the term cyclist should be avoided in communications promoting cycling to the non-cycling public and motorists. This has relevance to cycling promoters, writers of cycling material and cycling event organisers in composing messages to best reach their audience. Alternatives to the term are suggested.

Introduction

A large proportion of communication intended for people who ride a bicycle may miss the mark by referring to them as *cyclists*, a term with which most riders do not identify and for which others hold negative connotations.

It is suggested here that when addressing the public or motorists terms should be used that retain a human or behavioural element such as 'children riding bikes', 'commuters cycling to work' or 'locals cycling to the shops' in place of the term *cyclist*.

Background

Though the range of people who ride bikes is vast they are all generally referred to in conversation and the press as cyclists.

While technically the term 'cyclist' refers to anyone on a bicycle it is apparent that in popular use it refers only to a narrow sub-set of all the people who ride bikes.

When reading that 'a group of cyclists is riding to the beach', or that 'cyclists hope for lower speed limits' it is a fair bet the images these statements may generate were not those of the group of twelve year old children actually referred to.

During focus group research conducted on behalf of Bikewest (Donovan Research 1999 unpublished) the group was asked about the perception motorists have of cyclists. The results indicate the term *cyclist* had negative connotations and appears to define for them, almost exclusively, on-road, Lycra wearing, sporting riders.

In today's Australian usage it appears that the term 'cyclist' is imprecise and has widespread negative connotations which can dilute or distort the messages cycling promotion organisations distribute to make cycling appealing. Furthermore, messages aimed at people who do ride may be missed by them when they are addressed to 'cyclists'.

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Experience in the health promotion field has encouraged practitioners to work hard to get the right message for the audience, and then target the message to the right people. It became apparent in the early days of designing health promotion and disease control messages that people may not see themselves in the way that the educators had hoped. They may even actively refuse to classify themselves using the collective words preferred by the health professionals.

For example:

- The many people who smoke socially are unlikely to attend to messages addressed to 'smokers' as they may not see themselves as such.

- Otherwise functioning adults who drink more than is desirable for promoting good health are unlikely to attend to messages beginning "Alcoholics need to know..."

- Men who occasionally have sex with other men while overseas on holidays or in prison were found not to attend to the important health messages that were addressed to gay men, as they did not define themselves as gay men or identify themselves as gay.

In these examples people have been engaged in particular behaviours but did not classify themselves in the same way health professionals had, as smokers, alcoholics or gays. This then makes it easier for people to ignore messages which they see as irrelevant to them.

Health authorities subsequently tailored the messages to the *behaviours* not the collective nouns. This then changed the messages from focussing on group identity to behaviours, hence:

- Every cigarette is doing you damage.
- More than 4 standard alcoholic drinks per day is harmful.
- Men who have sex with other men should...

These messages have a behavioural reference rather than using the negative and stereotypical reference to groups, which many members of the target audience did not identify with. It can be asked, will people who ride to work twice a week, or cycle at weekends for exercise relate to messages, cautions or statistics that are addressed to 'cyclists'?

Who is it then, among the range of people who ride a bike, that self-identify as a cyclist and what proportion of this group of riders do they constitute?

Method

The Department of Transport's Bikewest Branch annually conducts a survey of around 400 Perth residents to monitor their attitudes and behaviours in relation to cycling.

The 2009 survey was conducted online with the random sample drawn from the contractor's online panel (MyOpinions) which is representative of the Australian population. Respondents had to be aged 18 or over and reside in the Perth Metropolitan area to take part.

Fieldwork commenced prior to Easter 2009 and was completed in early April. The sample was evenly split between genders, and the average interview duration was 11.3 minutes.

Among a range of questions on attitude, respondents were asked if they had cycled in the last six months, what level of frequency they cycled, whether or not they considered themselves to be a cyclist and why (or why not).

Results[1]

Ninety four (24%) of the sample of 400 indicated they had cycled in the last six months.

When these 94 respondents were asked if they considered themselves to be a cyclist 19 (20%) said yes, 71 (76%) said no. Four percent did not know.

These 94 were asked to indicate their level of cycling activity.

- Twenty (21%) indicated they rode a lot or regularly and of these 14 (71%) considered themselves to be a cyclist.

- Sixty five (69%) indicated they rode a fair bit or occasionally and of these 60 (91%) did not consider themselves to be cyclists.

- The remaining 9% did not know.

Asked more specifically about their cycling frequency, 47 (52%) cycled between 11 and at least 50 trips in the last six months, with 33 (37%) cycling between 21 to over 50 trips in the last six months.

The 19 respondents who self identified as cyclists were asked why they saw themselves that way.

- 7 (38%) indicated they love cycling and cycle everywhere and as often as possible.
- 5 (25%) indicated they cycle regularly.
- 6 (30%) indicated they were serious about cycling and its equipment etc.
- 1 response was irrelevant.

The 65 who rode bikes, but did not classify themselves as cyclists, were asked why not.

- 36 (50%) said they don’t cycle often enough.
- 12 (18%) indicated they only ride for recreation, pleasure, relaxing or exercise.
- 9 (12%) indicated they don’t wear Lycra or tights.
- Others responses included that they don’t ride fast enough, are not competitive, don’t have a professional bike and so on.

Conclusion

These results indicate that the majority of people who were surveyed and rode a bike at least occasionally in Perth during 2009 did not self identify with the term *cyclist.* This supports anecdotal evidence that most people who ride a bike do not self identify as a cyclist and, among people who do not ride a bike, earlier research indicates the term holds negative connotations.

This has implications for the language used when conveying information, warnings and promotions to people who ride bicycles.

Recommendation

Communications outside of the cycling industry may be better to avoid the term cyclist and use behavioural and human references.

1 *Results are rounded.*

These alternatives would include, among many others, ‘children cycling to school’, ‘commuters cycling to work’, ‘families riding in the park’, ‘couples riding to the beach’, ‘locals cycling to the shops’, ‘people cycling to lose weight’ and so on.

Limitations

The sub-sample of people who cycled was small though the strength of the differentiation between the non and self-identified cyclists make the concept worth exploring with a larger sample of riders. The connotations attributed to the term ‘cyclist’ may be peculiar to West Australian or Australia.

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The disruptive traveller? A Foucauldian analysis of cycleways

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Abstract

The relationship between the cyclist and the use of roadways and other spaces allocated for travel has a contested history. Pro-Cycling advocates have argued from a number of positions for the rights of cyclists to use road space and the location of responsibility for road safety. This paper examines how the widespread introduction of segregated cycle facilities in recent years, whilst having undoubted beneficial effects can also be seen to raise significant problems for cycling in the context of broader travel behaviours. Bonham's (2006) exploration of the manner in which travel systems and patterns act as disciplinary regimes can be extended to further develop an understanding of the impact of segregated cycle facilities. Drawing on the insights of Michel Foucault, we have examined texts on cycleways, historical and contemporary, produced in the United Kingdom and Australia, for the way in which cyclists are constituted and positioned. The findings are complex. Overall recent texts produced within the health sciences begin to normalise cycling while those produced within the field of transport position cyclists as deviant travellers – albeit in different ways and with different outcomes depending on the broader context. In each case, the cycleway becomes a special space which enables and constrains cycling while cycle practices are constituted as slow and disorderly, leisurely, often social and always requiring a ‘quiet’ (both in terms of traffic and noise) context. We conclude that the cycle path, by removing cyclists from road space, ultimately operates to maintain rather than challenge existing travel norms. We argue the consequences of this segregation may be profoundly at odds with the potential of cycling as a core component of sustainable mobility.

Introduction

The relationship between the cyclist and the use of roadways and other spaces allocated for travel has a contested history. Pro-Cycling advocates have argued from a number of positions for the rights of cyclists to use road space and for changes in location of responsibility for road safety. This paper examines how the introduction of segregated cycle facilities in recent years, whilst having undoubted benefits, also raises significant issues for cycling in the context of broader travel behaviours. In particular, we are interested in whether the separation of cyclists from other road users actively constitutes the cyclist as disruptive or ‘abnormal’, a traveller to be dealt with as a ‘special case.’ Further, we ask if displacing cyclists onto cycleways has the effect of excising them from the day-to-day travel routine and of facilitating ‘normal travellers’ (i.e. motorised transport users) in the unhindered conduct of their journeys. If this is the case, segregation of cyclists may operate, perversely and paradoxically, to maintain rather than to challenge existing travel norms and hierarchies.

This paper analyses texts on cycling for the way they place cyclists, especially in urban environments. We work from the position that what is written is not a more or less accurate reflection of reality but actively shapes that reality in ways that leave room for contestation (Larner and Walters 2004: 3). We focus on texts because they are sites in which discourses (bodies of knowledge) emerge and we are interested in the economic, transport and health discourses through which cyclists are constituted and positioned in relation to others. These discourses objectivise bodies in specific ways, establish new

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categories of being (subjectivities), create new techniques of measurement, produce new norms and relate bodies to each other in different, often competing, ways. In this understanding, cyclists are not self-evident, fixed beings but the unstable outcome of on-going processes of differentiation and contestation over the (mobile) body.

We have analysed historical and contemporary texts produced through parliamentary, research, planning and lobbying processes. We have compared texts produced in the United Kingdom and Australia (but especially South Australia) because they are countries with particularly low levels of cycling. We acknowledge that a comparison between these countries and the Netherlands or Denmark would provide rich insights into different ways of thinking about the place of cyclists in urban space; however, such a project is beyond the scope of this paper. We have examined texts for the way in which they 'locate' cyclists in urban space and we are particularly concerned with discussions of cycleways – off-road infrastructure designed for bicycle passage forming a separate right of way.

This paper is divided into three sections. The first establishes the theoretical underpinnings of our analysis. Our discussion relies on a very different theorisation of the individual, of the subjects (or categorisations) of travel and knowledge, and of the relationship between power and knowledge than generally used in the transport literature. And our paper will only make sense if the key features of this theorisation are explained at the outset. The second part of the paper analyses texts produced in the pre and post-WWII periods as competing discourses which target the cyclist as either a political or an economic subject. The final section examines contemporary texts for the ways in which cycleways are discussed and the characteristics, qualities and actions attributed to the 'cyclist'. Of particular interest is the way the cycleway and the cycling body is constituted, and potentially normalised, in discourses on health and whether or not this perspective challenges transport norms. Put simply we ask the question: do cycleways challenge or reinforce existing travel norms and hierarchies?

Bringing Foucault into transport

In contrast to the broader transport literature, we do not theorise the individual as a natural, pre-social being simply choosing one mode of travel over others. Drawing on Michel Foucault, we are interested in the techniques through which people in contemporary societies come to think of themselves as individuals and regulate themselves toward, alter or resist the subjectivities or subject positions (e.g. as cyclists, pedestrians, motorists) available to them in governmental[i] texts (Foucault 1982). We take the view that the production of knowledge about human beings – which has proliferated since the eighteenth century – and the operation of power which enables that knowledge, is central to our capacity to think ourselves first as individuals (Digeser 1992) and then as particular types of subjects (Foucault 1977; 1978). In this sense, those who produce and utilise transport knowledge participate both in shaping how people can think about their journeys and in structuring the field of action of individual travellers.

It is impossible to review the key elements of Foucault's work in this article, instead we offer a brief introduction accompanied by an example of how Foucault's work can be utilised in transport. Readers unfamiliar with Foucault are directed to McHoul and Grace (1995) for a concise introduction and Bacchi (2009) on applying Foucault to policy analysis.

Foucault offers an understanding of power as productive, as producing particular types of being and knowledges (Bacchi 2009). He identifies different types of power (Hindess 1996) and, although governmental and bio power are important to transport, our paper focuses on discipline as it foregrounds the role of 'spatialising' practices[ii] in processes of objectification and subjectification (the formation of subjects). Disciplinary power, fundamental to the self-regulation that characterises modern societies (Foucault 1991) has enabled the production of knowledge about the capabilities and capacities of human beings which in turn facilitates innovations in the exercise of power (Foucault 1977). It is through the operation of power at a micro-scale, the sorting and physical separation of the human mass – constituting difference through the discursive mechanisms (records keeping, data collection) involved in separating, scrutinising and monitoring bodies – that knowledge of singular bodies has been produced (Foucault 1977).

From the moment we are born – separated from our mothers, gendered male or female, weighed, measured, named, allocated the special space of a cot and monitored at regular intervals – we are subjected to and made subjects through myriad practices involving the operation of power and the production of knowledge. The procedures of inscription which bring individuals into effect and objectivise bodies in specific ways – as healthy or ill, learning or illiterate, political or passive, law abiding or deviant, mobile or stationary individuals – simultaneously enable the aggregation of those singular histories into knowledge of populations where norms, the limits to normal, and deviations from the norm are constituted (Foucault 1977). An important point here is that these are not *necessary* ways of knowing individuals. Rather, conditions at different moments enable objectification of bodies in new ways. With this knowledge, individuals are worked upon through systems of punishment and reward to regulate themselves according to the norm while those found wanting – disruptive, abnormal – might be removed altogether. Travel is but one domain in which bodies have been objectivised and subjectivised; separated, scrutinised and worked upon and, in the case of cycleways, removed altogether.

Through the late nineteenth but especially the twentieth century it became thinkable, practicable and meaningful to study urban movement. Until recently, the meaning of that movement has been asserted and widely accepted as ‘transport’ – the journey from *a* to *b* specifically to accomplish some activity or task at point *b* (Bonham 2000). Over time, the journey, or trip, has come to appear as ‘self-evident’ as mechanisms for the study of journeys – origin-destination studies, household travel surveys, vehicle counts – excise particular practices from the mass of daily activities and bring them under scrutiny. Objectifying travel as ‘transport’ establishes the journey as a by-product of its end points – derived-demand – and provides the imperative for trips to be accomplished as quickly, or economically, as possible (Bonham and Ferretti 1999). ‘Derived-demand’ functions as a ‘statement’ (Foucault 2002) within the field of transport, a statement which both disciplines those who would study travel and discounts, if not excludes, the many other possibilities of our journeys.

Drawing on Foucault’s (1980) understanding of power as productive, the objectification of travel as transport is productive in that it has enabled the development of a vast body of knowledge and brought new subjects into effect – the pedestrian, cyclist, motorist, passenger. These subjects have been facilitated through the operation of power at a micro scale involving practices of differentiation and separation of users of public space, identifying those who are stationary and those who move (Bonham 2002; Frello 2008), and subsequently scrutinizing, sorting, categorising and disciplining those who move according to the conduct of their journey (Bonham 2002). A number of practices – particular ways of moving, particular types of observations, pauses, conversations – have been separated out, excluded as NOT-transport and marginalised in the space of the street. Other practices – keeping to course, attuning hearing, sight and reflexes to the operation of vehicles – have been worked upon in disciplining the mobile body (Bonham 2006; Paterson 2007).

In cities across the world, the contemporary division and regulation of the public space of the street (and road) has been guided by a transport rationalisation of urban travel (Bonham 2000). Streets have been divided lengthwise and travellers allocated space according to the speed and order with which they travel (Bonham 2000). The mobile body has been incited to move at speed to ensure the efficient operation of the city. However, in the early twentieth century, widespread concern over motor vehicle related deaths and injuries underpinned debate over prioritising speed or safety. The debate was resolved (but never quite fixed) in favour of speed with ‘vulnerable’ road users giving way to the fast (Bonham 2002). The slow and disorderly – pedestrians, horses and carts – were removed to the margins, checked by the fast and orderly, or excluded altogether. Overall efficiency, measured in time, could only be assured if each traveller agreed to be orderly – hence all those road safety techniques and programs which train bodies in ‘correct movement’ (Bonham 2006). The public space of the street, often identified in political discourse as a site available to all citizens, effectively becomes an economic space where the subject of transport discourse, conducting the economical journey, gains primacy. Subjugating oneself within the discourse on transport – becoming the efficient or economical traveller, which in the twentieth century has meant taking up the subject position of the motorist – is rewarded with priority in the use of public space.

These individual rewards invoke wider social rewards through the increase in the reproduction of capital through the facilitation of movement (Cox 2010). Indeed, an entire literature on globalisation has employed this metaphor of increased flows in speed, volume and depth to describe globalisation of capitalism from the end of the twentieth century (Boran and Cox 2007). Transport discourses are thus woven into discourses on the nature of public good and of socio-economically responsible behaviour, reinforcing the linkage between travel behaviours and 'responsible citizens'.

The knowledge produced about individual travellers is not only enabled by the exercise of power but also facilitates the further exercise of power. Power-knowledge relations operate at a micro-scale subjectivising singular bodies while, at a macro-scale, the subjectivities constituted within different disciplines (such as economics, demography) are deployed in the government of populations (Foucault 1981; 1982; 1991). Further, the aggregation of data about singular bodies not only allows the calculation of norms (and deviations from those norms) but in liberal societies, where citizens are constituted as free and incited to exercise freedom of choice (Huxley 2008), this knowledge is central to government as populations are guided rather than directed toward particular ends (Rose 1990; Gordon 1991; Rose and Miller 1992). Following from this, an analytics of government:

> *...invites readers to think about individual subjects as being produced in specific social policy practices, for example, as worker-citizens in workfare programs, as parent-citizens in child and family services or consumer-citizens in a managerial and marketised mixed economy of welfare (Marston and McDonald cited in Bacchi 2009, 42).*

In terms of transport, knowledge produced about individual travellers and singular journeys is combined into knowledge of urban populations and used to guide the choices of the population toward economical movement and the economical operation of the city. This process values speed and prioritises the reduction of travel time ahead of the impacts on health, environment and social exclusion that accompany increases in speed and travel energy consumption (Lohan and Wickham 1998; Whitelegg 1993; 1997).

Placing cyclists

The division and regulation of street space according to a transport rationalisation of urban mobility has not gone unchallenged, and material outcomes have varied according to conditions in individual cities: the retention of the tramways in Melbourne or establishment of shared traffic precincts in German cities are cases in point. But bike riders have been a constant provocation within traffic and transport discourses and the related division of urban space. Cyclists remain difficult to locate in terms of propulsion and vehicle design (Cox and Van de Walle 2007), subjectivity and place. Historically, decision makers, lobbyists and bike riders have vacillated between providing for cyclists on-road, removing them to off-road spaces or ignoring them altogether. Evident within these discussions is a tension, which persists today, between the cyclist as a political subject, a citizen with equal rights to use public space, and the cyclist as an economic subject – either as a producer who participates in the urban economy or as an economical traveller located within a hierarchy of speed and order. Three brief examples must suffice to illustrate these points.

Attempts through the inter-war years to remove cyclists from the road often met with resistance. The first experimental segregated track installed in the UK in 1934 beside the Western Avenue in North London led to active campaigning from the Cyclists' Touring Club (1935) as they argued cycle tracks were 'the thin end of a wedge ultimately to drive bicycles off the road' (Way 1966: 165).[iii] By contrast, Frank Urry, a member of the UK's Ministry of Transport Advisory Council in the 1930s, argued the impracticality of removing ever growing numbers of cyclist-workers from the streets. In the former case, the cyclist was located within a political discourse of citizenship rights while in the latter case the cyclist was identified as an integral part of the urban economy thereby shifting attention from political rights to the most economical means of facilitating the worker. Similar discussions took place in South Australia where bike riding was linked to the worker (Honorary Committee to Report on State Traffic Act 1936, 1938: 10) and this particular economic construction seems to be at the heart of cyclists maintaining an on-road presence. In both the UK and South Australia, debates over cycle tracks were abandoned during WWII when austerity measures and the rationing of fuel for civilian motor vehicles meant personal (private) mobility was effectively given over to the bicycle, alongside public transport provision.

In contrast to the segregation measures of the pre-WWII period, cycling was largely ignored in post-WWII urban and transport planning. In South Australia, cycling was discounted within (Adelaide City Council 1957) or excluded from bureaucratic routines of data collection and reporting (e.g. Highways and Local Government Annual Reports) or studies of urban transport (e.g. Town Planning Committee 1963; De Leuw, Cather and Company 1968). Despite the shift of industrial and retail activity to suburban locations and anecdotal evidence that cycling was an on-going part of the journey to industrial workplaces, shops and schools, cyclists were simply ignored in post-war transport planning in Australia and the UK. Notable UK exceptions were the new town projects of Harlow and Stevenage (and subsequently in Milton Keynes) which included extensive cycle-only routes. In general though, engineering plans provided for motor vehicles – moving and parked – but not for cyclists (e.g. De Leuw, Cather and Company 1968). As cyclists were ignored in transport data collection and transport texts, they were also ignored in street space.

The aftermath of the 1960s freeway debates saw renewed interest in cycling that invoked a new round of discussions about the appropriate place of cyclists. The Director General of Transport in South Australia argued cyclists were to be encouraged '…to use low traffic volume residential streets and, where possible, exclusive tracks' (1974: 1). In the UK, urbanist Jean Perraton argued for the construction of cycleways.

> *On a modern road system the bicycle is an archaic anachronism, **delaying and worrying car drivers** and endangering its rider…The quality of urban living will be enhanced if [people] also have the opportunity to cycle on paths which are safer, quieter, with cleaner air and closer to grass and trees than urban **motor** roads (1968: 162). (Emphasis added.)*

There are a number of important points to be drawn from this text. First, Perraton constructs mobility practices in terms of progress by juxtaposing the 'modern road system' and the 'archaic anachronistic' bicycle. This evolutionary view of mobility operates to naturalise and depoliticise the reconfiguration of public space Perraton is proposing, one which facilitates motorists and excludes cyclists. Secondly, Perraton identifies the bicycle rather than the cyclist, as 'out-of-place' making this vehicle, rather than the motorist or motor vehicle, responsible for endangering the cyclist's life. Third, Perraton contests the place of bicycling in the transport order, constructing it in terms of lifestyle rather than access. If cyclists have no place in the transport order, they can be readily excluded from the road, a transformation completed in Perraton's use of the term *motor roads*. Finally, as the bicycle is characterised as '*delaying and worrying car drivers*' a hierarchical relation is established between the cyclist's journey as a problem and the motorists' journey as the norm. In this instance, segregated cycle facilities – paths or cycleways – become places for the abnormal journey and cyclists are treated as a special case.

Segregation of cyclists onto cycleways echoes the exclusion of 'abnormal' bodies (e.g. the sick, the mad, the delinquent) discussed in Foucault's genealogical works (1977). Removing this disruptive traveller facilitates the routine flow of urban life and enables closer scrutiny of the 'abnormal' body. However, cycleways were never seriously implemented in the UK or Australia, possibly because cycling could be positioned on the one hand as a mode of transport without a future – the disruptive traveller would eventually disappear – or on the other hand as a lifestyle activity that did not have to be prioritised in terms of urban infrastructure. Comparison with Dutch and Danish texts of this time would provide important insights into different discursive constructions of cycling and the alternative governmental tactics they enable.

Over the past two decades, automobile-oriented transport systems have been re-problematised in terms of environmental degradation, urban congestion, resource depletion associated with peak oil, and the health implications of aging populations and sedentary lifestyles (e.g. Freund and Martin 1993; Horton et al. 2007; DfT 2008). Environmental concerns gained traction through the 1990s bringing the mobile body under scrutiny, combining the economic subject who makes the journey as quickly as possible with an environmental subject who minimises resource use and waste *out of concern for the environment*. In addition, from the early 2000s the mobile body and practices of walking and bike riding have been increasingly scrutinised and worked upon within discourses on health. Seizing this moment, organisations and individuals sympathetic to cycling are shifting bike riding from problem to solution, and cycling practices are gradually being inserted into transport policy and planning. Alongside these developments, there are growing demands for closer scrutiny and accounting of cycling, including: cost-benefit analyses of infrastructure; on and off-road cycle counts; evaluations of cycling infrastructure, programs and promotions (e.g. SQWconsulting 2008). Through these mechanisms, discourses on cycling and the subjectivity of the cyclist operate as sites to resist marginalisation of bike riding within transport discourse. However, these discourses also subjugate cyclists in new ways, as we proceed to explore in the next section. They are not an escape from the operation of power or power-knowledge relations but they operate to fill the category of cyclist with new content. It is within this context and through the intersection of discussions on transport, environment and health that the provision of specific infrastructure measures such as cycleways are brought back in as ‘an opportunity to positively encourage cycling’ (Arup 2009: 4).

Cycleways in texts today

Although bikes still make up a fairly small proportion of traffic (in frequency and space), their growing on-road presence challenges the practices and priority of motor vehicle mobility. Transport professionals, academics and cycle lobbyists in the UK and Australia continue to debate the placing of bike riders in urban space. Australian state transport departments are implementing various mixtures of on- and off- road infrastructure: New South Wales has focused on off-road facilities such as cycleways, Western Australia appears to have a more even mix between on- and off-road paths, South Australia concentrates on on-road infrastructure. The following section examines texts produced on cycling spaces for the ways in which they simultaneously constitute the cyclist, and practices and rationalisations of bike riding. We focus on discussions of cycleways – those routes that provide cyclists with travel possibilities outside the existing road network and highway systems: segregated cycleways such as those that run along river banks, through parklands and across the countryside, rather than bike lanes marked out on the street. However, these segregated routes – also referred to in some literature (particularly from the US context) as bike trails – are often linked to specific segments of the urban road network so the discussions frequently overlap.

In the UK, the primary motive force behind the creation of surfaced and marked cycleways has come from Sustrans. Originally formed as a lobby group in 1977, Sustrans was registered as a charity in 1983 and has continued to work in partnership with local authorities on numerous projects, including the National Cycle Network and a mixture of signed on-road routes and off-road cycleways, frequently utilising disused former railway routes.

Sustrans weaves together discourses on transport and health as the stress in all its original descriptions of cycle routes is related to health, safety and congestion

> *[t]hese routes provide real, practical benefits to local communities countrywide, reducing traffic fumes, easing congestion and providing a pleasant alternative to the stress and danger of motor traffic (Sustrans 1994).*

Echoing commentators from the 1960s (e.g. Perraton 1968), Sustrans consistently emphasises the sharing of off-road routes for all non-motorised users. It foregrounds health benefits of cycling in its self-presentation and the lobbying process used to establish partnerships with statutory bodies for infrastructure and other projects (Sustrans 2009).

> *Sustrans provides creative, innovative and practical solutions to the transport challenges affecting us all. By working with communities, local authorities and many other organisations, we create change by putting people at the heart of activities, enabling many more people to travel in ways that benefit their health and the environment* (Sustrans 2010).

Sustrans' emphasis on health resonates with the emerging health promotion and preventive medicine literature. Over the past decade, the health benefits of cycling and walking have been tested, and supported, through medical studies that relate these modes of travel to mortality and morbidity amongst given populations (Andersen et al. 2000; Chief Medical Officer 2004; Hamer and Chida 2008). Further, as norms have been established in relation to the amount of exercise necessary to maintaining a healthy body, practices such as walking and cycling have been included in health surveys to determine the level of physical exercise undertaken by given populations (Kavanagh et al. 2005).

The mobile body objectified within the health and medical literature directly challenges the transport rationalisation of mobility and the concept of 'derived-demand' (see also Kitamura et al. 1997). The journey is not simply a by-product of its origin and destination but is itself meaningful – it might be performed in conjunction with an origin and destination (or not) but its meaning exceeds the 'trip'. This health perspective opens new ways of thinking about mobility and facilitates the production of new norms in relation to urban movement. The procedures inherent in creating health and medical knowledge lend considerable authority to this alternative view of mobility which commands serious attention and governmental action. In Europe, discourses on health have been recognised and encouraged through the creation of the *Lifecycle Project* (http://www.lifecycle.cc/) while in Australia the *Healthy Spaces and Places* (http://www.healthyplaces.org.au/site/) initiative links mobility, place and health. The emergent discourse on health and the governmental programs spawned by it have the potential to facilitate a cultural shift in practices of travel as they operate to regularise and normalise cycling (and walking).

In this context, the cycleway might become the place for working toward the healthy body and its users brought under scrutiny for securing health outcomes (Cohen 2003; 2008; Merom et al. 2003; Evenson 2008) rather than as displaced and disruptive elements of transport. However, to date, as Sustrans, amongst others, invoke the qualities of cycleways they simultaneously specify the set of mobility practices appropriate to the conduct of the healthy journey as slow, quiet, peaceful, often meandering, open to interruption and involving others.[iv] The cycling body constituted within transport discourse – as slow and disruptive/disorderly – is largely reproduced in discussions of health. Similarly, a range of practices – fast, direct, practical, continuous and solitary – are silently marked as inappropriate. But bike riders using cycleways – like mobile bodies everywhere – combine a range of practices at different times and under different circumstances.

Like health, safety has been a recurring theme in discussions on cycleways and the concept of 'quietness' links health and safety through reference to noise, speed and volume of traffic. In promotional materials for the range of cycleways and tourist routes constructed in the UK over the past two decades – many built in conjunction with Sustrans – constant and repeated reference is made to the 'traffic free nature' of the routing. Immediately, the cycle journey is marked as *NOT*- traffic, and therefore not part of the normalised flows of vehicular movement on the highways.

A series of examples illustrate this process whereby ‘traffic-free cycling’ becomes the selling point of such schemes. Sustrans explains the status of ‘The Jubilee River and Slough Linear Park: Traffic-free cycling opportunities between Slough, Maidenhead and Windsor’ (UK) as part of a wider project to promote cycling:

> *[Sustrans] is behind many groundbreaking projects including the National Cycle Network, over twelve thousand miles of traffic-free, quiet lanes and on-road walking and cycling routes around the UK (Sustrans, Slough Borough Council and The Royal Borough of Windsor and Maidenhead 2008).*

Similar concerns are expressed in promotional materials and leaflets for cycleways across the UK: ‘The Water of Leith is a peaceful, traffic free route from Leith to Balerno’ (Edinburgh Council nd); ‘Ride through the peaceful South Tyne Valley on a traffic-free greenway to the spectacular Lambley Viaduct’ (Hadrian’s Wall Heritage Ltd 2010); and, advertising holiday accommodation:

> *Although many parts of the UK now have too much traffic for safe cycling, there are parts of the country where you can cycle in relative safety. Some railway tracks have been converted into dedicated cycle ways which is probably the ideal way for families with children to take to the road plus there are numerous national cycle routes and waymarked trails* (Country Cottages Online).

These texts are at odds with attempts to promote daily cycling as they locate bicycling ‘outside of everyday life’ and ‘outside definitions of traffic.’ Arguably, the assemblage of ‘cycling as a holiday or leisure activity – safe cycling — absence of traffic’ casts doubt on everyday utility riding. Further, in constructing bikes as NOT-traffic the needs of cyclists can be readily dismissed in traffic modelling and planning.

In Australia, cycle routes often comprise a mixture of off-road cycleways and on-road ‘quiet’ streets. In a caption accompanying a map of the proposed bike network for Sydney 2010, producers of the NSW Action for Bikes strategy stated:

> *The result will be 420 km of major off-road cycleways and 214 km of major links on quiet streets. There will also be sealed road shoulders in semi-rural areas for experienced cyclists (Road Transport Authority 1999: 5).*

An update to that plan, explains:

> *The Metro Sydney Bike Network is made up of off-road paths and on-road links using quiet streets, with facilities offering safe and attractive travel for less experienced cyclists (NSW Government 2010: 10).*

Similarly, the Perth Bicycle Network, while including a wide variety of roads, also relies on quiet streets:

> *A local bicycle route adds value to the concept that ‘every street is a bicycle street’ by linking a series of quiet ‘residential’ streets which need little improvement in order to be attractive and safe for cycling, to provide continuity for somewhat longer trips (Bikewest 1995: 5).*

As ‘quiet spaces’ are designated appropriate to cyclists, the cycling body is simultaneously constituted as one which is averse to or which does not function properly in places with noisy, busy, fast moving traffic. The constant reference to ‘quiet’ places raises suspicions about the bike rider that uses ‘busy’ streets. The current debates over the place of cyclists echo those of the inter-war period. Much of the discussion focuses on where and how *cyclists should* ride to ensure their safety leaving little more than a disgruntled murmur, dismissed as irrational, around changing the conditions which place cyclists at risk.

Several additional issues are raised in relation to this problem of safety. First, a question arises about which cycling body is made safe from what. Various Australian studies have found that women prefer to cycle on off-road paths or less heavily trafficked roads (Garrard et al. 2006, Garrard et al. 2008). However, the vast feminist literature on women's use of public space (e.g. Trench et al. 1992; Valentine 1992; Wekerle and Whitzman 1995) suggests that quiet streets and cycleways at night, or in especially 'out-of-the-way' places, may be equally or more 'risky' than riding on a main road. Indeed this is acknowledged in some cycle planning literature and in anecdotal evidence from women cyclists (Arvidson 2008).[v] The cycleway as 'haven' resonates with those uncomplicated constructions of the home as 'escape' or 'haven' and risks fixing gender in terms of the spaces and practices of cycling, with off-road spaces being feminised and on-road cycling as masculine.

A second issue relates to the infantilisation of the bicycle rider, which takes place in two ways. First, the cyclist is constituted as a vulnerable or soft road user. They are often characterised as endangering their own lives, taking unacceptable risks or refusing to take responsibility for their safety. Second, off-road facilities are frequently discussed as serving the needs of novices: '...attractive off-road facilities are of particular value because they are more likely to attract new cyclists by overcoming concerns about safety' (SQWconsulting 2008, 4). This discursive positioning establishes cycle users as dependent and opens the way for those in positions of authority – 'responsible adults' or 'experts' – to take charge of bicycle journeys, removing cyclists from the road, providing special protections and particular treatments – with all the negative connotations associated with 'special treatment' in liberal societies (Bacchi 2004). Cyclists become those who are indulged. The subordinate status of the cyclist as a traveller is reasserted through the very means by which the intention is to promote and boost the image and activity of cycling.

Finally, as in earlier discussions of cycling, the cycleway is often discussed in terms of alleviating congestion – both in encouraging existing motorists to try cycling and removing cyclists from the road. The latter serves to reinforce the view of cyclists as nuisance factors – operating to slow down and to inconvenience the passage of motorists.

As attention is focused on practices, bodies and places of cycling, conditions on urban roads go unquestioned. They are simply not considered to be a 'problem'. Priority for fast, heavy, high volume, polluting traffic continues to be taken for granted as the necessary outcome of contemporary urban life. Neither aggressive disdain nor patronising concern addresses the inequalities that persist in the use of road space. Further, in designating cycleways as 'special' sites for cyclists while failing to challenge on-road conditions, we arrive at the current situation where cycling on the road is readily constructed in the media as inappropriate.

Conclusion

This paper is underpinned by the view that street space continues to be divided and regulated according to a transport rationalisation of urban travel – a fundamentally economic understanding of movement which makes governing that movement both thinkable and practicable. This rationalisation of movement spawns a plethora of programs to work on the mobile body and guide the traveller in the economical conduct of his/her journey. Further, the transport rationalisation of movement prioritises and allocates space according to speed and order so that practices of walking and cycling become difficult to place on the 'modern street'. Cyclists' use of road space has been contested for almost a hundred years as responses to cycling have vacillated between removing them onto segregated paths, ignoring them altogether or, more recently, incorporating them into the street.

We have been particularly concerned with the effects of removing cyclists onto the segregated path of the cycleway, the rationalisation through which it occurs and the practices which constitute 'cycling' as aberrant activity and the 'cycling subject' as 'disruptive traveller'. The cycleway has been deployed in both a transport and health rationalisation of cycling. Rhetorically and discursively cycleways, as separate spaces, reinforce norms established through the transport discourse. Further, health discourses have assisted in reproducing rather than challenging the way the cycling subject has been constituted within transport discourses – as slow, meandering, interrupted, requiring peace and quiet. In this respect, cycling is entrenched as a health rather than transport practice and, coalescing with modernist planning's spatialisation of activities, the cycleway becomes the appropriate place for cycling.[vi]

Paradoxically, the attempt to deal with inequalities that are inherent in the move to establish cycleways as special, protected-status spaces, results in reinforcing the cyclist and cycling as the 'problem' (Bacchi 2009). Focusing attention on the cycleway allows existing road conditions and travel practices to go unquestioned. Priority for fast, heavy, high volume, polluting traffic continues to be taken for granted, stifling debate on changing travel practices and operating against the establishment of new travel norms.

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Notes

i *Governmental does not refer to the activities of the government but to the programs of all those organisations that seek to guide the conduct of the population.*

ii *Spatialising practices – spatial distribution of elements (e.g. bodies, activities) form one of a number of instruments which enables differentiation and observation of individuals.*

iii *In the UK, a trial of compulsory cycleway use was introduced on the cycleway running alongside the Oxford Eastern Bypass (Way 1969). The cycleway, though segregated from the main carriageway, was still available to local motor vehicle traffic and subject to highway regulations.*

iv *The combination of slowness, health and safety is explicitly integral to the promotion and identity of the RAVeL network in Wallonia (French-speaking Belgium), which makes a virtue of the interplay of these particular mobility practices (http://ravel.wallonie.be). Importantly, the promotion of these paths – as with others identified as sites of tourism and leisure practices seen as contributing to new forms of productivity in a post-industrial economy – introduces a visual discourse complementary to the discursive one under scrutiny here.*

v *This finding is emerging from a study currently being undertaken by Jennifer Bonham and was raised in discussion at the recent Ethnographies of Cycling conference held at Lancaster University – 16 December 2009.*

vi *Some of the 'active travel' literature challenges this spatialisation as streets once again become places to secure health – in line with the role of promenading in the nineteenth century. See e.g. Global alliance for ecomobility (/www.ecomobility.org).*

Cycling to school

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Introduction

Analyses such as Thomson (2009) have considered the impact of personal factors such as children's and parents' attitudes and competency on the decline in cycling and walking to school (Peddie and Somerville 2005). This paper considers the impacts of impersonal factors that have changed over the past fifty years. These changes include increased volume and speed of motor traffic, changes in urban and road design, legal and quasi-legal changes, and changes in bicycle technology.

How important is cycling to school?

Child bicycle ownership in Australia and New Zealand is over 70% (Horspool 2007; Morton 2005; Peddie and Somerville 2005), but the proportion of children who cycle to school ranges from zero to nine percent. If Australia were to emulate the Netherlands, this rate could increase to 49% (Ministerie van Verkeer en Waterstaat 2009).

The benefits of cycling to school include the following:

- Children gain the freedom to travel independently and interact with their neighbourhood.
- Children obtain the short and long term cardiovascular and other physical and mental health benefits of exercise.
- The community benefits from reduced traffic congestion – especially at the school gate – and less vehicle exhaust pollution and greenhouse emissions.

There are several reasons why cycling to school is more important than the current low figures suggest. Horspool (2007) argues that cycling to school:

- is a routine (often daily) activity, it is likely to occur more often than non-routine activities such as riding to shops (18%) riding around the neighbourhood (28%), keeping fit (21%), riding in parks (20%) and racing (5%).
- is more likely to be sustained (Tin Tin et al. 2009).
- frees parents from the need to spend time chauffeuring children, and – to the extent that it replaces motor vehicle travel – it benefits the community through reduced congestion and pollution.

Changes in cycling to school

The author recalls that cycling to school was very common around 1960 at his primary school in Colac. Three primary schools participated in the Pedal Pod Pilot Program that was conducted by the author in 2009 for Pedal Power ACT. A bicycle count showed that nine percent of students at these schools rode their bikes to school on 8 December 2009.

Sixty-nine percent of 5 to 8 year-olds, 62% of 9 to 11 year olds, and 48% of 12 to 14 year olds ride bicycles. This includes 54% of girls and 66% of boys (ABS 2009). Table 4.1 shows that cycling to school rates vary over time, and from place to place.

This paper has not been subject to peer review.

Table 4.1 Cycling to school over time and space, Australia and New Zealand

Year	Location	Primary school (%)	Secondary school (%)
1960	Colac Vic	30 (est)	
1974	Essendon Vic	0	
1989–1990	NZ	12	19
2003–2006	NZ	6	3
2005	NZ	3	
2005	Essendon	0.00	
2009	Canberra	9	

Sources: Horspool 2007, Peddie and Somerville 2005; the author.

Responses to changes in cycling to school

Initiatives to increase levels of cycling to school are a subset of government or community initiatives that aim to decrease car travel by increasing active travel (walking, cycling and public transport).

Rawas (2005) lists a number of cycling-to-school initiatives by schools, parents and/or governments in various countries, including 'Road Safety and You,' 'Injury Prevention Program' and 'Injury Free Coalition for Kids,' 'Active and Safe Routes to School', 'Way to Go', 'Le Pedibus', 'School Safety Programme', 'Safety Month Campaign', 'TravelSmart to School', and 'Bicycle Shed Initiative.'

Peddie and Somerville (2005) describe a Victorian 'TravelSmart Schools' program that piloted a curriculum program with seventeen schools, School Travel Planning (33 schools) and 'Congested precinct' (12 schools).

Most of these initiatives are school-based or community-based, rather than attempting to address more broadly-based factors such as social attitudes and legal changes.

Causal factors

Peddie and Somerville (2005), Horspool (2007), Lang (2007) and Thompson (2009) have identified factors that affect decisions on whether to cycle to school. They can be summarised as follows:

- Distance and urban form (roads, pedestrian crossings, footpaths, lack of street lighting, lots of cars parked on the street, the lack of bike lanes, large volume of traffic, the width of the roadway and footpaths, absence of footpaths, the lack of places to safely leave a bike, the cleanliness of air and noise pollution, distance, lack of connectivity, boring routes.)
- Road safety
- Social norms and parental influence
- Don't have a bike
- Personal safety
- Time pressures
- Children's competency to negotiate traffic and cross the road
- Environmental barriers (topography, weather)
- Children have too much to carry
- Walking or cycling involves too much forward planning
- Having friends to ride to school with
- Convenience

Increased volume and speed of motor traffic

Motor vehicle ownership and use

Large increases in motor vehicle ownership and use represent a major change in road use. This helps to explain why children today are less likely to ride to school than in previous years.

The number of registered motor vehicles in Australia grew from less than one million in 1947–1948 (ABS 1995) to 11.2 million in 2006 (ABS 2008). The number of vehicles per person increased from 0.13 in 1947–1948 to 0.63 in 1999 (ABS 2001).

Speed and mass of motor vehicles

An additional disincentive for children to ride that is rarely discussed in other research is high motor vehicle speed. At higher speeds, drivers have less time to see and avoid other road users, and other road users have less time to notice the presence of vehicles and if necessary move out of the way. Vehicle stopping distances increase, and the severity of the consequences of collisions increases.

Vehicle mass, power and acceleration have generally increased since 1960, when a Holden sedan weighed 1,122 kg and had a 56 kW engine. 2009 Holden models range from the Barina – which is 3% lighter than the 1960 model, but 36% more powerful and with a 39% higher power-to-weight ratio – to the SSVE Commodore which is 70% heavier and has almost five times the power and three times the power-to-weight ratio (derived from Redbook 2009).

Because modern cars accelerate faster, they spend a higher proportion of their time travelling at the urban speed limit. Higher mass makes cars more dangerous in the event of a collision.

Legal and quasi-legal changes

Higher speed limits

As with the speed potential of motor vehicles, higher speed limits (complemented by road designs that facilitate higher speeds) mean that road users have less time to see and avoid other road users, that vehicle stopping distances increase, and that the severity of the consequences of collisions increases.

A 30 mph (48 km/h) speed limit was introduced in 1937 for built up areas (defined by the presence of street lights) in New South Wales. On 1 January 1963 Victoria increased its urban speed limit from 30 mph to 35 mph (56 km/h). NSW followed suit in May 1964. In 1974 Australian urban speed limits again increased, this time to 60 km/h. Compared with this 60 km/h speed limit, a 50 km/h limit would be expected to reduce pedestrian collisions by 14 percent, and fatal pedestrian collisions by 30 percent (McLean and Anderson 2008). One might expect a similar impact on the severity of bicycle collision.

With the introduction of urban freeways, speed limits in parts of urban areas increased to as high as 110 km/h.

In the first decade of the 21st century several Australian States and Territories reduced suburban residential speed limits to 50 km/h. This was the first time in over 50 years that urban speed limits had come down. Nevertheless, the current 50 km/h speed limit in residential streets is higher than was the speed limit on major urban highways prior to 1963. These changes in speed limits are depicted in Figure 4.1.

Helmet laws

Bicycle helmets were made compulsory in 1991. They are a disincentive to cycling (whether to school or elsewhere), for a number of reasons.

Firstly, they were an inconvenience. This inconvenience was compounded by the fact that bicycle manufacturers, unlike motorcycle manufacturers, failed to provide secure on-bike helmet storage. So the helmet became an inconvenience not only during the bicycle trip, but also afterwards.

Horspool (2007) found that regulations (including helmet laws) constituted 6% of the reasons given by year 9 and ten students in North Shore City, New Zealand, for not cycling to school. He also found cycling to school fell from nine percent in year eight, to three percent in years nine and ten.

Horspool (2007) found that “...boys are seven times more likely to cycle to school than girls.”

> *Year 9 and 10 students are 3 times more likely to be concerned about their image cycling and they said that cycling is not cool, and that Year 9 and 10 girls mentioned that cycling in a uniform/skirt is a barrier.*

The requirement to wear a helmet effectively ruled out cycling for fashion-conscious schoolgirls (or boys) with styled hair. For students who do not cycle to school, girls are more likely to be concerned that their friends may consider them as “uncool” if they rode to school. This number increases significantly from 8% of Year 8 to 25% of Year 9 students. Girls are also more likely than boys to consider that other students may think that cycling to school is ‘uncool’ (girls 8% in Year 8, 25% in year 9 and 26% in year 10, compared with boys 4% in year 8, 8% in year 9 and 10% in year 10).

The requirement to wear a helmet is a direct reason to not cycle, and also an indirect reason because of the inconveniences that helmets cause.

Increased complexity and bias in the Road Rules

The Road Rules have become too complex for some people – even Government Transport Ministers – to understand. For example, in 2009 the Rules changed so that turning drivers were no longer required to give way to pedestrians crossing the road the driver was leaving. The author asked State and Territory Transport Ministers about the give way rules that apply to pedestrians at intersections. Several provided outdated, incomplete or incorrect information.

In 1960s Victoria, a driver turning left at an intersection was required to give way to all traffic.

Under the current Australian Road Rules, (National Transport Commission 2009) children under 12 (and adults who accompany them) may ride on footpaths. A driver who is turning at an intersection **must** give way to the following road users, if they are travelling along the street from which the driver is turning:

- cyclists riding on the road;
- other motorists; and
- pedestrians walking between footpaths.

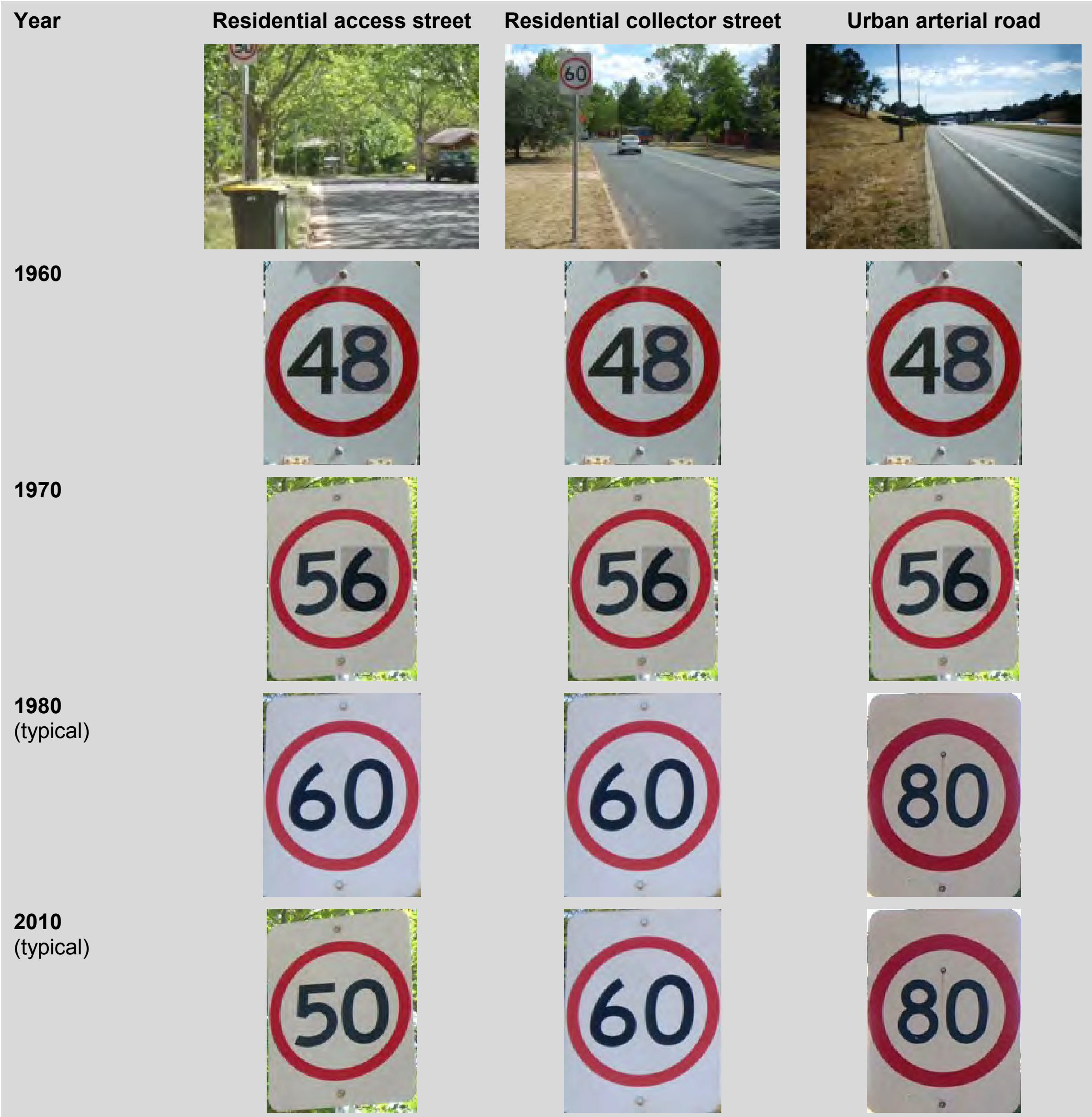

Figure 4.1 Urban speed limits (km/h) 1960–2009

The turning driver is <u>not</u> required to give way to:

- pedestrians crossing the road the driver is leaving;
- pedestrians walking along either road; or
- children cycling between footpaths.

There is a specific bias here, in that a turning driver need not give way to children cycling between footpaths (or the adults who accompany them), even though the driver must give way to all other foot, cycle or vehicular traffic that is travelling along the street from which the driver is turning.

Partly because of this, Pedal Pod Rules (VicHealth 2009) require all riders to dismount at every intersection.

Recommended minimum age for riding on the road

Increases in the minimum recommended age for riding unaccompanied on the road provide parents with another reason to forbid their children from riding to school.

The author recalls that, when the author started cycling in the 1950s in Colac (Victoria) there was no mandated or recommended minimum age for cycling on the road. There is still no mandated minimum age for cycling on the road, but several authorities recommend that children as old as eleven should not ride on the road without direct adult supervision.

In early primary school the author commenced cycling to school with his older brother. The first part of the trip involved crossing the Princes Highway, which like all urban streets had a speed limit of 48 km/h. The author recalls that most children rode on the road.

A 1,400 kg motor vehicle driver travelling at 50 km/h carries 300 times as much energy as a 35 kg child riding a 15 kg bicycle at 15 km/h. So it can be argued that the driver has 300 times as much responsibility to use the road safely.

Our society recognises this argument by restricting the right to drive a motor vehicle to people above a certain age, who have satisfied tests of their knowledge of the road rules and of their driving skills.

Conversely, our society does not mandate a minimum age or skill level for riding a bicycle.

Bailey and Natora (1999) in an Australian study reviewed the development of children's traffic cycling skills, and found that the most common child cyclist causes of crashes were inattention and failing to give way. Citing Amberg et al. (1978) they noted that

> *the age of the children was the most important factor in determining their cycling ability and that, on the basis of their results, these authors raised doubts as to whether children under the age of eight should be permitted to ride in traffic. While they reported that children between the ages of 8 and 12, especially those who cycled most, showed significant improvement over their younger counterparts, it was only the majority of 13 year olds who manoeuvred their bicycles competently enough to ensure success in more complex traffic situations.*

Various public agencies make recommendations on this matter. These recommendations focus on age rather than skills. For example:

- Based on Bailey and Natora (1999), VicRoads advises that:
  - ...up until age 12 most children do not have the skills and experience to be safe in complex traffic without supervision. (Vicroads. Pers. Comm. 2009).
- The Victorian Department of Education website recommends under 'Road Safety' that:
  - children under the age of 9 should not ride bicycles in traffic unless accompanied by an adult[1] and that: Before the age of 12 years, children should not ride a bicycle on the road without direct adult supervision.[2]
- Kidsafe ACT (2009) recommends that:
  - children under nine should not ride on the road without an accompanying adult to supervise.

These authorities do not appear to believe that current driver training produces drivers who are capable of safely sharing the road with children.

1 *www.education.vic.gov.au/ecsmanagement/mch/childhealthrecord/childhealth/transport_safety.htm*
2 *www.education.vic.gov.au/management/schooloperations/edoutdoors/activities/cycling/activity.htm*

Changes to bicycle technology

Difficulty and complexity of bicycle controls

A further reason for the decline in cycling-to-school is increased difficulty and complexity of bicycle controls.

A typical 1960 children's bicycle had an upright riding position, no gears and a back-pedal brake, with no handlebar controls other than the mandatory bell. In contrast, the handlebars of a modern mountain bike may have a bell, two brake levers, four gear levers, and a gear change sequence so complicated that few people fully understand it.

The legs of a young child are strong enough to operate a back-pedal brake. Not all young children have hands strong enough to effectively pull against the springs of hand brakes that are fitted to most geared bicycles.

It is no surprise that the author’s 2009 school bike shed survey (see below for details) found that most of the bikes being ridden to two primary schools were simple-to-operate single speed BMXs.

Increased pedalling effort due to changed fashions

Prior to the introduction of BMX bikes in the 1970s, bikes used relatively smooth, free-rolling “road” tyres. Modern BMX and mountain bikes have knobbly tyres that offer a relatively high rolling resistance.

41% of Australian bike sales in the period 1998-2005 were BMX bicycles, 43% mountain bikes and ten percent comfort/city/hybrid (Cycling Promotion Fund 2006). Horspool (2007) found that 53% of children’s bikes were mountain bikes, 23% road bikes, 14% BMX and 9% “other.”

Tests by the author indicate that a mountain bike, with its knobbly and (relatively) low pressure tyres, takes ten percent longer than a commuter bike to travel the same distance, and that a single speed bike takes about ten percent longer than a multi-geared bike. This indicates that the effective operating range of a mountain bike is ten percent less than a commuter bike, and the effective range of a BMX bike is twenty percent less.

On this basis, one could expect that BMX bikes and mountain bikes would be under-represented in school bike sheds, compared with their respective ownership rates.

The author conducted a school bike shed survey in Canberra on 8 December 2009. The survey found that, of 52 bikes, 60% were single speed BMX bikes, 31% were multi-geared mountain bikes and nine percent were comfort/city/hybrid bikes. Compared with Horspool's figures, BMX bikes are highly over-represented in school bike sheds, and road bikes are under-represented.

These results suggest that the simplicity of the BMX bike is a more important factor than its speed. The results would also be consistent with routes that include terrain for which road bikes are unsuited, and with a preference for an upright riding position, rather than the crouched position of modern road bikes.

Decline in reliability and practicality

A century ago, Frank White (West Australian 1898) reported one puncture per 7,500 km on a ride from Fremantle (WA) to Rockhampton (Qld) and return. In 1910 round-Australia cyclist Francis Birtles averaged one puncture per 3,200 km (Fitzpatrick 1980: 139).

On a 1,500 km trip along the Murray River in 2008, bicycles with standard tyres averaged only 400 km between punctures, while bicycles with “puncture-resistant” tyres averaged 6,300 km between punctures (Tozer 2008).

In 1960 the author’s bicycle was factory-equipped with mudguards, a luggage rack and a chain protector. It was common for girls’ bikes to also have a low step-through frame and skirt guard, so that they could be ridden safely and comfortably when wearing a skirt.

Relatively few modern bicycles come fitted with accessories such as mudguards and luggage racks. Girls’ bikes commonly have higher step-through heights than older-style ladies’ bikes, and skirt guards have become so rare that some young women don’t even know what they are.

Horspool (2007) reported that ‘*Year 9 and 10 girls mentioned that cycling in a uniform/skirt is a barrier*’ and that ‘*Many children indicated that their bike was not suitable….*’ Bailey and Natora (1999) noted that

> *There is strong anecdotal evidence from current children's cycle skills training programs in South Australia that very few children present themselves with … entirely appropriate bicycles for their body size and road conditions.*

Changes in urban and road design

Increased car availability has made it easier for parents to send their children to schools that are beyond reasonable cycling distance.

In the 1950s the author rode to school on streets with wide verges that permitted him to cycle away from the path of passing cars. Where wide verges still exist, they are often occupied by parked cars, forcing cyclists to ride closer to the main motor vehicle flows.

The proliferation of urban arterial roads has made cycling more complex. Children whose school routes include these roads must cope with multi-lane roads and complex intersections.

Summary

Australia is unlikely to realise its full potential to increase rates of cycling to school without changes at the industry, social, State and national level, to address:

- the volume, mass and speed of vehicles on school routes;
- the distance and complexity of cycling routes to schools;
- helmet laws;
- complexity and bias in the Road Rules;
- a focus on the age of the child, rather than the ability of drivers to safely share the road with child cyclists, as the factor that determines whether a child should be permitted to ride on the road; and
- children's bicycles that are complex, unreliable, slow and poorly equipped.

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The application of a naturalistic driving method to investigate on-road cyclist behaviour: A feasibility study

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Abstract

Background: The aim was to develop a naturalistic cycling method using a helmet-mounted video camera to investigate the behaviour of on-road commuter cyclists and their interactions with other road users in urban areas. Cycling is increasing in popularity in Australia; however, cyclists are physically vulnerable road users. To date, there has been little research on behavioural risk factors associated with collisions between cyclists and drivers, and much has relied on post-event data. Absent from this approach is an understanding of what contributed to collisions and near-collisions, in particular the behaviour of cyclists and drivers.

Method: The technique used in this pilot study to examine commuter cyclists' riding experiences during regular trips was based on the 100-Car Naturalistic Driving Study and used helmet-mounted video cameras to capture footage representing the cyclists' view. Six participants each recorded 12 hours of cycling footage. Participants also completed a pre-study questionnaire, provided weekly updates and a semi-structured exit interview.

Data: The video footage was reviewed and low-light footage and footage of time spent riding off road were excluded. In total, 46 hours and 16 minutes of footage were reviewed, no crashes were recorded and 36 other event types were identified for further analysis. The 100-car study data dictionary of variables was modified to analyse the current data, including changing the referent from driver to cyclist, and two cycling-specific variables were developed (head checks and cycling facility). Descriptors related to driving behaviours and internal vehicle cameras were excluded. In addition, the VicRoads Definitions for Classifying Accidents was used to classify events.

Conclusion: With modification, the naturalistic driving method was successfully adapted to investigate the experiences and behaviour of on-road cyclists. One of the strengths of this method is the continuous recording that allows repeated, detailed review and analysis of events over the entire trip including pre near-collision risk factors. A large-scale study using this method is planned that is expected to provide insights into the causal and contributing factors involved in near-collisions and potential collisions between cyclists and drivers.

Introduction

The number of people cycling in Australia is increasing. Cycling participation, defined as cycling at least once a week, has increased by 11% from 2001 to 2007 (Department of Communications Information Technology and the Arts 2008), but little is known about the behaviours of cyclists and drivers or the characteristics of collisions and near-collisions involving cyclists. Additional information is needed to determine the causes of the incidents and in turn how the number and severity of collisions may be reduced.

This paper has been subject to peer review. It has been published previously in Road and Transport Research 2010, 19(2) 32–41.

Previous research into risk factors associated with cyclist–driver collisions has focused on post-event data including official records (Australian Transport Safety Bureau 2006; Watson and Cameron 2006) and self-reported questionnaires (Aultman-Hall and Hall 1998; Rivara et al. 1997), and fixed-point observations have been limited to a single site (Daff and Barton 2005; Harkey and Carter 2006; Johnson et al. 2008). Extensive analyses of hospital data has provided insight into the severity and types of injuries sustained and their cost (Stutts et al. 1990; Veisten et al. 2007). However, Victoria Police has stated that as few as 1 in 30 cyclist collisions are reported (Harman 2007). Hence, research based on police-reported or hospital injury database crashes is unlikely to be representative of all cyclist crash types.

In the event of a cyclist fatality, the police reports are the primary source of post-event data, and are typically generated from the account of the driver involved and witnesses, often other drivers. This is problematic as there is likely to be recall bias and it is unlikely that drivers are able to provide an accurate account of the cyclist's pre-event actions or looking behaviour. Yet in an Australian report of cyclist deaths, cyclists were deemed to be responsible in over 60% of crashes and driver and/ or cyclist failure to observe the other contributed to a third of crashes (Australian Transport Safety Bureau 2006). Further, in a recent report, cyclists' failure to 'look properly' was the main contributing factor in 31% of cyclist fatalities (Knowles et al. 2009). In order to gain new insights into pre-event behaviours, including cyclists' visual scanning behaviour, it is important to look beyond driver accounts and investigate the cyclists' perspective of events.

Arguably the best way to understand cycling crashes and the behaviours and circumstances that lead to these events is to observe cyclist–driver interactions in a naturalistic context. Naturalistic driving studies have provided detailed data on drivers in their 'natural environment'. In these studies, there is no attempt to control the road or driving environment; rather, road users are studied in situ with the use of video cameras. Naturalistic studies generate data on events that the participant may not consider noteworthy, yet may provide insights needed to improve safety without being reliant on the cyclist's memory or the relevant question to trigger a response.

The first comprehensive naturalistic driving study was the 100-Car Naturalistic Driving Study conducted by researchers at the Virginia Technology Transport Institute in the USA (Neale et al. 2002). The 100-car study was designed to investigate exposure and pre-crash behaviours. One hundred vehicles were instrumented with five cameras to record activity inside and outside the vehicle. Participants quickly disregarded the presence of the cameras and extreme driving behaviours were recorded including risk taking, aggressive driving and traffic violations (Dingus et al. 2006). Importantly, the research captured for the first time typically unreported minor events and insights into pre-collision behaviours. The naturalistic method has also been used to identify on-road behaviours of motorcyclists (Doerzaph 2008) and to evaluate the effectiveness of collision-avoidance systems including driver warning and vehicle control (McLaughlin et al. 2008).

Walker (2007) provided new insights into cyclist-–driver interactions in relation to drivers' overtaking behaviour. Walker, as the single participant cyclist, found that the overtaking distance drivers afforded cyclists was influenced by his appearance, 'sex' (he wore a wig and clothing to appear as a woman) and position on the road. The study used a combination of ultrasonic distance sensor, handlebar-mounted camera and laser pointer to measure the drivers' overtaking distance. However, the handlebar-mounted camera would have provided only a limited view of the cyclist's perspective and the interplay between the cyclist and drivers. It is likely that the use of a helmet-mounted camera would have provided insight into how the proximity of the passing vehicles influenced the cyclist's positioning on the road.

The use of head-mounted video cameras to record another perspective has had diverse applications such as televised sports coverage of motor sports and skiing (Brown et al. 2008), a surgeon's view of surgical procedures (Schneider et al. 2006), police activities in the UK (Associated Press 2007) and, increasingly, by the general public on video-sharing websites such as YouTube. Brown and colleagues (2008) used head-mounted cameras to explore the experiences of walkers and mountain bikers in rural Scotland. They found that the device freed the participant to concentrate on the activity, rather than the filming, and had untapped potential for investigating fast, dynamic activity. Spinney (2009: 829) has also used video to explore a more nuanced understanding of the cycling experience and suggests that ‘video has the potential to bring the researcher into the picture’.

The aim of this paper is to describe the application of a naturalistic driving method to investigate the behaviour of on-road commuter cyclists in metropolitan Melbourne. By adapting the approach used in the 100-car study (Neale et al. 2002), the method was used to investigate the entire commuter trip including all road types and traffic conditions experienced by participants.

Methods

Four data sources were used in the study:

- video footage recorded using a helmet-mounted camera; this was the primary data source for information on cyclist–driver behaviour;
- a pre-study questionnaire;
- weekly email updates including progress reports of hours filmed, events experienced and problems experienced with the camera; and
- a semi-structured exit interview.

Details on the equipment and procedures relating to each data source are described below.

Helmet-mounted video camera and recording system

An Oregon Scientific ATC3K Action Camera was used to record all trips. The compact video camera was powered by two AA batteries and weighed approximately 240 grams. The footage was recorded at 640 x 480 VGA resolution at 30 frames per second. A standard 4GB memory card was provided with capacity to record up to 2 hours of footage per card. Participants were supplied with sufficient batteries and memory cards to record 12 hours of footage. A small LCD screen on the camera indicated how much memory had been used and participants changed the memory cards and batteries throughout the study. The data was downloaded by the researcher at the end of the study.

A pilot test was conducted to evaluate optimal camera-mounting positions and the helmet was the preferred location. Helmet mounting provided a view of the road environment that was closest to the cyclist’s perspective and recorded head movements. Other mounting options evaluated were under-seat and handlebar mounts. Under-seat mounting provided the best view of the behaviour of vehicular traffic behind the cyclist and captured rear-end events. This is important as in Australia this collision type results in the highest proportion of cyclist fatalities (21%) (Australian Transport Safety Bureau 2006). However, the under-seat mount does not record forward travel and given the relative rarity of rear-end collisions, this rear-view option was discarded in favour of a forward-facing camera. Handlebar mounting was considered, as the camera could be secured and the footage recorded was stable. However, as noted in relation to the Walker (2007) study, a limitation of this mount is that this view does not capture cyclist’s head movements or the broader environment, both important in the event of a collision or near-collision. Additionally, many commuter cyclists are likely to have equipment attached to their handlebars such as a trip computer, light and bell, and there may not be sufficient space to attach the video camera.

Extensive tests were conducted to determine the most effective means to attach the camera to the helmet. The manufacturer-provided accessories were used to attach the camera to the crown of the helmet. This position was unsuccessful as the camera was unstable and slid laterally resulting in unsteady, tilted footage. In addition, it was highly conspicuous and it was thought that this may influence the behaviour of drivers or other cyclists who observed the camera. The preferred mounting location was in a vent of the helmet, either on the crown or to the side, varying with the design of the participant’s helmet. To fix the camera in this position, the camera was pressed into a bed of putty that lined the chosen vent and secured with an exterior grade reinforced tape positioned such that the back of the camera could be accessed to replace the memory cards and batteries. The putty minimised slippage and acted as a mild shock absorber. Nested in the helmet vent, the camera was less proud and therefore less visible and potentially less likely to influence the behaviour of other road users.

A camera was attached to each participant’s helmet during the induction process. Participants rode short trial rides, which were downloaded to confirm the camera was in the correct position. Due to the strength of the mounting arrangement, participants could not easily remove the camera; however, the camera could be removed without damage to the helmet at the end of the study.

Other study components

Participants completed a pre-study questionnaire, weekly email updates and a semi-structured exit interview. The pre-study questionnaire was completed at induction and included 36 questions related to on-road cycling and driving behaviour, as well as standard demographic questions (Australian Bureau of Statistics 2007). All participants were contacted weekly by telephone or email, to monitor their progress. In these updates participants provided details of any collisions or near-collisions and the number of hours recorded. Semi-structured exit interviews were conducted and topics included how the presence of the camera may have affected behaviour and details of riding experiences.

Participants

Six participants completed the pilot study. Three females and three males were recruited using the snowball technique (Wasserman and Faust 1995). This population is not representative of the cycling population in Australia, which is 66% male (Department of Communications Information Technology and the Arts 2008). However, this study was intended to pilot the helmet camera and refine the method. A larger scale study is planned in which participants will be representative of the known commuter cyclist population. Inclusion criteria were adult commuter cyclists (over 18 years) who travelled on the road for the majority of their trip (70%) and commuted a minimum of 3 hours per week. All participants commuted to the Melbourne central business district. All non-electric bicycle types were accepted, with the exception of recumbent bicycles.

Data collected

The duration of footage required was calculated using the average distance ridden by commuter cyclists. In Victoria, the average distance ridden by commuter cyclists is 24.3 km return trip and over 50% of cyclists rode 3–5 days per week during the warmer months of October to March (Bicycle Victoria 2007). Participants were asked to ride their typical route and to ride as usual. No restrictions were placed on the time of day, nor were participants expected to ride an equal number of morning and afternoon rides.

The assumptions were that participants would ride the average distance for a minimum of 3 days per week at a speed of at least 20 km/h, the speed of a healthy, untrained adult (de Geus et al. 2007), resulting in 12 hours of recording over a 4-week period. The pilot study was conducted from January to April. It was also assumed that over the 12-hour period of recording participants would have time to become accustomed to the camera and ‘forget’ it was there, minimising behavioural bias.

As in other naturalistic studies, there is a systematic bias in participants' exposure, as the cyclists were regular commuter cyclists who rode at least 3 hours per week, more than triple the average cyclist's participation rate of 1 hour per week (Department of Communications Information Technology and the Arts 2008).

Data analysis

Analysis of the data was conducted in four stages: initial review of the footage, identification of collisions and near-collisions, calculation of incident rate, and classification of near-collision characteristics. The footage was reviewed using InterVideo WinDVD 5 viewing software. The data from the initial review was recorded using Excel spreadsheets, and the in-depth analysis of the near-collisions was conducted using an integrated video analysis software package called Snapper©[1]. The aggregated descriptive statistics were calculated using SPSS 15.0 for Windows.

The recorded image was inherently unstable due to a combination of head movement, jaunty body movements when pedalling and the roll of the bicycle over the road surface. In its original format, the footage caused severe reviewer nausea, which was minimised by processing the footage through a freeware image-stabilising software program called VirtualDub version 1.8.8 with an image stabiliser plug-in called Deshaker[2].

Initial review and data screening

An initial review was conducted to determine the amount of useable video footage, and low-light footage and time spend riding off road were excluded. Due to poor low-light sensitivity, footage recorded pre-dawn or post-dusk was mostly black with occasional vehicle headlight or tail light and details of the cyclist's trip could not be identified. Footage of off-road riding, namely off-road bicycle paths, parks and footpaths, was also excluded. Footage of riding in car parks, including underground car parks, was included in the data analysis.

Identification of collisions and near-collisions

Collisions and near-collisions were defined as per the 100-car study data dictionary (Dingus et al. 2006). The footage was reviewed to identify collisions, defined as an event in which the participants made contact with another road user in which kinetic energy was transferred or dissipated. Near-collisions or non-collision events in decreasing severity were also identified: near-crash, requiring rapid and evasive manoeuvre to avoid a crash; crash-relevant, requires evasive manoeuvre to avoid a crash, less severe than rapid movement; proximity conflict, extraordinarily close proximity of the subject vehicle with another vehicle; non-conflict, increases the level of risk associated with driving, but does not result in a crash or near-crash; and non-subject conflict, any incident captured on video that does not include the subject driver.

Collision and near-collision incidence rate calculation

The rates of collision and near-collisions were calculated using the number of collisions or near-collisions as the numerator and the number of on-road minutes observed (excluding low-light footage and time spent riding off road) as the denominator. This figure was multiplied by 60 to calculate the rate per hour.

1 *http://www.webbsoft.biz/prod_snapper.php*
2 *http://www.guthspot.se/video/deshaker.htm*

Classifications of event characteristics

Collision and near-collision characteristics were further classified using modified variables from the 100-car study data dictionary and the VicRoads Definitions for Classification Accidents (DCA) codes. The 100-car study data dictionary classifies 44 collision or near-collision characteristics that comprehensively define elements of the event from a driver/vehicle focus. Some modification was needed to apply these variables to the cyclist footage. In total, 20 variables were adopted from the 100-car study without change. These include event severity, pre-incident behaviour, the road and traffic environment and the behaviour of the secondary vehicle involved. A further eight variables were modified, mainly changing the referent from driver to cyclist. Finally, 16 variables were excluded that mainly related to driver behaviour recorded by the internal cameras.

Two additional cycling-specific variables were developed and added to the data dictionary. First, head checks made by the cyclist and second, referred to cycling facility, the type and its absence or presence at the site of the event. The 100-car study variable that described the type of incident was replaced with the DCA codes. Accompanied by illustrative diagrams, the DCA codes were more specific and had more options than the 100-car study variable and will enable a direct comparison with the VicRoads CrashStats data.

Results

Footage

In total, 68 hours and 55 minutes of footage was recorded by 6 participants. Approximately 32% of the time recorded was excluded due to low light or off-road riding. The descriptive statistics for the footage from the initial review is presented in Table 5.1.

In total, 22 hours and 38 minutes of footage recorded was excluded due to low light or riding off-road. Footage recorded by the female participants was more likely to be excluded due riding off road (23.3%) than riding in low light (8.9%). Footage recorded by male participants was more likely to be excluded due to riding during low light times (20.1%) than riding off-road (13.4%).

Rate of collision and near-collision events

No collisions were recorded. A total of 36 other, near-collision events were identified. The overall rate of near-collisions was 0.76 per hour. The rate for females was lower (0.38 per hour) than for males (1.13 per hour). The near-collision rates per hour are displayed in Figure 5.1.

Table 5.1 Descriptive statistics of the participants’ commute (am and pm)

	Time recorded	Excluded time, low light	Excluded time, off-road	Total time for analysis
	(hours:minutes)	*(hours:minutes)*	*(hours:minutes)*	*(hours:minutes)*
Females (*n* = 3)	35:50	3:13	8:20	24:16
Males (*n* = 3)	33:05	6:38	4:27	22:00
Total	**68:55**	**9:51**	**12:47**	**46:16**

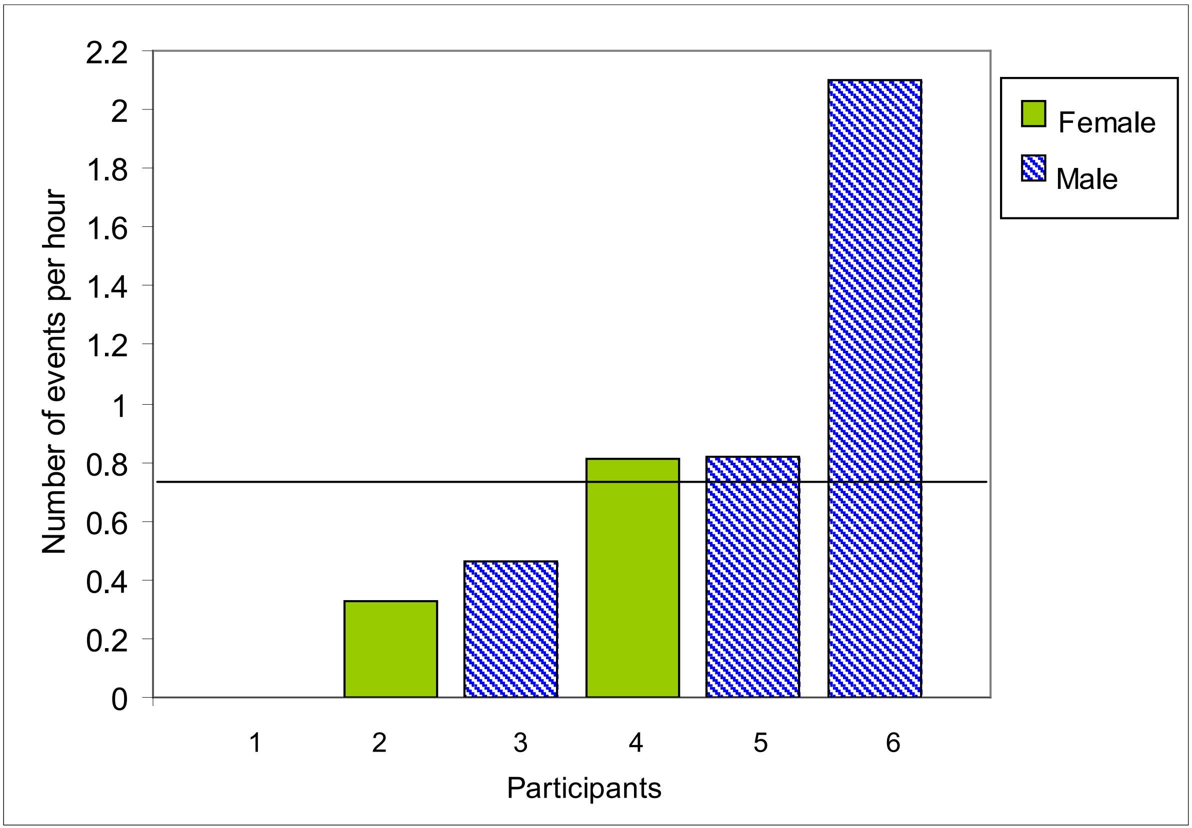

Figure 5.1 Individual participant rate of near-collision events per hour (median event rate)

Overall, the median event rate for all participants was 0.75. The median rate for the female participants was 0.38 per hour and included one participant who experienced no events. The median rate for the male participants was 1.13 and included the highest rate of 2.1 events per hour.

Event characteristics for each of the 36 events were coded to determine if all variables could be applied in a naturalistic cycling study. In total, 30 variables were coded for each event and provided extensive details on the behaviour of the cyclist and the driver pre-event and post-event as well as of the road environment. The results for 6 variables are presented in Table 5.2, to illustrate the types of information that can be derived from the video footage using the modified 100-car study variables.

Male participants experienced more than double (2.3) the number of near-collisions than female participants. A high percentage of incidents occurred while participants were travelling straight (females: 81.8%; males: 96%).

Table 5.2 Summary of event characteristics (n = 36 events)

	Females (n = 3)	Males (n = 3)	Total (n = 6)
Number of events	11	25	36
Cyclist pre-incident – going straight	9	24	33
Lighting – daylight	11	22	33
Vehicle type – automobile	8	20	28
Bike lane present	8	8	16
Head checks (right)	4	15	19

For males, the small proportion of events that did not occur during daylight hours (12%) occurred during the dawn period. A high proportion of events occurred with cars (light passenger vehicles) (77.7%) rather than trucks, buses or motorcycles. The use of bicycle lanes was observed in more of the events involving female riders (72.7%) than male riders (32%). Males were more likely to head check to the right prior to the event (60.0%) than females (36.3%).

Discussion

The purpose of this study was to develop and trial a novel method for investigating and understanding experiences of on-road cyclists and how they interact with vehicles in the real-world environment. The process of recording the data was successful. All participants loaded and changed the batteries and memory cards in their cameras appropriately. The weekly updates by phone call proved to be too time consuming to manage and were replaced by email updates. This was more efficient for both the researcher and the participants, and provided an opportunity for detailed descriptions of near-collision events that had been experienced.

The positioning of the camera on the cyclist's helmet captured video footage that was close to the cyclist's own viewpoint including head checks. The camera remained attached to the cyclist's helmet for the duration of the study; however, it did not always capture the cyclist's view of the road and sometimes recorded footage of the ground or the sky. This may have been due to a loose chin strap causing the helmet to slip during the ride. While all equipment and mounting was checked thoroughly at the time of fitment, it is possible that the helmet chin strap may have loosened during the study, resulting in poor alignment of the helmet and camera. For future research, more rigorous fitment checks may be required during the induction process to optimise the position and stability of the camera. Alternatively, a self-calibration exercise may increase the time the camera is in the correct position; for example, participants could conduct a mirror check to ensure a consistent position of the camera during the study.

Further, the use of a multiple camera system would provide additional detail of the cyclists' trips from different perspectives. For example, under-seat mounting would record the movements of the traffic behind the rider. This could have important implications for understanding risk factors for collisions in which a cyclist is hit from behind, the most common fatal crash type for cyclists in Australia (Australian Transport Safety Bureau 2006).

Participants frequently shook their head when riding, typically after a vehicle had not given sufficient space when overtaking or turning. The head shakes were clearly visible on the footage, and provided an unanticipated benefit of the helmet mounting. A review of events that elicit this response is likely to provide valuable insight into the situations where cyclists feel their space has been infringed upon.

All participants rode a portion of their commute off-road. Notwithstanding that all participants identified themselves as on-road commuters, each rider spent some time riding on off-road paths, on the footpath or through parks. Off-road spaces were most commonly used to access short cuts, often footpaths designed for pedestrian access, at the end of on-road bike lanes where cyclists are 'squeezed' off the road and onto the footpath and off-road bike paths. Female participants spent more time riding off-road than male participants.

Preliminary analysis showed a wide variation in frequency of events per participant, from no events to more than two per hour. A larger sample of participants is required for more detailed analysis of behaviours including sex differences. The high proportion of observed events that occurred when participants were travelling straight and there was no deviation in their course may suggest that the near-collisions were due to driver behaviour. Further analysis of the footage will be conducted to determine whether driver or cyclist behaviour instigated the event. In the large-scale study, the analysis will include a detailed review of all variables, to attempt to determine the cause of the event as well as:

- whose actions led to the event (cyclist or driver);
- location details – cycling facility, traffic lanes and flow, surface condition;
- driver behaviour – vehicle manoeuvre, driver action, vehicle position; and
- cyclist head checks.

The low-light time recorded by the male participants was more than double that recorded by females. It is assumed that during the study period participants commuted at the time of day that they would usually ride. Most of the low-light riding time for females occurred at the end of their commute home, whereas the males rode in low light conditions on both morning and afternoon/evening commutes. The conclusions can be drawn from this finding are limited, due to the small number of participants in this pilot study; however, sex differences in riding in low light have been reported in previous studies. Research of Melbourne commuter cyclists by Garrard (2003) found differences between male and female riding times and suggested this might be due to different working hours, responsibilities at home or feelings of personal safety. Further investigation of night riding may have direct implications for night-time safety for cyclists, regarding cyclists' use of reflective clothing and adequate front and rear lighting.

The other stages of the study – the baseline questionnaire, weekly updates and exit interviews – were not analysed for this paper, as the methodologies for these approaches are well established (Silverman 2001). However, these data will be used in the analysis of the larger scale study to investigate the attitudes and beliefs of participants in relation to their on-road behaviours.

Strengths and limitations

The main strength of this method was the continuous recording that allowed repeated, detailed analysis of the cyclist's entire trip. This is important for the identification of pre-collision and near-collision risk factors. The camera position provided the cyclist's point of view and important details about events that might not be reported by a cyclist post-event or be subject to recall biases.

The main limitation is the manual review and coding of the footage which is a resource-intensive process. However, manual review is currently the primary method of data reduction and is used to analyse footage from naturalistic driving studies (Neale et al. 2005; Dingus et al. 2006). Efficiencies were gained by establishing clear definitions of events and pre-screening to target the events of interest. In the future, it might be possible to automate some elements of the coding process and expedite the data reduction stage.

The camera's poor low-light sensitivity was another a limitation. This could be addressed by participants not filming during low-light times, although this would introduce a behavioural bias that would limit the conclusions that could be drawn about preferred commuter cyclist riding times. Alternatively, a camera with greater light sensitivity could be used and, as the video camera technology continues to improve with newer models, it is likely this limitation will be addressed.

Conclusion

This paper has described the novel application of naturalistic study methods to record and analyse the behaviour of commuter cyclists and drivers. The adaptation of the 100-car study definitions provided a framework to classify cyclist–driver near-collisions. The preliminary results have been able to establish a process for identifying near-collision rates not previously reported. This creates a starting point for further study of cyclist exposure to risk and to identify the components of collisions and near-collisions that need to be addressed to improve safety for on-road cyclists. A large-scale study using this method was planned to be conducted from October 2009 to March 2010 and it is anticipated that insights will be gained into the causal and contributing factors associated with near-collisions and, potentially, collisions between cyclists and drivers.

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Cycling and roundabouts: An Australian perspective

Fay Patterson

Hub Traffic and Transport

Abstract

The ‘technical bible’ for traffic engineers, the Austroads series *Guide to Traffic Engineering Practice*, has recently been replaced by three new Austroads guides: *Guide to Road Design*, *Guide to Road Safety* and *Guide to Traffic Management*. The new guidelines covering roundabouts now incorporate designs for the marking of bicycle lanes in roundabouts, representing a change in technique to one not seen in comparable international guidelines.

This paper examines the international research on bicycle lanes in roundabouts and considers whether the issues raised in the literature are applicable to Australia. It concludes that although overseas experience cannot be directly translated to Australia, the safety benefit of Australian cycle lane practice is clearly questionable. Good practice should be for any cycle measures to be well-designed and tailored to a particular roundabout, as part of a ‘toolbox’ of measures; but the new Austroads guides mean that it is more likely that cycle lanes will be the first (and quite possibly only) cycle measure considered. If so, this may well be at the cost of other, more effective measures (such as the C-roundabout design) that could also benefit other road users.

Introduction

The ‘technical bible’ for traffic engineers, the Austroads series *Guide to Traffic Engineering Practice*, has recently been replaced by three new Austroads guides: *Guide to Road Design*, *Guide to Road Safety* and *Guide to Traffic Management*. The new guidelines covering roundabouts now incorporate designs for the marking of bicycle lanes in roundabouts, representing a change in technique to one not seen in comparable international guidelines.

This paper examines the international research on bicycle lanes in roundabouts and considers whether, and how, the issues raised in the literature are applicable to Australia. The paper commences with a brief overview of crashes at roundabouts and roundabout design before going on to review the literature on a country by country basis. It then turns to a discussion of Australian research and practice, concluding with a discussion of the lessons that can be learnt from international experience.

Cyclists and roundabouts

As a traffic engineering treatment at intersections, roundabouts provide increased safety over uncontrolled or priority (give way/stop) controlled junctions. Elvik (2003) estimates an average reduction in crashes from installing roundabouts at 30% to 50% as a result of installing roundabouts. Table 6.1 shows substantial crash reductions for a number of countries after installation of roundabouts (FHWA 2000).

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However, these safety results do not favour cyclists and motorists in the same way. In the UK, only 7-10% of bicycle crashes occur at roundabouts, but these are 14 times the rate of motor vehicles and the crash rate is 2–3 times that at signalised intersections (Nottinghamshire County Council 2006; Department for Transport UK 1997). At New Zealand roundabouts, cyclists account for 6% of all crashes compared with 1% at traffic signals and 4% at priority junctions. Cycle crashes at roundabouts account for 24% of all injury crashes and cyclists are 20 times more likely to be injured than other road users (Wood 1999). Cyclists comprise 18% of injuries at roundabouts in NSW, compared with 6% at cross intersections (Robinson 1998).

Table 6.1 Mean crash rate reductions from roundabout installation in various countries

Country	Mean reduction (%)	
	All crashes	Injury crashes
Australia	41–61	45–87
France		57–78
Germany	36	
Netherlands	47	
United Kingdom		25–39
United States	37	51

Source: FHWA (2000)

Table 6.2 Cyclist crash types at roundabouts, New Zealand and United Kingdom

Crash type	New Zealand	United Kingdom
	%	%
Entering vehicle circulating cyclist	68	50
Entering cyclist, circulating vehicle		7
Sideswipe on roundabout	10	
Both vehicles circulating		8
Cyclist crossing as pedestrian	8	
Exiting vehicle, circulating cyclist	9	10
Rear end shunt (motorist hits cyclist)		10
Rear end shunt (cyclist hits motorist)		4
Other types	5	1

Source: Compiled from Campbell et al. (2006), Galway Cycle Campaign (2001)

Table 6.3 Reported proportions of 3 major crash types at roundabouts

Country	Crash description	Type of roundabout	Type of crash		
			Entering – circulating	Rear end	Single vehicle
			%	%	%
Australia	All crashes	Single and multi lane	51	22	18
France	Injury crashes	Single and multi lane	37	13	28
Germany	All crashes	Single lane	30	28	17
Switzerland	All crashes	Single and multi lane	46	13	35
United Kingdom	Injury crashes	Single and multi lane	20–71	7–25	8–30

Source: FHWA (2000)

When examining cycle crashes on roundabouts, one crash type predominates – entering motorist hitting a circulating cyclist. This crash type has been estimated to account for 50–70% of all cyclist crashes: Victoria 60% (VicRoads 1995); NSW 70% (Robinson 1998); United Kingdom 50% (Davies et al. cited Nottinghamshire County Council 2006). Table 6.2 summarises typical cyclist crash types for New Zealand (Campbell et al. 2006) and the UK (Galway Cycle Campaign 2001). Table 6.3 shows that entering/ circulating crashes are also the dominant crash type for motor vehicle – motor vehicle crashes.

An overview of cycling and roundabouts

To assist in understanding the research on cyclist safety at roundabouts, this section provides an overview of the types of roundabouts, design philosophies and bicycle treatments covered in the literature. Common features used to describe roundabouts are shown in Figure 6.1. The diameter of the central island is equivalent to the inscribed circle diameter less the circulatory roadway width, and is often quoted separately.

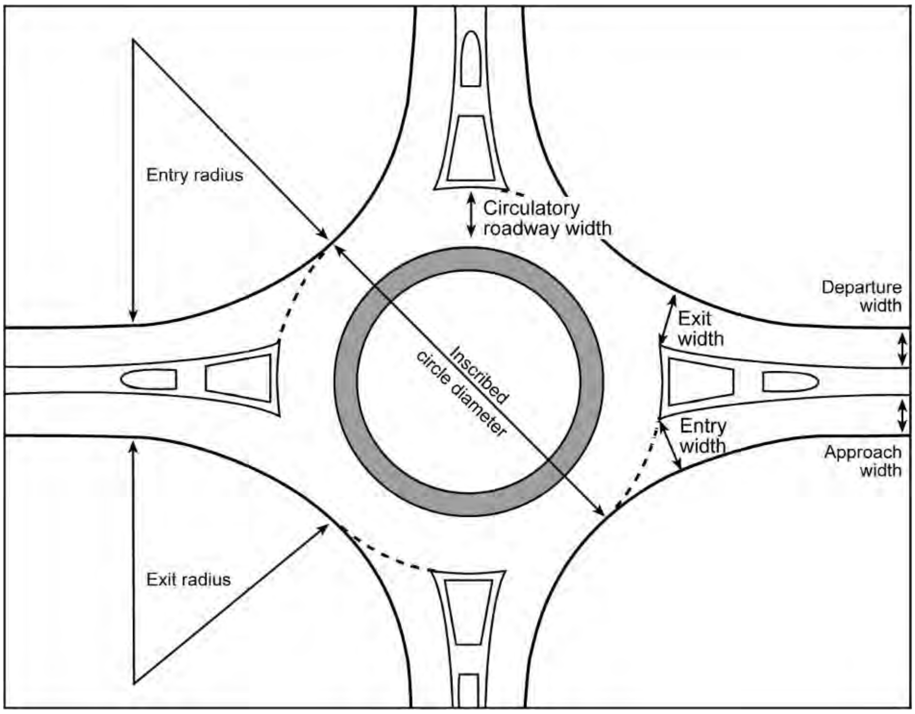

Figure 6.1 Terminology used in defining roundabout characteristics
Source: Chris Crothers adapted from FHWA (2000)

Types of roundabouts

The precursor to the modern roundabout looked very similar but had different priority rules, with motorists on the circulating roadway giving way to entering traffic, or with priority assigned by signage. These ‘traffic circles’, ‘rotaries’ or ‘gyratories’ had a poor safety record and have been superseded by roundabouts – apart from as a legacy issue in some countries. These should not be confused with roundabouts, despite their physical similarities.

Roundabouts are often described based on size and, to a certain extent, complexity; these vary between countries and their related design guidance. This paper follows the typology set out below as one that is fairly simple, robust and generally compatible with the presentation of research:

- Mini roundabouts – This describes roundabouts of less than 4 m in diameter. In the UK and Europe, these feature a painted or low dome central island (see Figure 6.2). In Australia, these typically have a constructed central island.

- Small single-lane roundabouts – These are used extensively for road calming purposes and are therefore the type of roundabout most frequently encountered by cyclists (see Figure 6.3).

- Large single-lane roundabouts – The difference between 'small' and 'large' tends to vary between countries (see Figure 6.4).

- Multi-lane roundabouts – These are mainly limited to two lanes on the approach, departure and within the roundabout. As they are often provided at complex intersections, other features such as slip lanes may be present (see Figure 6.5).

- Variations on multi-lane roundabouts – Different roundabout designs have been developed to deal with particular types of situations, such as those involving trams or trains. The more famous forms include the Dutch 'turbo-roundabout', which forces a spiral type of movement.

- Functional roundabouts – There are some locations where streets can function as a roundabout, although not formally constructed as one. An example of this is Whitmore Square, in Adelaide. Functional roundabouts may be multi-lane and can feature signalisation.

Figure 6.2 Mini roundabout

Source: Wikipedia Commons (Photo URL: http://commons.wikimedia.org/wiki/File:Mini-roundabout.jpg). Photographed by Norman Rogers in September 2004

Figure 6.3 Small single-lane roundabout, Norwood, South Australia

Source: Author's collection

Figure 6.4 Large single-lane roundabout, Sweden

Source: Brüde and Larsson, 2000

Figure 6.5 Britannia roundabout, Adelaide, South Australia

Source: Author's collection

Neither of the latter two categories are standard roundabout designs, particularly for Australia. They are sufficiently rare and complex that no general conclusions about their performance for cyclists can be drawn from research. Hence they are not considered further in this paper.

Design philosophy

There are two main and different design bases underpinning the design of roundabouts around the world.

Figure 6.6 presents the radial design base. This is used in much of continental Europe (hence 'Continental' design). Approach and departure legs are radial to the centre of the roundabout, hence vehicles must slow considerably to pass through the roundabout. The geometry is relatively 'tight', with narrow entry and exit lane widths – usually 4 m (i.e. single-lane) – contributing to speed reduction.

Figure 6.7 presents the tangential design base. This is used in the UK, Australia and New Zealand, as well as some European situations. Approach and departure legs are tangential to the centre of the roundabout, with traffic speed reduction achieved by deflecting vehicles from a straight-through path of travel. Traffic speeds and capacity are generally higher – and the space taken greater, given an equivalently sized central island.

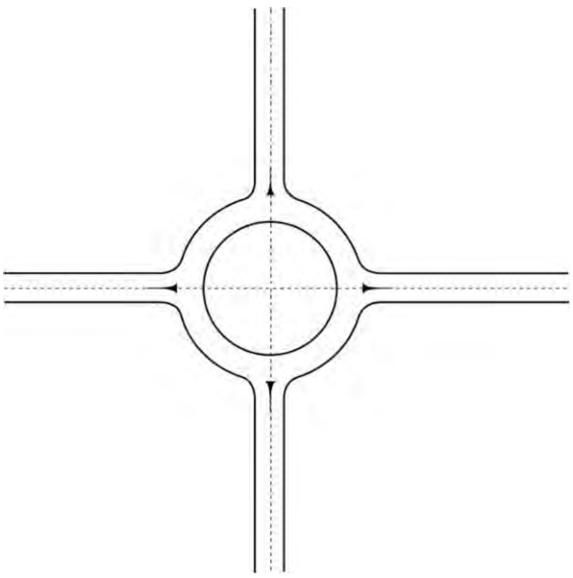

Figure 6.6 Radial design philosophy

Source: Chris Crothers adapted from Herland and Helmers, 2002

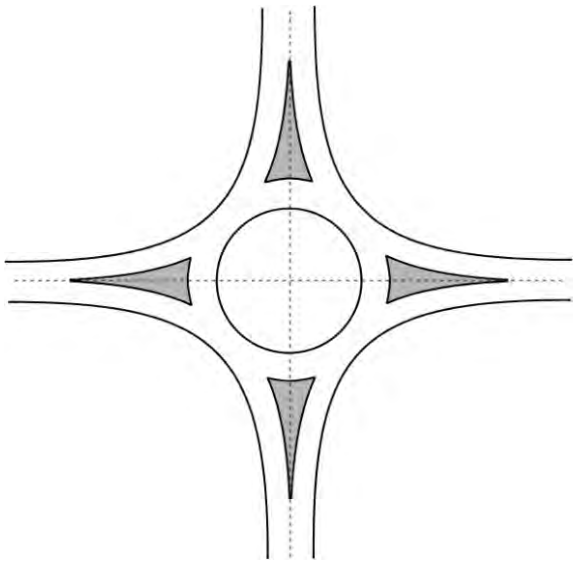

Figure 6.7 Tangential design philosophy

Source: Chris Crothers adapted from Herland and Helmers, 2002

Bicycle treatments at roundabouts

There is a variety of different types of cycle treatments possible at roundabouts, as shown in Figures 6.8–6.12. This typology uses the term 'cycle paths' rather than 'cycle tracks'.[1]

Cycle lanes (on road cycle facilities), as shown in Figure 6.9 can include different pavement treatments (e.g. coloured treatments) and/or minor separation between the bicycle treatment and the traffic lane (e.g. small kerbs or islands). The manoeuvres cyclists undertake are as for motor vehicles and the lanes are considered part of the roundabout. This remains the case until the cycle lanes reach about 1 m from the traffic lane, at which point the lanes function as separate *cycle paths*.

[1] *There can be a lack of clarity in the use of terminology, notably 'cycle lanes' versus 'cycle tracks' versus 'cycle paths'. 'Cycle lanes' refer to on-road cycle facilities while 'cycle tracks' and 'cycle paths' are equivalent, both referring to facilities exclusive to cyclists that run alongside but 'off' the road.*

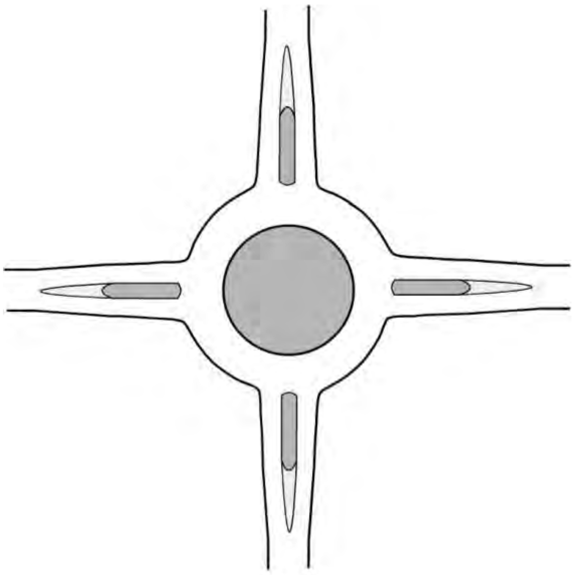

Figure 6.8 Roundabout with mixed traffic

Source: Chris Crothers adapted from Daniels et al 2009

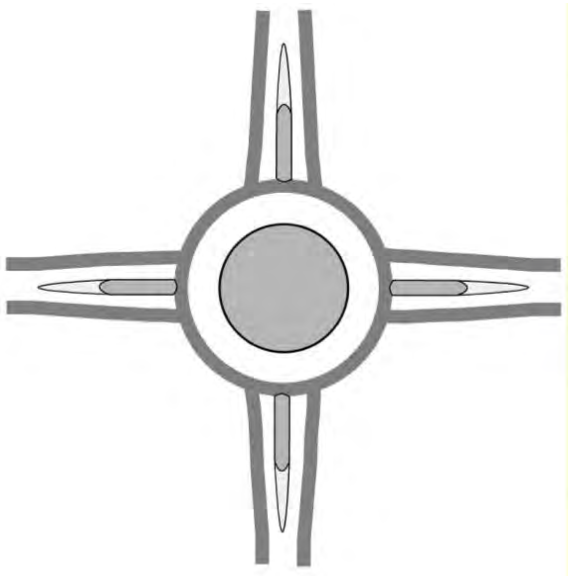

Figure 6.9 Tangential design philosophy

Source: Chris Crothers adapted from Daniels et al 2009

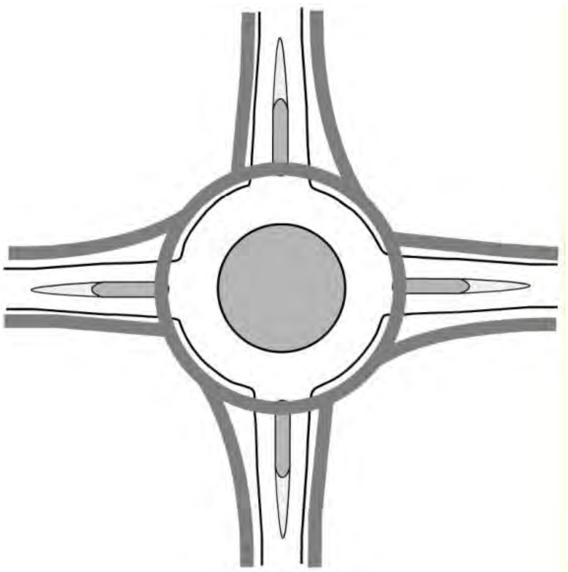

Figure 6.10 Roundabout with separated cycle path – priority to cyclists

Source: Chris Crothers adapted from Daniels et al 2009

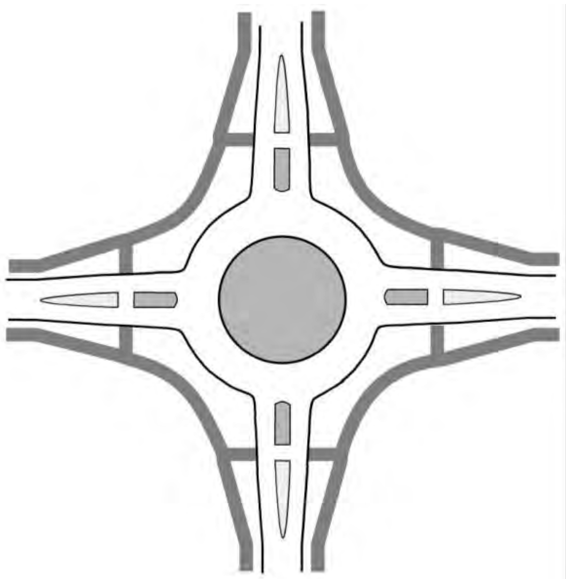

Figure 6.11 Roundabout with separated path – no priority to cyclists

Source: Chris Crothers adapted from Daniels et al 2009

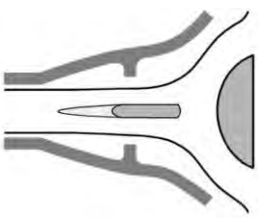

Figure 6.12 Grade separated cycle paths

Source: Chris Crothers adapted from Daniels et al 2009

Reviewing the Literature

This section summarises findings regarding cyclist safety at roundabouts in Continental Europe, the UK, New Zealand and Australia, with a focus on cycle treatments. Following early experiences with traffic circles, US practice moved away from roundabouts and its experience is limited –particularly with cycling at roundabouts; hence, research under US conditions has not been reviewed. Partial or full signalisation of roundabouts is outside the scope of this paper, but generally improves safety (e.g. Transport for London 2005a).

Continental Europe

Some apparent contradictions between stated practice (e.g. one-lane roundabouts only) and descriptions of existing roundabouts (e.g. as having two lanes) may relate to legacy issues for roundabouts pre-dating the current practice.

Belgium

Daniels et al (2009) investigated 90 larger single-lane and multi-lane roundabouts. This study confirmed that roundabouts present safety hazards for cyclists, regardless of the type of cycle facility provided. It also found that the crash rate for roundabouts with cycle lanes was higher than for mixed traffic, cycle paths or grade-separated cycle paths. Poor safety results were also noted for roundabouts replacing traffic signals, multi-lane roundabouts and roundabouts in built-up areas.

Germany

Brilon describes the German experience and practice based on a series of research projects over 15 years. Gyratories were abandoned after the 1960s, with interest in roundabouts as an alternative stimulated in the 1980s by their success in the UK. But the British design – and particularly the tangential design philosophy – was not simply copied. Design parameters were instead developed from basic principles of intersection design (Brilon 2005).

Mini-roundabouts: Experience has given rise to the design parameters now used. No particular safety issue was identified for cyclists using mini-roundabouts constructed according to these parameters.

Compact single-lane roundabouts: Brilon notes:

> *Cycle lanes at the peripheral margin of the circle are not allowed since they are very dangerous to cyclists. Up to a traffic volume of about 15,000 veh/day, cyclists can be safely accommodated on the circular lane without any additional installations. Above this traffic volume separate cycle paths seem to be useful. These, however, should also have a distance of around 4 to 5 m from the circle (2005: 6–7).*

In terms of design, the legs of the intersection are radial, to improve sight-lines and reduce speed. Tangential design of entry lanes is not allowed.

Compact two-lane roundabouts: These have posed safety issues for all road users, such that in Germany a ‘semi-two-lane’ roundabout has been developed as a preferred option. This features two lanes on the approach and one lane on the exit. The circulating lane can be used by two passenger cars side-by-side, but buses and trucks must use it as a single-lane only, and there are no lane markings in the circulating lane. Cyclists are banned on this circulating lane, hence separate cycle paths or other separate cycle facilities must be provided for cycle access. Even then, the design rules are:

- if possible, only a single-lane roundabout should be built
- if necessary for capacity, provide bypass lanes first; then consider a compact two-lane circle with single-lane entries; then consider two-lane entries if necessary.

The design rules also specify avoiding each increase in capacity, where possible. Two-lane exits are completely banned at any two-lane roundabouts.

Larger roundabouts: Gyratories (which are two-lane) are not recommended, nor are other multi-lane roundabouts. The potential for new forms is mentioned, with a trial of a spiral form similar to the Dutch turbo-roundabout being undertaken (very carefully) in the city of Baden-Baden. Otherwise, *signalised multi-lane roundabouts* are noted as being a good solution in specific situations.

Schnull et al. (1993) found that cycle tracks and cycle lanes increase risk over no treatment. For cycle tracks, this may have been related to priority rules or two-way travel.

The Netherlands

The before and after study by Van Minnen and Schoon (1993) found no major differences in crash rates for cyclists between the different cycle design types (mixed traffic, cycle lanes, separate cycle paths). Injury rates, however, indicated that a separate cycle path was safer than both other design types at roundabouts with a considerable traffic volume (Schoon and Van Minnen cited in Daniels et al. 2009). Schoon and Van Minnen also found that mixed traffic was safer than cycle lanes (cited in Reynolds et al. 2009) recommended the use of separate cycle path designs (cited in Russell and Mandavilli 2004; Daniels et al. 2009; Reynolds et al. 2009).

Flannery and Elefteriadou (1999) note that in Schoon and Van Minnen's study, the 'before' period was longer than the 'after' period and that no fatalities had been recorded up to 1990, in which year four cyclist fatalities occurred on bicycle lanes in roundabouts (all with exiting trucks). The elimination of cycle lanes in circulating roadways was being considered as a result. The OECD (1998) notes that in a follow-up paper by Van Minnen and Schoon, the roundabouts studied were small with single circulating lanes and single lanes on both entry and exit roads. This probably also applies to the earlier study.

The main issue investigated in the most recent literature relates to the safety of giving bicycles using separate cycle paths priority over traffic when crossing traffic lanes at urban roundabouts (e.g. Dijkstra 2004). Although this issue is (currently) outside Australian practice, Dijkstra's research found that on roundabouts with mixed traffic, the number of casualties per roundabout was about the same as for those with cycle lanes, but roundabouts with separated cycle paths had considerably fewer casualties per roundabout. On this basis, cycle lanes were not supported.

Dutch roundabout design follows the Continental design philosophy. Fortuijn (2003) compares some of these design features with US design standards (reproduced as Table 6.4). Van Minnen (1998) noted that while the safety of two-lane roundabouts is less than that of one-lane roundabouts for all road users, safety can still be adequate if entries are radial, the speed of motorised traffic is sufficiently low, and if separate cycle tracks are provided – or when there are grade-separated interchanges at higher traffic volumes and multi-lane carriageways.

Table 6.4 Comparison of roundabout design dimensions

Who[1]	Site category	Inscribed circle diameter	Inner radius of circulatory roadway	Traversable apron	Speed[2]
		m	m	m	m/h
FHWA	Urban single-lane[3]	30-40	9.5–14.5	?	35
	Rural single-lane	35-40	11.5–14.5	?	40
	Urban double-lane	45-55	13.5–18.5	–	40
	Rural double-lane	55-60	18.5–21.5	–	50
CROW	Urban single-lane[3]	32	10.50	1.5–4	36
	Rural single-lane[3]	36	12.75	3.0–4	36
PZH	Rural single-lane[3]	37.4	13.50	4	36–38
	Turbo (double-lane) [3]	50.2	12.00	4	37–39

1 FHWA 2000. CROW: Eenheld in rotondes (Uniformity in roundabouts) – Dutch guideline. PZH: As used in the Province of South Holland (a region with high volumes of tractor-trailer traffic).

2 35 km/h is considered bicycle friendly.

3 90-degree entry angle.

Sweden

Brüde and Larsson (2000) reviewed 72 Swedish roundabouts used by more than 100 cyclists a day, as part of a review of 650 roundabouts. This confirmed speed as a risk factor for all road users. The research found that the number of bicycle accidents at multi-lane roundabouts was twice that predicted from traffic and cyclist volumes. (Single-lane roundabouts had no such difference). Roundabouts being multi-lane was the greatest factor related to crash rates, but the research identified two other factors for reducing cyclist crashes:

- for single-lane roundabouts, having a central island greater than 10 m in diameter; and
- using bicycle crossings (separated bicycle paths) rather than using the carriageway.

Bergh (1997) noted that of some 120 roundabouts installed in Sweden to the early 1980s, most were large-scale, with centre radii up to 70 m (only 4 were under 20 m), but that the more recent installations were of smaller roundabouts. Design guidelines were mainly based on UK practice, with slight modifications to suit Swedish conditions such as large vehicle sizes (Bergh 1997). Changes to the design guidelines were anticipated, but it is not known if this resulted in a change in the design philosophy.

Bergh reports a study of Swedish, Danish and Dutch roundabouts of varying radii, lane numbers, traffic flows and cyclist provisions. This found that:

- small-scale, single-lane designs had the greatest safety;
- separate entry/exit crossing cycle paths were the best solution in high traffic flow conditions; and
- outer circular cycle lanes were a ‘doubtful solution’.

The OECD (1998) noted a further study of small single-lane roundabouts (diameters of 4–18 m) which showed improved cyclist safety results over other non-signalised intersection types, but with no specific bicycle safety measures described. From a review of small roundabouts used for speed reduction, Hydén and Várhelyi’s (2000) recommended that cycle lanes on the approach should transition to a mixed traffic situation before (not at) the roundabout, and that roundabouts should be as small as possible with single-lane entries, exits and circulating lanes.

Denmark

Hels and Orozova-Bekkevold (2007) related hospital admission data in Odense with roundabout design. They found cyclist volume, traffic volume and potential vehicle speed to be the greatest predictors of injury accident rates. However, the results were indicative only due to the small study size.

The Danish Road Directorate’s (2000) cycle guidelines includes a section on roundabouts, with advice recommending:

- use of Continental design geometry (narrow entry lanes and exits);
- use of separated cycle paths for multi-lane entries, exits or circulating carriageways (but by noting that with only 3 signalised roundabouts, Denmark has limited experience with these, it implies that multi-lane roundabouts are associated with signalisation); and
- mixed traffic for mini-roundabouts.

In rural areas:

- for small to medium-sized single-lane roundabouts with relatively low speed profiles: cycle tracks (essentially wide cycle lanes with a low kerb separation from the carriageway) that are designed to reduce speeds; and
- for large roundabouts: separate cycle paths located 30 m from the circulating carriageways, or grade-separated paths.

In urban (lower speed) areas:

- small single-lane roundabouts: mixed traffic or cycle tracks;
- for medium single-lane roundabouts: cycle tracks located 5 m from the circulating carriageway; if space is constrained, mixed traffic or cycle lanes – however cycle lanes should be used with caution; and, if volumes are high or space is constrained, signalisation; and
- for large single-lane roundabouts: cycle tracks located 5–7 m from the circulating carriageway and desirably on plateaux.[2]

France

French roundabouts are often noted as being similar in design to the UK and Australian practice (e.g. FHWA 2000); however, Guichet (1997) noted that a large-scale increase in roundabouts in France over the preceding 12 years was driven by:

- improved safety;
- reduced geometric size and hence cost; and
- aesthetic and visual preferences, including as a focal point for the community.

This points to France moving away from large, multi-lane roundabouts – unlike the UK or Australia. Gårder (2009) notes that 90% of roundabouts in France are single-lane, with volumes of fewer than 2000 vehicles/day. Guichet also noted that safety studies have been numerous and positive for France’s roundabouts. (Unfortunately, these studies are not readily available in English). Guichet (2005) presents photos showing small and large single-lane roundabouts, with zebra crossings on legs in urban locations and single-lane entries and exits, and no bicycle lanes.

[2] *Raised pavement sections.*

In an interview with Scrase (2005), Guichet notes that:

- new roundabouts comprise comparatively small, single lane designs;
- very large roundabouts with multiple lanes 'cause problems and are not good for safety';
- the number of accidents involving cyclists is far lower than for other types of intersections, with the proportion of fatal injuries being 1.8%, compared with 4.7% at other intersections;
- in some countries, traffic engineers are 'seeking to build roundabouts that are too complicated';
- new design guidelines were released in 1998 and 1999; and
- French traffic engineers focus on safety while their British counterparts focus on capacity.

In short, it appears that French roundabout practice is now more in-line with other Continental European practice, and their research into the safety of roundabouts should be interpreted as reflecting Continental rather than UK and Australian practice – for at least the majority of French roundabouts.

Summary of Continental research

The research points to cycle lanes in roundabouts performing poorly, and practice has generally moved away from the use of these. Instead, design responses focus on the size, geometry and complexity of the roundabout, and separated cycle paths. Vehicular speed is considered a major contributory factor, and multi-lane roundabouts present (much) greater safety risks to cyclists than single-lane roundabouts. Finally, the literature indicates that care needs to be taken in the design of cycle facilities for roundabouts.

Overall, the use of a Continental design philosophy is directly related to safety. The question of how applicable the cycle lane research is to Australia is complicated by the fact that Australian roundabouts use a design basis that is avoided in Continental Europe, as it is seen as contributing to cyclist crashes.

The research does not directly identify mechanisms contributing to cyclist crashes at roundabouts, and the effect of different road rules on crash risk cannot be identified.

United Kingdom

The UK has a long record of installing roundabouts, and UK practices have been the basis for Australian design guidelines with generally similar road rules and culture. Hence UK research has clear applicability to Australia.

Allot and Lomax's (1991) review of UK literature about cyclist safety at roundabouts confirmed the cyclist risk at roundabouts. This research identified design features that increase cyclist risk, including those that maximised vehicle flows and speeds, e.g. flared entries, excessive entry capacity, wide circulatory carriageways and large roundabouts – although in regard to the last, large roundabouts (up to 70 m in diameter) were feared by cyclists, evidence was not available to identify a relationship between accidents and roundabout size/ geometry; smaller roundabouts (5–40 m in diameter) with flared entries were the most dangerous for cyclists. Noting a Hertfordshire study, the authors showed that the outer 1.5 m of a roundabout were most hazardous for cyclists, Allot and Lomax suggested hatching out the outer areas of a roundabout to encourage cyclists to ride away from these areas. They also argued that design advice and practice gave insufficient weight to safety factors – particularly for cyclists and motor cyclists – and needed to be improved, with roundabouts sometimes an inappropriate solution (cited in Peel 2002).

The application of the Continental design to UK roundabouts has been investigated by the UK Department for Transport (1997). Advice to apply Continental design features now forms part of design guidance for roundabouts, principally for small to medium-sized roundabouts (e.g. Transport for London c2005b; Cycling England c2006; Nottinghamshire County Council 2006; Department for Transport 2008). Overall, these design guides note low crash rates at mini-roundabouts, similar to those at signalised intersections. However contrary to this, an examination of mini-roundabouts by Kennedy et al. (1998) found higher relative cyclist crash rates than for priority junctions or signalised intersections. The UK publications also identify features of Continental roundabout design for application to single-lane roundabouts; recommend separation and/or signalisation for large (often multi-lane) roundabouts, advise that circulatory cycle lanes on roundabouts can be considered – and suggest they be coloured red or green. This needs to be done carefully, due to the lack of evidence of safety benefits to cyclists and the potential that coloured lanes may introduce additional hazards. Kennedy et al. (1998) also describes an innovative circulatory cycle lane treatment in York that attempts to overcome these issues.

The possible hazards of cycle lanes are highlighted by a CCN (2000) report that total injury crashes more than doubled in less than 2 years after installation of a cycle lane in a roundabout in Weymouth, Dorset. Most injury-crashes involved cyclists. The roundabout was subsequently removed.

Lawton's (2003) case study of changes to roundabouts trialled 'cycle strips' (Figures 6.13–15) that, placed in front of each entry arm, reduced drivers overshooting the give way line. Lawton concluded that measures designed to:

- completely separate cyclists and drivers result in only cyclists modifying their behaviour;
- promote separation within a space lead to both cyclists and motorists modifying their behaviour; and
- influence perceptions (such as signing and geometry) result in only drivers modifying their behaviour.

Figure 6.13 Cycle strips, Nottingham

Source: www.ctc.org.uk/DesktopDefault.aspx?TabID=4347

Figure 6.14 Cycle strips, Nottingham

Source: www.ctc.org.uk/DesktopDefault.aspx?TabID=4347

Figure 6.15 Cycle strips, Nottingham

Source: www.ctc.org.uk/DesktopDefault.aspx?TabID=4347

Summary of UK research

Much of the research has focused on the use of Continental design parameters to reduce the poor safety record of UK roundabouts. UK research regarding bicycle lanes is scant and mainly sourced from the Continent, but is supported by the few installations undertaken so far.

New Zealand

New Zealand is very similar to Australia in terms of many design guidelines, road rules and culture. It is similar to Australia in terms of research and practice.

Campbell et al. (2006) examined cyclist crash statistics at New Zealand roundabouts. They also developed the ‘cyclist roundabout’ or ‘C-roundabout’ to improve safety for cyclists. The concept is essentially the German semi-two-lane roundabout. It uses a European-style confined geometry to achieve a low speed environment that allows a mixed traffic solution for cyclists, with larger vehicles such as trucks or buses travelling through in single file. An example of this has now been constructed and is being evaluated, with positive results so far (Campbell et al. 2009).

Turner and colleague’s (2009) NZ research related cyclist risk at roundabouts to increasing circulating speeds and multi-lane roundabout installations. Increased approach visibility led to higher speeds, challenging the New Zealand (and Australian) practice of providing good visibility.

The relevant design guidance in New Zealand is provided by the *Manual of traffic signs and markings* (MOTSAM). Clause 3.18.07, regarding cycle lanes at roundabouts, states that cycle lanes are *not* to be marked on the circulating lanes of roundabouts, and cycle lanes on the approaches should be terminated 30 m from the limit lines or at a connection to a cycle path.

Australia

Research

There is little Australian research regarding cycling at roundabouts. Of the primary research, most reviews crash statistics, including – but not necessarily focused on – roundabouts. For example, Robinson (1998) confirmed the poor safety of roundabouts for cyclists in New South Wales, while Green and Harrison’s (2002) limited reviews of sites identified a need for more research.

There is no known research regarding the performance of cycle lanes in roundabouts. This is not necessarily surprising, given that few roundabouts have such cycle lanes. And with generally low cyclist volumes using such roundabouts, there is a poor data set for statistical analysis. However, nor is there non-statistical research. Both Johnson, Charlton and Oxley (2010) and Wadhawa and Bancroft (2004) have used video observations to capture cyclist behaviour and experiences. However, Johnson and colleague’s (2010) research was not explicitly focused on roundabouts and that of Wadhawa and Bancroft (2004) did not feature roundabouts with cycle lanes.

There is also no research regarding the effects of one of Australia’s interesting measures – the regulation whereby cyclists can continue through or turn right from the left-hand lane. This would arguably be even more difficult to research.

Secondary research references discuss much of the same international research covered by this paper (e.g. Parker 1998).

Practice

International research was reviewed by Austroads *Guide to Traffic Engineering Practice Part 14 – Bicycles* (1999; now superseded), which recommended mixed traffic and separated cycle path solutions, and did not support installing bicycle lanes in roundabouts.

VicRoads (2005) uses largely the research reviewed by this paper to describe and advise on cycle treatment at roundabouts, referring to many elements common in European practice, namely:

- continental design features;
- separated cycle paths at multi-lane and rural one-lane roundabouts;
- mixed traffic for small – and large – single-lane roundabouts; and
- a layout for small single-lane roundabouts featuring zebra crossings or pedestrian signals on the legs (although this would not be acceptable in many Australian jurisdictions).

The VicRoads advice also includes features that are less well supported by the research:

- bicycle lanes through medium-sized single-lane, large single-lane and urban multi-lane roundabouts – again with zebra crossings or pedestrian signals on legs
- separated cycle paths at multi-lane roundabouts are shown in indicative layouts as being immediately adjacent to footpaths, adjacent to the carriageway.

NSW RTA (2004) guidelines do not refer to research findings in the document, although there are some research references in the bibliography. Design guidance provides for cycle lanes in single-lane roundabouts at speeds of 50 km/h or less, separated from entry and exit lanes by median strips. The guidelines note that a number of such treatments exist in Australia, although no assessment of the safety or effectiveness of these is made. Guidance on separated cycle paths for single-lane roundabouts is provided separately.

Queensland Transport's *Cycle Note B7 – Cycling and roundabouts* is no longer available from the Queensland Transport website and has not been reviewed. However, Queensland is well known for its bicycle lanes in roundabouts.

The new Austroads publication *Guide to Road Design Part 4B: Roundabouts* includes a new geometric design method for roundabouts. No commentary has been found indicating the new design method's impact on safety for cyclists, apart from a general note that the method will reduce speeds.

More specifically, the new Austroads Guide includes bicycle lanes marked in the circulating roadway as a treatment, although it also notes that:

> *The benefit of treatments suggested within [Section 5.3 Cyclists] to improve the situation for cyclists at roundabouts has not necessarily been confirmed through appropriate studies.*

The lanes are preferably separated from the approach and departure carriageways with concrete strips.

Discussion of Australian practice

Compared with international practice, Australian practice regarding cycle lanes is not well supported by research. Guidance on their application also lacks the cautionary tone of UK advice.

Arguably, Australian cycle lanes practice differs from the cycle lanes considered in the international research. They are not continuous around the outer edge of the roundabout. Instead, they are similar to UK ‘cycle strips’ with cycle lanes on the approach and departure. However, there is little research regarding these, and the Australian practice also has distinct differences from the UK.

Of course, cycle lanes could improve safety by encouraging cycling. Daniels et al. (2009b) confirms the ‘safety in numbers’ effect for cyclists at roundabouts. But we can question whether cycle lanes are the best infrastructure to generate a ‘safety in numbers’ response.

Australia is similar to the UK in that primary research on cycle lanes is scarce, but so far is not encouraging. Other measures – such as separated cycle paths – could produce the same (or better) response, with a lower crash risk.

In particular, under-represented cycling population groups – those with the greatest numbers to generate a ‘safety in numbers’ effect – are also those who most desire a high degree of separation from motor traffic (Garrard et al. 2008). In Australia, separation is not provided for by cycle lanes in roundabouts.

Conclusions

Roundabouts improve traffic safety, and so will continue to be used. At mini and small roundabouts, mixing with traffic is generally appropriate for cyclists. However there are particular safety issues relating mainly to large single-lane and multi-lane roundabouts.

A great deal of research has occurred internationally, and roundabout practices have been developed accordingly. Although referred to in Australian guidelines, international practices have not been actively pursued as safety measures. In particular, Australian practice in installing separated cycle paths at roundabouts has suffered from the implications of tangential design (on vehicle speeds, space needed). Well designed and implemented cycle paths could be the best means to attract ‘new’ cyclists, as well as catering for existing cyclists.

However, Australia’s focus is now on cycle lanes in roundabouts. Although overseas experience cannot be directly translated to Australia, the safety benefit of Australian cycle lane practice is clearly questionable. Good practice should be for any cycle measures to be well designed and tailored to a particular roundabout, as part of a ‘toolbox’ of measures; but the new Austroads guides mean that it is more likely that cycle lanes will be the first (and quite possibly only) cycle measure considered. If so, this may well be at the cost of other, more effective measures (such as the C-roundabout design) that could also benefit other road users.

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Concepts for a cycle network upgrade for Adelaide

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Abstract

The Defence and Systems Institute (DASI) of the University of South Australia has been running for some years a course for experienced graduate engineers at the Defence Science and Technology Organisation (DSTO) in systems engineering, called System Engineering and Complex Problem Solving (SECPS). For the past two years the students have been asked to develop a preferred concept for an upgrade to Adelaide's cycle network using system engineering principles - a field of activity outside their normal Defence oriented work life.

This paper examines the learning experiences of students carrying out the SECPS course, and perhaps more importantly, whether their discussions could inform the debate on strategic planning for developing cycle transport networks in Australia. The quality of the engineers taking the course is reflected in the high quality of many of their submissions.

The views of the students have been integrated into one coherent view of the needs and possible solution concepts, formulated in terms of the Soft System Methodology of Checkland (1981) and Checkland and Scholes (1990). This was a ready vehicle for expressing the overall contributions of the highest grade students, and may be refined at a later date as new information is added.

The feedback from the students was positive as to the benefit of carrying out the assignment, although more research needs to be carried out to evaluate their learning outcomes. It remains to be seen whether the student inputs may be of value to the transport research community, or at least whether a process can be formulated for achieving value in the future.

Introduction

As Shulman (1987) argued, teachers need a large number of different competencies. His conception of 'Pedagogical Content Knowledge' involves the integration of the competencies particular to the content domain and competencies involved in education. Engineering education research, then, involves the

> *...selection, legitimation [sic] and educational reconstruction of topics to be learned, selection and justification of general aims of teaching and learning…, as well as the instructional sequencing that takes the learners' cognitive, affective and social preconditions into account.*

This paper looks at one particular approach to educational reconstruction in the skill domain of systems engineering. Students are typically mature Defence engineering graduates with a number of years experience in the industry. They already have a great deal of specialty knowledge in mechanical, electrical or software engineering, but need to understand the system level viewpoint.

The course – System Engineering and Complex Problem Solving (SECPS) – is designed to teach students how to solve complex engineering problems using systems thinking processes. The purpose of the course is not just to teach students how to develop technological systems, but to design systems that are complicated by the inclusion of the human element in the system – socio-technical

This paper has been subject to peer review.

systems. DSTO has recognised that human complexity is an area that their employees are relatively unfamiliar with, and they strongly support the development of skills in this field (Nandagopal 2006).

The course is problem-based and focussed on the civil transport domain – an area far removed from every day work life experience of the students. The first question is whether selection of the primary assessment task is capable of achieving the intended teaching and learning objectives.

Duit (2007) in his discussion on science education said that there needs to be a balance between domain content, and orientation on the students' needs, interests and learning processes. The word 'balance' is operative here, since there are two opposing traditions, the academic tradition of focussing on content, and the more recent social approaches, as discussed by Schnotz et al. (1999) which tend to focus on students' needs at the expense of domain content.

According to Klafki (1969) in his 'Educational Analysis', education involves deconstruction of the domain content into elementary ideas or concepts, and the construction of instruction contents to reflect those concepts with due consideration to teaching and learning methodologies and the practicalities of teaching and learning. He raised a series of questions that should be answered by the prospective educator.

What do we wish students to know about for our particular course? They need to know:

> *the fundamental systemic processes involved in understanding a complex engineering problem, and developing a concept for addressing that problem, taking due account of the social aspects.*

What we choose to teach is based on standard systems engineering process theory, covering needs analysis, requirements definition, functional analysis and allocation to physical systems, creation of possible solutions, and the final selection of a suitable candidate solution.

How we teach the domain content is informed by constructivist pedagogy, as discussed by many authors, including Duit and Treagust (2003) and Phillips (2000). We give lectures, either face to face or on-line, demonstrate concepts in class and through focussed questions for discussion, group work on the application of the ideas to a practical complex problem, and finally – the subject of this discussion – the application of the concepts to a practical complex problem by the individual student.

Yong (2005) says about Problem Based Learning (PBL):

> *The ill-structured problem scenario calls forth critical and creative thinking by suspending the guessing game of, 'What's the right answer the teacher wants me to find?'*
>
> *By using interesting real world problems, PBL can increase students' interest in the course and their motivation to learn science, make students more active learners, improve students' problem solving skills and 'lifelong' learning skills.*
>
> *PBL promotes metacognition and self-regulated learning by asking students to generate their own strategies for: problem definition; information gathering; data-analysis; hypothesis-building and testing…*

These views express many aspects of the teaching pedagogy of University of South Australia. So we are convinced that some form of problem based learning is an appropriate assessment task for these students. This is also supported by the work of Brodie (2007) from the University of Southern Queensland (USQ), who was the first to try virtual Problem Based Learning (PBL). As for their student cohort, ours is typically of mature age with a wealth of prior knowledge and skills, and a proportion of them working on-line. Most have domain knowledge in one area of engineering, and are seeking an appreciation of system level issues, and how to tackle them in a sensible way.

The final question raised by Klafki (1969) is:

> *What are particular cases, phenomena, situations, experiments that allow making the structure of the referring content interesting, worth questioning, accessible, and understandable for the students?*

We discuss a particular case that is intended to demonstrate the application of the concepts covered in the course, in a situation that is 'interesting, worth questioning, accessible and understandable.' It is interesting to the student because it is so far removed from experience, and yet it addresses something that is observed every day, if not used. The complexity of the task lies in trying to comprehend how all the artefacts demanded by the task description apply to such a case.

We also suspect that the assessment activity may be of interest to the educational community, since it is a practical example of using a subject matter which lies outside the domain of knowledge of the students involved, and yet is intended to inform the professional actions of those students in their current work day practices.

How well does that mechanism transfer the desired knowledge and skills back to the work domain? While this off-domain task is not unique, it provides a case study that may be of value. We are encouraged by Anderson and Helms (2001) who say that:

> *… more studies on the actual teaching and learning practice are urgently needed. This …should include studies on the actual state of instructional practice that may inform policy makers, curriculum developers and instructional design of more efficient instructional approaches.*

A second question is whether the act of carrying out the assessment task in a field unrelated to the students' own is able to make a contribution to the field of engineering addressed – in this case cycle network design concepts, and their justification. As Millar (2003) said 'research can inform practice… by providing the kinds of insights that enable us to see the familiar in a new way.' My interest is whether student assignments can inform practice.

According to Larsen and El-Geneidy (2009) research into cycle network planning has involved cost-benefit analyses of cycling facilities (Hopkinson and Wardman 1996; Ortuzar et al. 2000), attempts to understand how different cycling facilities affect the behaviour of cyclists (Tilahun et al. 2007; Aultman-Hall et al. 1997), factors that affect route choices and commuting habits (Dill and Gliebe 2008; Sener et al. 2009; Howard and Burns 2007), and cycling safety (Landis et al. 1997; Jensen 2007). Overall, the research shows that the cyclist facilities that are available in a community have a large influence on cyclist behaviour, and cyclist safety.

Larsen and El-Geneidy (2009) themselves, put forward a methodology for determining the best routes for cycle paths, based on easily obtainable data. They identified areas where new cycling infrastructure would benefit existing and potential cyclists, based on:

- areas with high cycling activities (from cyclist behaviour surveys);
- areas with high potential of cycling activities (based on frequency of short distance car trips);
- areas where there is a need for new facility through surveys;
- areas with higher risks for collision; and
- segments that will complete the network (addressing discontinuities)

It is important to note, however, that the mere existence of cycling infrastructure will not cause new cyclists to take to the road. It is necessary to implement a coordinated program of raising awareness of the benefits of cycling, including the health benefits discussed by Sallis et al. (2004) – and is an issue of prime concern in the current paper.

Pucher and Buehler (2008) present an excellent overview of what makes cycling irresistible in Netherlands, Denmark and Germany, as compared with other countries, in particular USA and UK. The statistics that they discuss show that Australia is at the very low end of bicycle usage. Yet, the differences between the countries are not so significant that similar programs of cycle infrastructure improvement would be expected to fail in Australia. Perhaps, though, the devil is in the detail. I have heard Australian cycling transport researchers suggest that our distances travelled are too great to make it cost effective to set up the 'Copenhagen system' as it is often called, in this country. Curtis (2006), for instance, in her exploration of the 'Network City' idea for future development of Perth for sustainable travel, noted that 'Australian cities share similarities with US cities in terms of their low density, spreading cities…' Indeed there are even closer similarities between Australian cities and Canadian cities, with the possible exception that the weather is more extreme in Canada.

Never-the-less, Pucher and Buehler (2005) show that significant levels of investment in cycling infrastructure in Canadian cities has elevated the numbers of cycling commuters to three times those found in US cities of similar size. Still, they suggest that much more needs to be done, especially in terms of penalties to car drivers and inducements to cyclists, in order to expand the cycling uptake further, and make progress towards the levels of uptake found in Germany, Denmark and Holland.

Australia is not lacking in cycle strategies. These include *The Australian National Cycling Strategy 2011-2016* (Austroads 2010), *Safety in Numbers – A Cycling Strategy for South Australia 2006-2010* (SA Government 2006) and the *City of Greater Geelong Cycle Strategy* (City of Greater Geelong 2008). Some elements of these and previous plans have been implemented. However, the evidence suggests that there is still a great deal to do. A fresh look at the issues may tease out what are the most important attributes we need for an Australian cycling infrastructure, how they relate to the statistics, what legislative changes are required, the attitudinal change necessary from Government if it ever wants to cause an attitudinal change in its citizens.

Works such as this study may contribute to an overall sustainable transport strategy specifically directed at Australia. They can, perhaps, learn from European *Charter on transport, environment and health* (WHO 1999), the various cycling strategies produced in Europe, articles like the *Promotion of transport, walking and cycling in Europe: Strategy Directions* (Oja and Vuori 1999), and from our New Zealand counterparts with their W*alking and cycling strategies – best practice* (Macbeth et al. 2005).

The brief

This paper is based on sixteen student assignments achieving the highest grade of High Distinction (for the whole course as well as for the assignment alone) over the two year period that this assessment task has been run.

The complete design brief is shown in Appendix A. In summary, the students are told that they have been seconded from DSTO to project manage the South Australia Government's project 'Cycle for Life' – an upgrade to Adelaide's cycle traffic network. They are to work with a leading engineering firm, 'Innovative Solutions Australia' (ISA) to complete the project within three years, in line with the Government's opening of their 'Carbon Neutral Adelaide' initiative. Together, they are to carry out detailed planning, design, implementation, operation and maintenance of the system. The overall aim is to reduce the dependence of Adelaide commuters on cars and so reduce their overall carbon footprint. The system must dovetail with similar projects to move commuters onto public transport in preference to cars, and other environmentally friendly projects being considered for 'Carbon Neutral Adelaide.'

Their task, for the purposes of the assessment task, is to undertake a Project Definition Study, develop a Conceptual Design, and create the documentation necessary for detailing a functional baseline. This evidence will be used by the Project Board to make a decision as to whether to proceed. The students can alter the design brief to suit their vision providing they can convince the

Project Board that the cycle network will achieve the aims, and contribute significantly to achieving a carbon neutral Adelaide, while remaining overall cost neutral. In other words, they have no limit to the budget, except that they need to demonstrate that there will be no net cost.

The scope of the task is provided by the list of deliverables:

1. Expansion of the design brief (using Soft Systems Methodology) to the extent required for the exercise.
2. A brief set of operational requirements.
3. A maintenance concept.
4. Technical performance measures for the above two categories.
5. A functional analysis and allocation for the system.
6. Synthesis and generation of two candidate system concepts.
7. Selection of the preferred concept with justification.
8. A draft system specification.
9. A project management issues statement that identifies unusual features of this project compared with your Defence experience.

The learning goals of the assessment task were informed by Engineers Australia, who paved the way for engineering education with their ‘Manual for The Accreditation of Professional Engineering Programs’ which focused on a number of graduate attributes including teamwork, problem solving, communication and lifelong learning skills. The goals for our students were for them to demonstrate the appropriate use of the range of tools, processes, and skills they have learned and developed during the course in addressing the task deliverables stated above. This invokes the application of key graduate qualities that are considered essential to students graduating from University of South Australia, including the demonstration of being able to:

- operate effectively with and upon a body of knowledge;
- work autonomously (and collectively);
- communicate effectively; and
- be effective problem solvers.

And to a lesser extent for this particular task:

- demonstrate preparedness for lifelong learning;
- demonstrate commitment to ethical action and social responsibility; and
- demonstrate an international perspective.

The assessment criteria are founded in the pedagogy developed by Biggs (2003), Ramsden (2003), and others. The highest marks are awarded to demonstrations of deep learning and reflection on the implications of learned knowledge and processes. A pass is awarded when students demonstrate a superficial level of understanding of the application of the basic processes and concepts discussed in lectures, to the problems in hand.

The implication is that for the best marks students need to carry out extensive research through any means available, including libraries and Internet resources. Demonstration of their autonomous research, their understanding of it, and the application of it to the problem, demonstrates the three latter qualities in the list above – lifelong learning, ethical action, and international perspectives.

If the students are to inform cycle network design to a meaningful extent, they would need to demonstrate the highest level of research and effort. So it was considered only relevant to examine the highest graded work for the purposes of this paper.

How do we know if the students achieved the desired learning experiences from the assessment task? The final deliverable from the task was to comment on the unusual features of the project compared with their Defence experience. It gave them a chance to feedback to the lecturer their overall insights gained from the course, and apply them to their work life experience.

The Soft System Methodology analysis

While all the deliverables are of value, this paper examines just the needs analyses and the synthesis of possible options. The discussion that follows is a synthesis of the ideas and concepts developed by the students, as interpreted by the author.

The first step of the systems engineering process involves identifying the problems, if there are any, in the current system in question. Where this involves social interactions to a significant extent it is often better to consider the Soft Systems Methodology (SSM) approach as developed by Checkland (1981), Checkland and Scholes (1990) and others. This approach was developed to handle complex systems consisting of both technical and human elements, with widely varying points of view. While there have been further refinements of the process (e.g. Bustard et al. 2000; Tanji and Kielen 2002), we consider only the original version developed by Checkland.

SSM was considered as a seven step process:

1. Understand problem situation.
2. Express problem situation.
3. Create Root Definitions of relevant systems.
4. Generate conceptual models.
5. Compare models with reality.
6. Choose feasible, desirable changes.
7. Action to improve problem situation.

Figure 7.1 shows an example of a ‘Rich Picture’ of the relevant elements of the Adelaide cycle network. The rich picture is intended to express the problem situation by highlighting the issues involved, the interconnections, and the overall context.

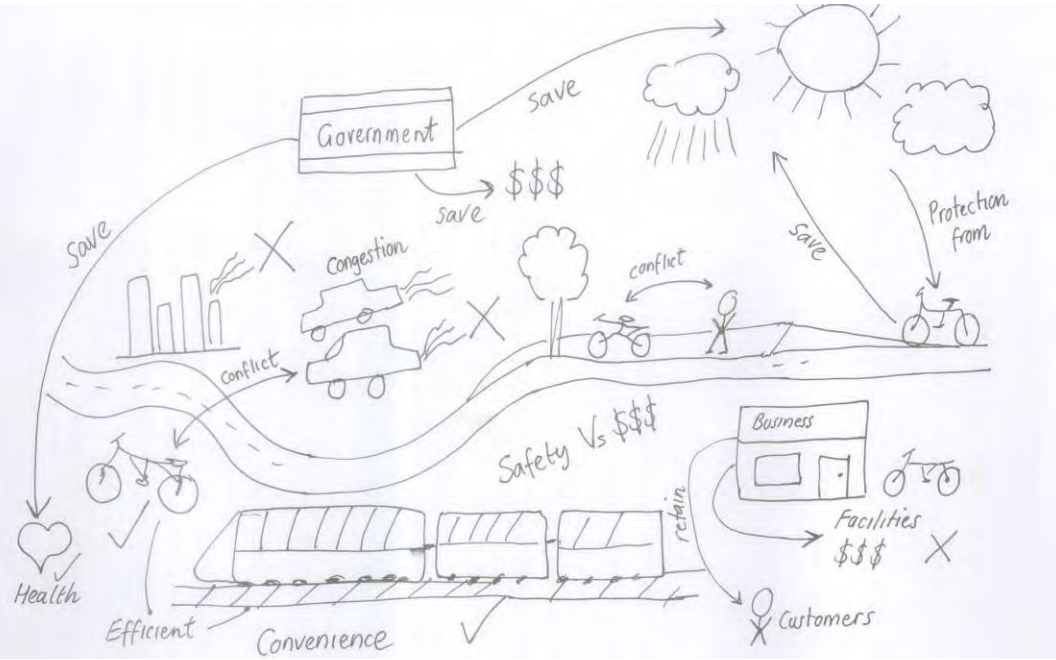

Figure 7.1 ‘Rich Picture’ of the Adelaide cycle network (by Michael Frangos On-line09)

Step 2 is to determine what exactly the problems are. Problems with the current Adelaide cycle network, as determined by the students, include:

- The network
  - Cycle lanes are not continuous, forcing cars and trucks into the same.
  - Space as cyclists.
  - Cars park on cycle lanes.
  - Cycle routes are not direct (so cycling takes even longer).
  - There is no special care taken of cyclists at intersections.

- Maintenance
  - The cycle network is poorly maintained.
  - Maintenance costs of the cycle network are high.

- Public transport
  - There is no continuity between the cycle network and the public transport system.
  - It is often impossible to take bikes on public transport.

- Legislation
  - No effort is made to discourage commuters from using their cars for commuting.

- Facilities
  - There is often a lack of secure bike storage at destinations or hubs.
  - There is a general lack of facilities for cyclists to change and shower.

- Perceptions
  - The public perceive the cycle network as poor and underutilised.
  - Cyclists find many motorists are aggressive or careless towards them.
  - Cyclists fear motor traffic.
  - Pollution from motor transport discourages cyclists.
  - Cyclists often find the distances are too great for commuting.
  - Cyclists dislike getting sweaty on the way to work.
  - Cycling find inclement weather uncomfortable.

Cyclists are put off from cycling by the ‘helmet hair’ outcome of wearing helmetsIn Step 3 of the SSM, ‘Root definitions’ expand the various systems into short textual definitions. Root definitions are a clear description of the systems to be modeled (Barry and Fourie 2001). According to Checkland and Scholes (1990)

> *A root definition expresses the core purpose of purposeful activity system. That core purpose is always expressed as a transformation process in which some entity, the ‘input’, is changed, or transformed, into some new form of the same entity, the ‘output’.*

Essentially, root definitions are mission statements. They tell us:

- what is to be done;
- why it is to be done;
- who is impacted; and
- what are the environmental constraints.

These questions are often addressed using the CATWOE analysis (Lehane and Paul 1996). The core of CATWOE is the transformation process and the world view, or 'Weltanschauung', that makes it meaningful. The other elements express who will undertake the purposeful activity (the Actors), who can stop it (the Owners), who will benefit from it (the Customers) and what environmental constraints apply to the system (the Environment).

A summary of the CATWOE analyses by students for the Adelaide cycle network is shown in Table 7.1.

The CATWOE analysis is intended to clarify the root definition so that a simple statement can be made to describe the desired transformation. This may be as simple as a sentence describing what a system has to do, or can be as complex as describing a system to do X (the what), by means of Y (the transformation process – T), in order to achieve Z (the longer term aims of the owners – O).

Table 7.1 CATWOE elements for the Cycle for Life project

C	**Customers**	Adelaide commuters and citizens – including: • Sport and recreation groups (represented by Life Be In It Council). • Motorists (represented by Royal Automobile Association). • Cyclists (represented by Bicycle SA, Cycling SA and Cycling Adelaide). • Pedestrians (represented by Pedestrian Institute of Australia). • University students (represented by UniSA and Adelaide University Students Associations). • Adelaide businesses.
A	**Actors**	Prime Contractor (ISA), Construction companies, Transport authorities (Adelaide Metro, TransAdelaide, Torrens Transit, SouthLink and Transit Plus), advertising companies, South Australian Police, SA Tourism Commission, Local Councils, Utilities (power and water), Emergency Services (Ambulance, Metropolitan Fire Service and SES), Economic Development Board, Department of Education and Children's Services, Department for Environment and Heritage.
T	**Transformation Process**	• Unpopular, underutilised cycle network → Popular, well utilised cycle network. • Current cycling conditions and community attitudes towards cycling → Improved cycling conditions and more positive community attitude towards cycling and cyclists. • Adelaide transport system with current level of safety and efficiency → Adelaide transport system with improved level of safety and efficiency.
W	**'Weltanschauung'**	• Increased commuter cycling and public transport usage and reduced motor vehicle usage will reduce greenhouse gas emissions, health care costs and congestion in cities. • Cycling is a desirable activity that should be embraced by the Adelaide public. • A transport network that is safer and more efficient will benefit all commuters.
O	**Owners**	SA Government - Department for Transport, Energy and Infrastructure (Transport SA)
E	**Environmental Constraints**	Planning SA, budget constraints, requirement to be cost neutral, requirement for overall carbon emission neutral Adelaide.

There is no one right answer to a root definition that describes the problem situation. Rather, there are a number of different viewpoints, depending on the stakeholder in question. A summary of root definitions suggested by students is presented in Table 7.2.

Table 7.2 Summary of Root Definitions

Stakeholder	Root Definition
SA Government	*"A South Australian Government owned system which will increase the proportion of regular bicycle and public transport commuters in Adelaide and reduce motor vehicle usage whilst remaining overall cost neutral."* OR *"An SA Government owned popular, well utilised cycle network system, completed by ISA and associated construction companies within the financial and planning limits imposed by the SA Government, in order to decrease carbon emissions and associated costs."*
Adelaide Commuters	*"A SA government system which will improve the safety and efficiency of Adelaide's transport network, without impacting the tax payer."*
Adelaide Cycling Enthusiasts	*"A SA government system which will improve cycling conditions in Adelaide and create a more positive community attitude towards cycling and cyclists without impacting the tax payer."*
Adelaide businesses	*"A SA government system which should improve Adelaide's cycling infrastructure but not be detrimental to local businesses which are currently struggling in the face of the global financial crisis."*

Students identified additional activities that need to be undertaken in parallel with network construction, which include:

- An environmental scan of good cycle networks throughout the world.
- Identify reasons for poor existing network.
- Advertise and encourage use of new cycle system to commuters.

Step 4 in the process looks at possible conceptual models for addressing the problem. A conceptual model is derived from the root definitions by identifying the activities that will bring about the specified transformations. An example is shown in Figure 7.2.

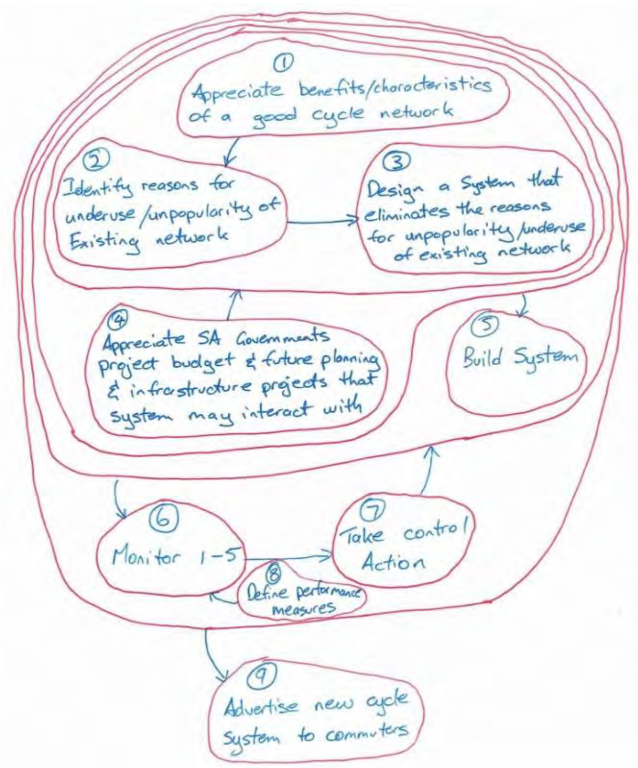

Figure 7.2 Conceptual model of the CFL system (Brett Morris – Mlb09)

An important element of this particular model is that it includes a control loop to monitor how well the transformation process is being carried out. Checkland and Scholes (1990) recommend that the judgement as to whether the process is working should address three 'e's – efficacy, efficiency and effectiveness. In other words we should ask – does it work (efficacy)? does it use minimum resources (efficiency)? and does it achieve the overall long term goal of the owner (effectiveness)?

In classic systems engineering terms, these questions might be considered in terms of the technical performance measures (TPMs). Students derived a wide variety of TPMs, including – safety, continuity, conflict potential, quality of ride and throughput (addressing efficacy); cost to construct and to maintain, ease of implementation (addressing efficiency); and impact on motor vehicle traffic and carbon emission reduction (addressing effectiveness).

Step 5 is intended to compare the simplified models with reality, and using the comparisons to define feasible and desirable changes to the real world. The set of questions that need to be addressed in arriving at these decisions are (Checkland 1999):

- What combination of structural, process and attitudinal change is needed?
- Why is it needed?
- How can it be achieved?
- What enabling action is also required?
- Who will take the actions?
- When?
- What criteria will be used to judge success or lack thereof and completion of the transformation process?

An example of this process carried out by the students in the current study is shown in Table 7.3.

Table 7.3 Conceptual Model – Real World Comparison Matrix

Activity	Does this exist in the real world?	How is it done?	How is it judged?	How well is it done?
1. Appreciate good cycle networks	Yes	Study Tour to investigate successful networks	Internal review	Well, provided the right people are used
2. Identify reasons for poor existing network	Yes	Market research, stakeholder meetings	Against standard market research practices	Reasonably well
3. Design a network that captures good aspects of cycle networks and eliminates poor ones	Yes	By using an established design process (e.g. design spiral) and standards	Designed to standards and internal review, public reaction after completion	Well, provided the correct standards and process is chosen
4. Appreciate SA Governments budgetary, planning and infrastructure constraints and interactions	Yes	Thorough research during the design phase	Internal review	Can be hit and miss
5. Build cycle network	Yes	Tender and select a contractor to build it	Construction standards	Well, provided the correct standards and process are chosen
6. Monitor activities 1 - 5	Yes	A process is put in place during the design and build phases	Internal/External review	Well
7. Take control action	Yes	Highlighted by monitoring of activities	Internal review	Well
8. Define performance measures	Yes	Stakeholder meeting	By stakeholders	Very well
9. Advertise and encourage use of new cycle system to commuters	Yes	By hiring advertising agency	Changes in network usage	Well, as long as aimed at target demographic

Step 6 defines the changes that need to take place, which are systemically desirable and beneficial, culturally and technically feasible and ethically based. All students were able to articulate their view of what needs to happen. The various system needs are summarised in the next section.

System needs

The following systems are required as part of the overall ***Cycle for Life*** (CFL) system:

1. A system to provide cycling infrastructure
2. A system to promote cycle commuting
3. A system to reduce motor vehicle use
   a. Penalise car use
   b. Remove freight carriage from critical roads
4. A system to recover costs (to achieve cost neutrality)
   a. Carbon trading
   b. Tree planting
   c. Sustainable power generation
5. A system to monitor financial benefits/problems
   a. Healthcare cost reduction
   b. Road upkeep cost reduction
   c. Travel time reduction
   d. Cost recovery through social and environmental accounting
6. A system to monitor tangible and intangible benefits/problems
   a. Well-being
   b. CO_2, NO_x emissions
   c. Travel time increases/decreases
7. A system to improve public transport
8. A system to police the network
9. A system to maintain the network.

The system boundary is generally taken to be a 10 km to 15 km radius circle centred on the Adelaide CBD (see Figure 7.3). This relates to the maximum distance people might commute to work, although if extra distance is added through public transport, significantly longer distances can be managed.

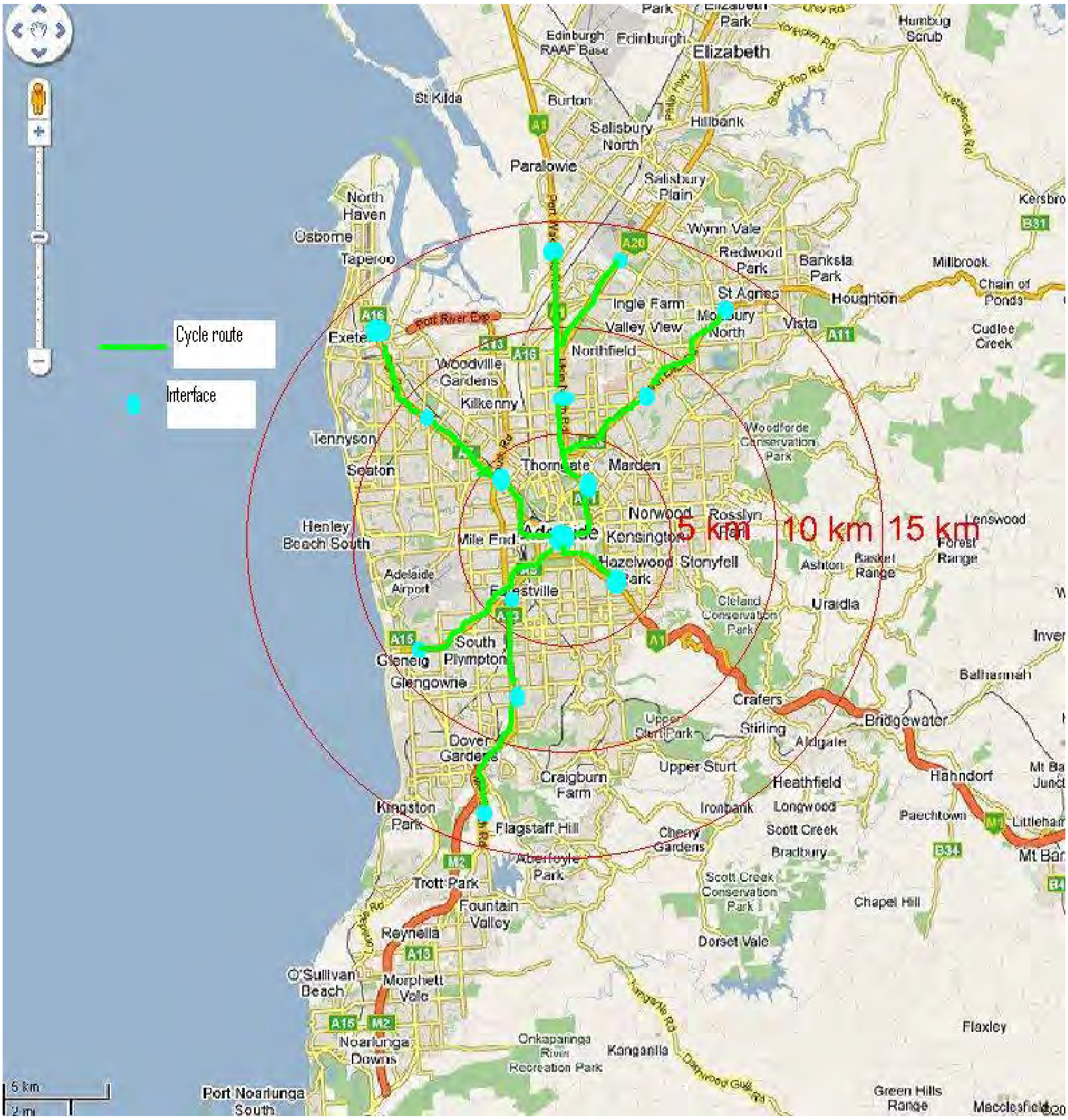

Figure 7.3 Typical system boundary with nodes or hubs marked along major arterial routes

Step 7 is the implementation phase, but may also be seen as the input to a second process which, according to the SISTeM (Soft Information Systems and Technologies Methodology) of Achouri and Atkinson (2007), develops detailed socio-technical solutions to the problem situation. While this is strictly an information systems methodology, it is relevant to the socio-technical system in general. According to Haskins (2008), most systems will benefit from a combination of hard systems engineering with extensions that incorporate the intentions of soft systems methods. However, the students were not asked to adapt the SISTeM methodology to their problem situation.

One of the problems with SSM is that participants may come to believe that simply by knowing the issues, and carrying out the process, they will come up with a worthy solution. This is not necessarily the case. Forrester (1994) warns that without proper systems dynamics modelling, the stakeholder group may come up with a completely erroneous conclusion as to recommendations for the future. With this caution in mind, it is instructive to look at some of the system solutions that the students came up with.

System Concepts

Possible cycle network concept solutions include:

The cycle network

- Construct a cycle network that is continuous, direct and safe.
  - Construct dedicated (off-road) cycle tracks network.
  - Improve existing cycle network.
  - Provide exclusive kerbside cycle lanes along main arterial roads (remove option for parking conflict and bus stop conflict) – protected with guard rails, or raised ledge (see Figure 7.4). These kerbside lanes can be one-way or sometimes two-way.

Figure 7.4 Cyclists using a bicycle lane in Copenhagen (Paul Poulsen – Adl09)

Source: http://www.streetsblog.org/wp-content/uploads/2006/11_20-26/shared_lane_copenhagen.jpg

- Provide cycle lanes aligned with the major arterial roads and highways leading into the CBD that are exclusive, continuous, raised, bi-directional cycle lanes constructed on central median strips.

- Upgrade the road network by changing dual lane roads into bus/T2 transit lanes and general use lanes, with a cycle lane adjacent to the transit lane. Prohibit parking on the roads in the network. Provide bus stops on transit lane/cycle lane dividers, with pedestrian access across cycle rights of way (perhaps via pedestrian overpasses). Provide cycle lanes with dedicated turn right arrows at major intersections. This concept is illustrated in Figure 7.5.

- Provide cycle paths along train and tram corridors and alongside the O-Bahn (see Figure 7.6).

- Convert minor roads running parallel with main arterial roads into ‘bike roads’ – allowing bikes to pass through, but not cars (open at both ends for access, but closed to cars in the middle).

- Provide dedicated cycle crossing lights at intersections.

- Provide underpasses or overpasses where practicable for cyclists to avoid major intersections.

- Provide physical protection for cyclists on cycle lanes on roads with speed limits grater than a specified value.

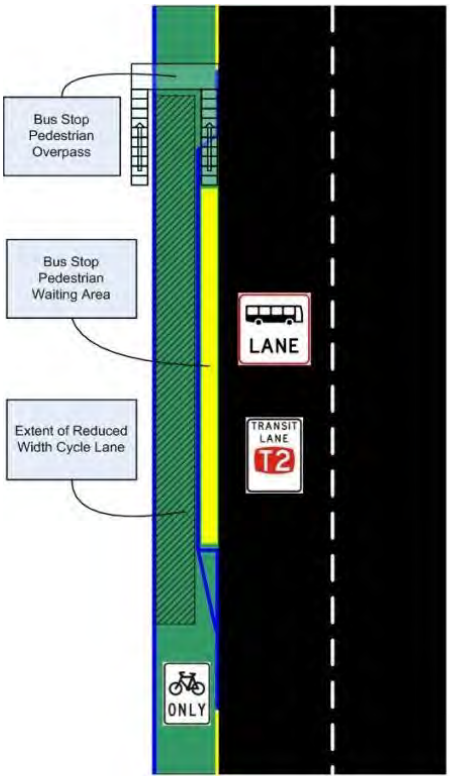

Figure 7.5 Cycle Lane with Bus Stop (Joanne Luscombe Adl09)

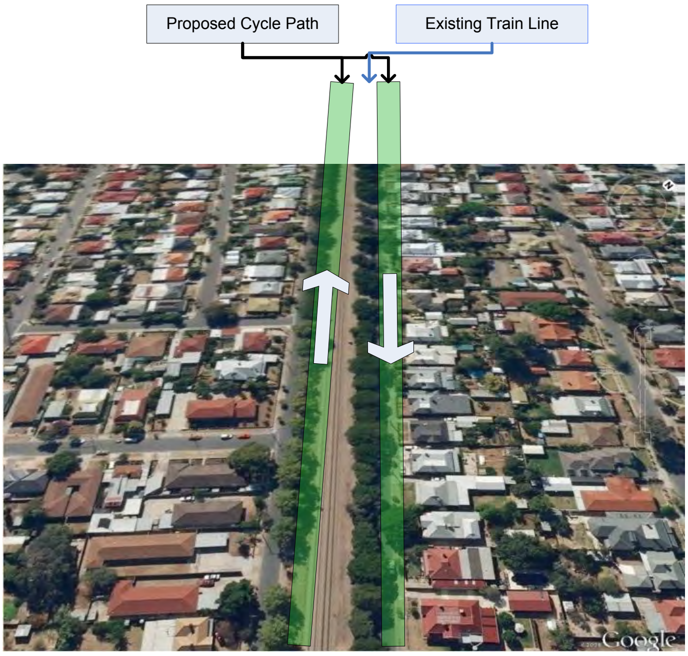

Figure 7.6 Cycle Path Along Rail Corridor (Joanne Luscombe Adl09)

Integration with public transport

- Encourage mixed mode commuting where commuters take public transport for one leg or partial leg of a trip, and cycle the rest.
- Upgrade complimentary public facilities to cater for cyclists by providing parking racks, changing rooms, bicycle storage bays and lockers.
- Upgrade buses, trains and trams to carry bicycles.

Regulatory

- Impose a charge on all non-resident motorists entering the CBD.
- Police enforce law relating to poor behaviour of motorists, cyclists and pedestrians.
- Allow salary sacrifice for bicycle and cycle-gear purchases, and tax breaks for business owners who provide satisfactory bicycle facilities such as showers and cycle parking.
- Hold motorists legally guilty in an accident with a cyclist, unless it can be proved the cyclist deliberately caused the collision.
- Increase taxes on motor vehicles and petrol, and increase car parking costs in CBD to provide revenue for upgrading the cycle network.
- Abolish law requiring cycle helmets for commuters (to encourage more cycle use)
- Provide financial incentives:
  - Register bikes that use the network and use money from registration to upgrade and maintain the cycle network.

  - Keep cycle access free of registration, and derive money for the network upgrade from other means.
  - Provide rebate to cyclists according to their use of the network.
- Offer rebates for installing electric motors on bikes so commuters can travel further.
- Penalise road haulage firms for trucks using Metropolitan roads during peak hours. This will be offset by providing tax breaks to road haulage companies who travel outside peak hours.
- Provide regular police bicycle patrols along cycle lanes.

Town Planning

- Keep the CBD free of cars by building parking areas underground in the Green Belt, and providing public transport to and from CBD.
- Provide subsidised car parking at Park'n'Ride areas outside the CBD (beyond the Green Belt).
- Regulate new building developments to demand that bicycle facilities be included.
- Offer low cost bike rentals in CBD.
- Operate free "cycle ferries" (buses or trailers with the capacity for transporting many bicycles) from hubs around Adelaide to central location to overcome the problem of distance.
- Provide free secure bicycle parking in the CBD.
- Provide facilities at transport hubs for cyclists for showers, drinking water, change rooms, bike parking or storage.
- Provide interfaces with public transport and car parking space at transport hubs.
- Include cycle sensitive traffic lights at intersections.
- Give cyclists a head start at traffic lights.
- Light cycle lanes at night using renewable power (e.g. solar).
- Clearly designate cycle lanes, and provide clear and efficient signage for cyclists.
- Provide an online feedback tool to report faults which require inspection and repair.
- Maintain cycle paths so they are free of debris, smooth and free of irregularities.

Education and training

- Provide free defensive cycling courses for users (especially children).
- Provide mandatory primary school cycle training to help promote cycling as a commuting option (removing much of the rush hour run to school).
- Provide mandatory motorist training to respect rights of cyclists.
- Promote in the media the benefits of cycling and the need for mutual respect between cyclists and motorists to the population of metropolitan Adelaide.
- Provide *education*, *encouragement* and *enforcement* programs to support existing and potential cyclists (especially targeting children and their parents, and motorist training).
- Liaise with health, sport and recreation agencies to identify promotional synergies.

Student perceptions

The statements from the students at the end of the assignments as to the project management issues demonstrated an overwhelming appreciation of the value of the work, even for those students who obtained much lower marks. A few of the comments are repeated below.

> *…increased awareness of previously unexplored issues such as social systems interactions.*

> *I believe that (unintentionally!) I may have been applying some of Checkland's SSM in defining the problem to these work packages but I am not entirely sure if a ship can be called a soft system?*
>
> *…this project has been very dynamic, and considered the system as a whole, often not possible in research.*

However, this does not address the issue of whether the students achieved the desired learning outcomes, outside the narrow view of assessment grading. For this to be evaluated, we would need to carry out a coordinated evaluation process, as discussed in the next section. Circumstantial evidence from former students suggests that there are often aspects of the course that they apply in their work situation – at the personal level, but sometimes also at organisational level.

Evaluation of learning outcomes

According to Lockee et al. (2002) the evaluation of a program, course or learning artefact involves measures of knowledge, skills and attitudes against desired outcomes. The heart of the matter, is to determine whether students "learn what the course is designed to teach." An examination of student attitudes also provides a useful measure of success, and includes the measurement of interest, motivation and attitudes "toward participating in the learning experience." These data are typically collected "through self-administered or interviewer-administered questionnaires, open-ended interviews, observations, and focus groups." It is also important to understand the student perceptions of whether it is more productive to carry out the instructive exercises as part of a group, or individually. Data on this aspect can be obtained as part of the process.

Another aspect that may be desirable to measure is the professional impact of having carried out the course or program. However, it is difficult to evaluate the small contribution of a single course or learning artefact towards the impressions of employers or potential employers of a student who has completed the overall program.

Lockee et al. (2002) evaluated learning outcomes through the level of performance of students in assignments and projects, but also through their contributions to their personal electronic portfolio. Review of the portfolios by a committee allowed them to determine whether each student had acquired the skills and knowledge appropriate to the professional standards of their particular field. Attitudinal outcome data was also collected at the end of each module, to try and determine whether the students 'felt that their experience and efforts were worthwhile and professionally beneficial.'

Slack et al. (2003) chose to evaluate the quality of deep learning displayed by students carrying out cross-national on-line problem-based learning in occupational therapy. The work the students carried out involved a problem-based case study, as well as a reflective account of their learning – similar in effect to the electronic portfolio used by Lockee et al. (2002). The difference was, that Slack et al. (2003) evaluated the learning displayed in "transcripts from peer-to-peer sessions of synchronous communication" through categorisation according to "the SOLO (Structure of the Observed Learning Outcomes) taxonomy" (Biggs and Collis 1982, 1989).

This technique, however, has advantages for on-line interactions that are not shared in face-to-face learning environments. For instance, on-line discussions tend to be characterised by short statements which aid in following a thread, and these may be more amenable to analysis against the SOLO taxonomy than the more free flowing discussions in a class. The technique, therefore, may not be feasible in the face-to-face case.

Interestingly, Gallavara et al. (2008) in their discussion of the "approaches to evaluation of learning outcomes in the Nordic countries," admit the following:

> *The institutions themselves don't really know yet how they are going to evaluate whether the students are fulfilling the learning outcomes and how they make sure that the learning outcomes are in accordance with the descriptions of the national qualification framework within the programmes.*

So the evaluation of learning outcomes is not a trivial exercise, and there are no clear methodologies that show how it should be done. According to Wojtczak (2002), the main problem is to achieve both validity and reliability at the same time. Simple questions that may be asked and analysed by electronic means, tend to be reliable but not valid. Complex questions, or observations of learned skills applied in practice tend to be valid but not reliable. The only suggested solution, however weak it may be, is to use a variety of evaluation methods and hope that they agree. If they agree all is well and you can assume both validity and reliability; if they do not agree, then there appears to be no solution.

In order to evaluate the learning outcomes of students doing the SECPS course in the future it will be necessary to set up a well considered, valid and reliable process. Two methods will be considered for future cohorts. Firstly, develop a questionnaire to directly address aspects of the students' learning and attitudes towards the learning process, which culminated in the particular assessment item described in this paper. It seems feasible and not too onerous to set between five and ten question statements and ask students to rate whether they agree or disagree on a scale of one to five. In addition, it is worth setting a small part of the assessment product to be the development of an electronic portfolio. Several courses at University of South Australia already use this method for evaluating student learning, and new technologies are coming on line to facilitate the process. However, the derivation of reliable data from the activity is fraught with difficulty. Experience from colleagues suggests that the analyses are likely to be resource intensive, and the results may suffer from poor reliability. One possible way forwards might be to analyse the portfolios against the SOLO taxonomy. This will be subject of future research.

Conclusions

In order to integrate the ideas expressed by outstanding students in the SECPS course on the development of an upgrade to the Adelaide cycle network, the discussion has followed the Soft Systems Methodology of Checkland (1981) and Checkland and Scholes (1990). This is not to say that every student used this methodology (even though it was stated as a deliverable), but it is a convenient way of structuring the concepts expressed.

As this is a summation of the student body, the arguments are, perhaps, more complicated than if we had tried to follow just one viewpoint. However, the purpose of this paper is to examine the insights and rich complexity of concepts and options discussed by students in the various cohorts that have carried out this exercise. It is also important to take into account that all the facts relevant to real life management decisions on the problem are not at the students' disposal. So it may be that planners who have responsibility for planning the upgrades for the Adelaide cycle network have significant issues that are not appreciated by the students which prevent planners from making apparently logical and obvious decisions that will improve the situation.

This raises the possibility that a future line of research might be to survey the decision makers and planners to determine what these other factors might be, and feed these back into the assignment brief to see how future students will handle the additional constraints. Another line of future research is to examine the cycle network planning literature in detail, particularly the State and national strategies for cycling infrastructure, and the relevant transport statistics, and determine whether a realistic strategy can be developed for Australia that would be capable of increasing the bicycled journeys by an order of magnitude over five or ten years.

There is an interesting opportunity here, in that we are able to feedback ideas and constraints from the literature, and future research, to the students. These would be inputs, as it were, to a human machine capable of outputting refined analyses on cycle transport network planning.

The student reaction to this assignment seemed positive, by all accounts – they expressed the view that they were able to appreciate a project at the system level – often for the first time. It will take, however, additional research to determine whether the learning objectives from this course are being internalised to a sufficient degree for previous students to apply the lessons in the work place. Options considered for evaluating student learning outcomes include carrying out a focussed survey for each student cohort, and having them prepare an electronic portfolio of their learning outcomes as part of their assessment. How to analyse such portfolios in a reliable way will be the subject of future research.

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Appendix A – Design Brief

Congratulations! You have just been seconded from DSTO to be the project manager for the South Australia Government's project "Cycle for Life" – an upgrade to Adelaide's cycle traffic network. You will work with one of the leading engineering firms in the area, "Innovative Solutions Australia" (ISA). It is your job to complete the upgrade within the stipulated three year period to coincide with the Government's grand opening of the "Carbon Neutral Adelaide" initiative (promised at the last election).

You will be provided with a team of engineers (with a range of skills) to assist you in detailed planning, design, implementation, operation and maintenance of the system. It is anticipated that the system will comprise an innovative network of easily constructed cycle traffic options that are cheap to build and maintain, safe and fast for users, with minimum conflict with other vehicles or pedestrians.

The current cycle network in Adelaide is *ad hoc*, with the occasional cycle lanes along major roads that are either parked on by motorists forcing cyclists out into heavy traffic, are broken up with storm-water drains, potholes, or spread over with glass, rubble and concrete. Most cycle lanes only last for short sections, and disappear when the road narrows, just when cyclists need them most. Cyclists suffer from car-door openings into their path, or gaps in traffic that motorists cross without giving way to cyclists. Adelaide has the luxury of an extended cycle-path along Linear Park, but this is shared with pedestrians and dogs on leashes, with inevitable dangers for the cyclists (and pedestrians) which limit cycling to slow speeds.

Adelaide made a perfunctory attempt to lure motorists out of their cars by building car parks at major public transport hubs. However, Adelaidians were not impressed, and stayed away in droves – with no sign that they trusted the regularity and efficiency of the public transport system, nor that they would risk bringing in their bikes by car, and cycling to work from the hubs. With this in mind, it is important to note that the overall aim is to reduce the dependence of Adelaide commuters on cars and so reduce their overall carbon footprint. Whatever system is considered for cyclists must dovetail with similar projects to move commuters onto public transport in preference to cars, and other environmentally friendly projects being considered for "Carbon Neutral Adelaide."

You won the position because your systems expertise and your organisation and people skills were recognised by the ISA Chief Systems Engineer who saw your presentation at the last Australian systems engineering conference. She had confidence that you could handle the technical and organisational aspects and guide a multidisciplinary project team to achieve an exciting outcome within the timescale. Accordingly, she approached your boss and secured your services.

The first step is to undertake a Project Definition Study for which you will need to conduct a Conceptual Design and create the necessary documentation to form a functional baseline upon which the decision to proceed can be made. You have the flexibility to alter the design brief to suit your vision providing you can convince the Project Board that the cycle network will achieve the aims, and contribute significantly to achieving a carbon neutral Adelaide, while remaining overall cost neutral.

News Item (BICYCLE SA E-NEWS 11.02.2008)

Figures released by the Department of Health and Ageing show that the current level of cycling in Australia saves the Government annually:

- $82.9 million health savings from recreational cycling.
- $71.2 million health savings from commuting cycling based on the 2006 census.
- $9.2 million savings on greenhouse gas emission reductions based on the 2006 census.
- $63.9 million savings on reduced congestion in capital cities based on the 2006 census.

Deliverables

The deliverables will comprise a project review package comprising at least the following activities:

1. Expansion of the design brief (using Soft Systems Methodology) to the extent required for the exercise.
2. A brief set of operational requirements.
3. A maintenance concept.
4. Technical performance measures for the above two categories.
5. A functional analysis and allocation for the system.
6. Synthesis and generation of two candidate system concepts.
7. Selection of the preferred concept with justification.
8. A draft system specification
9. A project management issues statement that identifies unusual features of this project compared with your Defence experience.

A longitudinal assessment of impact on two mountain bike trails built to sustainable standards

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Abstract

People have been riding bicycles in forests, over hills, through fields and along tracks for over a hundred years but it wasn't until the late 1970s and early 1980s that bike manufacturers started to build bikes specifically for the enjoyment of riding on non-paved surfaces. Since then the sport/recreation has grown considerably to become a mainstream physical activity. There are several styles of mountain biking and that which is the subject of this paper is cross-country and the paper concerns trails built specifically for cross-country riding on singletracks (i.e. in single file).

In recent years considerable effort has been made in Australia to adopt singletrack building techniques that make the trails more durable and have less impact on their surrounds than did many of the early trails. The guidelines for such construction are published by the International Mountain Bicycling Association (IMBA). Trail builders in Australia have been encouraged to adopt the guidelines through the efforts of Mountain Bike Australia (MTBA).

The question is: how "sustainable" are these mountain bike trails? For each of two South Australian trails built to the IMBA guidelines, the transect profile at twenty randomly-placed transect points was recorded once every three months for a twelve-month period. Some previous studies in Australia, New Zealand, England and the United States measured trail transects at numerous points once only. Their results rely on a single measurement at each of these trail transects and an assumption of the shape of the trail surface when the trail was built.

For the two trails monitored in the South Australian study, 37 (92.5 percent) of the 40 transect points showed no change or showed minimal change (soil movement) over the course of the study. The remaining three transect points (7.5 percent) showed considerable change. Use of the trails was estimated at between 8–12 passes per day on one trail and between 25 and 30 passes per day on the other. Rainfall was just under 700 mm per annum at both sites.

Introduction

Mountain biking (MTB) has become increasingly popular in Australia since about the mid-1980s after its beginnings in the early 1970s in the USA. The term "mountain biking" encompasses several styles of using a bicycle. The focus of this paper is on cross-country mountain biking and the singletrack trails on which a large number of cross-country mountain bikers like to ride.

Early mountain bike tracks were often old vehicle tracks that were established with little or no regard to principles of limiting their impacts on the environment or in such a way as to minimise the need for maintenance. Mountain Bike Australia (MTBA), the peak Australian body responsible for the competitive aspects of mountain biking, has for many years expended considerable energy encouraging the building of single-tracks to the guidelines generated by the International Mountain Bicycling Association (IMBA) headquartered in the US.

This paper has been subject to peer review.

These guidelines (IMBA (2004); and see IMBA (2007) and Parker (2004)) encourage the design and construction of "environmentally sustainable" trails. This activity is defined in IMBA (2007) as encompassing the principles of:

- protecting the environment;
- requiring little maintenance;
- meeting the needs of users; and
- minimising conflict between user groups.

In particular the principle "protecting the environment" encompasses limiting deleterious effects on local fauna, flora and landscape; and "requiring little maintenance" aims for trails with long-term resistance to erosion from natural forces, and wear through use. The term "sustainable" applies over a length of time rather than an instant and this concept combined with the two principles from the IMBA definition are the basis of this study that aims to answer the question: "how sustainable are singletracks built according to the IMBA guidelines?"

Mountain Bike Australia has been active in promoting best practice through sponsoring IMBA trail design and construction workshops and through disseminating information to mountain bike members and clubs. With MTB track-building progressing in many areas of the country, MTBA is particularly interested in building a picture of how cross-country single-tracks built to the sustainable guidelines in all parts of Australia fare under the local conditions of use, soil type and rainfall.

This paper reports and comments on a monitoring and assessment program on two singletracks located in South Australia and built to the IMBA guidelines. The study aim was to look for changes under measured use and rainfall conditions over a twelve-month period. The trails are the 600 m *Dynamic Tension* at the Mt Crawford Forest, Cudlee Creek Native Forest Reserve Trails Area and a 1 km section of *Tunnel Vision* at Eagle Mountain Bike Park. Both are within easy driving distance from the Central Business District of Adelaide at 43 and 14 km respectively. An additional criterion for selection was that a rider, once started, would finish the trail and not take a detour – hence the entire trail would be subject to the same use.

The study commenced in September 2008 with the first set of transect point cross-sectional area measurements taken. Subsequent surveys occurred in December 2008, March 2009, June/July 2009 and the final survey was performed in September 2009.

Background

Previous research

Research into the impacts of recreational activities on ecological systems has been undertaken in earnest throughout the western world since at least the 1960s (White, Waskey, Brodehl and Foti (2006)). Comprehensive discussions of the possible effects of use (all types, amount and behaviour), environment (vegetation, soil type, topography and climate) and management on recreation trails can be found in numerous publications including Marion and Olive (2006), Thurston and Reader (2001), Foti, White, Brodehl and Waskey (2006), and Goeft and Alder (2006). The detail of these discussions need not be repeated here in the limited space available. Marion and Olive (2006) in particular give comprehensive descriptions of the parameters likely to have impacts on trails and stress the importance of trail design factors.

Since the increase in popularity of mountain biking from the 1970s, research activities have been varied in focus, range of parameters and duration. Some research focuses specifically on the impacts of mountain biking and some compares the impacts of a range of trail users such as mountain bikers, walkers, horse-riders and motorised vehicles on trails. For example, Marion and Olive (2006) report in detail on the work that has been done into trail-related horse impacts and trail-related impacts by Other Recreational Vehicles (motorised 2- and 4-wheel drives, all-terrain vehicles and motorcycles). They further describe the possible impacts of trails on flora and fauna.

White et al. (2006) (and reported in a different format in Foti et al. (2006)) used a 'point-measurement trail assessment procedure' to measure the effects of mountain bikes on '162.3 miles of mountain bike trails' (about 261 km) in five Common Ecological Regions (CERs) in the southwest of the USA. The innovation in their study was to use the CERs as 'a mapped ecological region framework to guide comparative recreation impact research'. The parameters they studied on mountain bike trails were maximum incision and trail width at varying trail slope levels. Their study involved a once-only measurement at randomly-positioned points on the selected trails. The study required an assumption for the original trail surface level from which the maximum incision was measured and it is this assumption that is the main criticism of the conclusions they draw when comparing the impacts of mountain bikers and hikers. Nevertheless the measurement technique itself is sound and this and the random selection of measurement points on the trail have been adopted and adapted for the South Australian study. Note that Marion, Leung and Nepal (2006) give a comprehensive discussion of the pros and cons of a variety of trail monitoring methods.

The report by Marion and Olive (2006) is an assessment of a range of trails in Big South Fork National River and Recreational Area, Kentucky, USA. The assessment considered a range of user types and proportions of users. The report contains a detailed description of a comprehensive trail assessment methodology and includes a Trail Monitoring Manual. Some of the methods contained in the Marion and Olive report and manual were adapted for this study in South Australia.

Tread profile changes

The possibilities for tread profile changes in relation to trails are through compaction and soil movement.

Compaction of a trail normally occurs through use from the action of users (humans and animals). Parker (2004) contains a discussion of the meaning of compaction, how it occurs and how it affects trails. This discussion is not repeated here as the relevant point is that compaction will have an effect on the tread profile; and measurements of compaction levels for the soils of the two trails, though possible, were not carried out for this study due to the cost of the effort coupled with the minimal gain in outcomes for the study, since any compaction is included in measurements of the changes in tread profile cross-sectional area.

There are two reasons why soil moves from/along/to trails: (1) the action of users (humans and animals); and (2) the action of wind and water. Additionally there are two points of view to take into consideration: from the point of view of a longitudinal section of trail of (say) several metres and the point of view of the transect of the trail across the tread.

From the longitudinal section point of view, soil that moves within the confines of the tread is soil movement but is not lost (or gained). From the point of view of a transect there are three considerations. Soil that moves longitudinally along the trail but stays on the trail is soil loss or gain since it is lost from or moves into the transect. Soil also moves within the tread (intra-tread) and to and from the outside of the tread (extra-tread) constituting a loss or gain of soil. With the emphasis in this study on transect measurements, the transect point of view is taken and no attempt is made at extrapolating the measures to estimate the longitudinal view. Note that Marion and Olive (2006: 19) extrapolated their cross-sectional area findings to either side of the transect points to estimate soil loss from segments of trail.

Soil displacement is concerned with effects from users (IMBA 2004) and consists of three elements: (1) soil displaced from the tread to outside the tread boundary; (2) soil displaced from one part of the tread to another; and (3) soil moved along the trail.

Soil displacement can occur on mountain bike trails where soil is pushed to the outside of the tread. This can occur on any section of trail including straight and flat sections and could result in a concave profile. On corners (in particular descending corners) this can create or add to a berm of soil (a berm is a raised bank or ridge of soil or material on the outer edge of a corner and can significantly aid cornering). Such displaced soil can affect nearby vegetation (e.g. cover vegetation). Displacement also occurs along the most used part of the tread through speed and braking and even lateral movements of the bike. Soil displaced to the outside of the tread can create a bermed edge which can trap water on the trail. Such displaced soil is not usually lost until rain falls, and due to the trapping nature of the modified tread, erosion is more likely to occur.

The term ‘erosion’ refers to the effects of wind and water to whatever degree (IMBA 2004). Debilitating erosion (e.g. heavy rain and driving wind) is specifically concerned with the gouging of one or more deep grooves in the tread surface. These deep grooves are not caused by human or animal activity e.g. tyres and hooves. More gentle or benign erosion can be responsible for soil movement at a transect point in the same three ways (longitudinally, intra-tread and extra-tread) that it moves from the actions of users (displacement).

To differentiate quantitatively between soil moved due to users and that moved due to wind and water would require the use of control trails that would experience no use whatsoever or would experience exactly the same use but would not be affected by wind and water. Neither of these options is workable, hence this study does not refer solely either to soil displacement, as that is concerned with users; or solely to erosion, as that is concerned with wind and water.

Of the three ways soil moves from a transect point of view that of extra-tread soil movement (from the tread to the outside and vice versa) is considered in this study by taking the measurements to 20cm either side of the baseline used tread width along the transect. Intra-tread soil movement is considered by measuring the changes in the profile of the transect. The third of these is impossible to measure using a pure transect technique but Marion and Olive (2006) extrapolated their cross-sectional area findings to either side of the transect points to estimate soil loss from segments of trail. This technique relies on several assumptions and is not considered in this study.

Methodology and data collection

Genesis and elements

The study methodology is an amalgam, adaptation and improvement of elements of some of the studies briefly touched upon in the preceding section. In particular, the works of Marion and Olive (2006) and White et al. (2006) were of considerable benefit when the South Australian study was designed. The study reported here covers twelve months and is the first longitudinal study of MTB trails designed and constructed according to the IMBA guidelines for building sustainable trails.

Out of the raft of aspects that could be considered in a study on mountain bike trails, MTBA decided to look at arguably the most important of these: the factors directly related to the physical properties of trails.

The study looks at changes to the cross-sectional profile of the trail through displacement, erosion and compaction from each of the trails by conducting observations at 20 randomly-selected transect points along the trail. The specific parameters are (1) the cross-section profile of the trail, and (2) the used tread width. Each parameter is measured at each of the transect points, for each of five quarterly surveys over the year. This enables comparisons of the first survey (the baseline) with subsequent surveys.

The cross-section profile of the track is the shape of the trail surface perpendicular to the trail. The used tread width is where at least 95 percent of riders travel.

The technique to measure both parameters uses a horizontal beam set up in the same position for each of the surveys. It is important that the methodology adopted does not influence the manner in which a rider uses the trail. Reference pegs placed each side of the trail at each transect point were used and placed in such a way as to be as 'invisible' as possible to riders. Informal discussions with many riders over the course of the study indicated that very few realised the existence of any pegs until alerted to their presence.

Transect profile measurement methodology

A transect profile (cross-section of the trail) is found by measuring the vertical distance from a horizontal straight edge to the trail surface at several measuring points along the trail transect (Figure 8.1). The transect is the plan view line between two reference pegs: the upside reference peg (URP) and its downside counterpart (DRP) placed each side of the trail. The straight edge is mounted on tripods and positioned so that the edge of the beam from which the measurements are taken is directly above the holes drilled into the middle of the top surface of each of the reference pegs. Accuracy is achieved using plumb bobs dropped from the straight edge to the pegs. Similarly, the vertical distance from the straight edge to the trail surface is found by dropping a plumb bob to the trail surface. A flat, steel tape measure is clamped to the top of the beam, and positioned so that the horizontal distance of each measuring point from the upside reference peg is recorded. A view of the apparatus setup is shown in Figure 8.1.

The extent of the measurement is governed by what is adjudged to be the used tread width. The used tread width is bounded by the Upside Tread Boundary (UTB) and the Downside Tread Boundary (DTB). The used tread is defined as that part of the full tread that is used by at least 95 percent of riders. The UTB and DTB are adjudged in the first (baseline) survey and are two of the reference points at which measurements are taken during each survey. If, during a subsequent survey, the used tread width is adjudged to have changed, then the new used tread boundaries are labelled UTB' and DTB'. Measurements are taken at these new boundaries and at the original UTB and DTB to enable a comparison of the transect profiles.

The transect boundaries extend to 20 cm either side of the used tread. These boundaries are referred to as the measuring limit and are designated the Upside Measuring Limit (UML) and the Downside Measuring Limit (DML). Similar notation is used (i.e. UML' and DML') when the used tread width is adjudged to have changed. Measurements are then taken at all of the reference points.

The method for determining each measuring point along the transect follows that given in Marion and Olive (2006) called the 'variable-interval cross-sectional area method'. This method reduces the profile of the tread across the trail to a series of connected straight lines between the points where the transect visibly changes its slope (see Figure 8.1). This method is in the majority of cases more accurate than measuring at points at regular intervals across the transect.

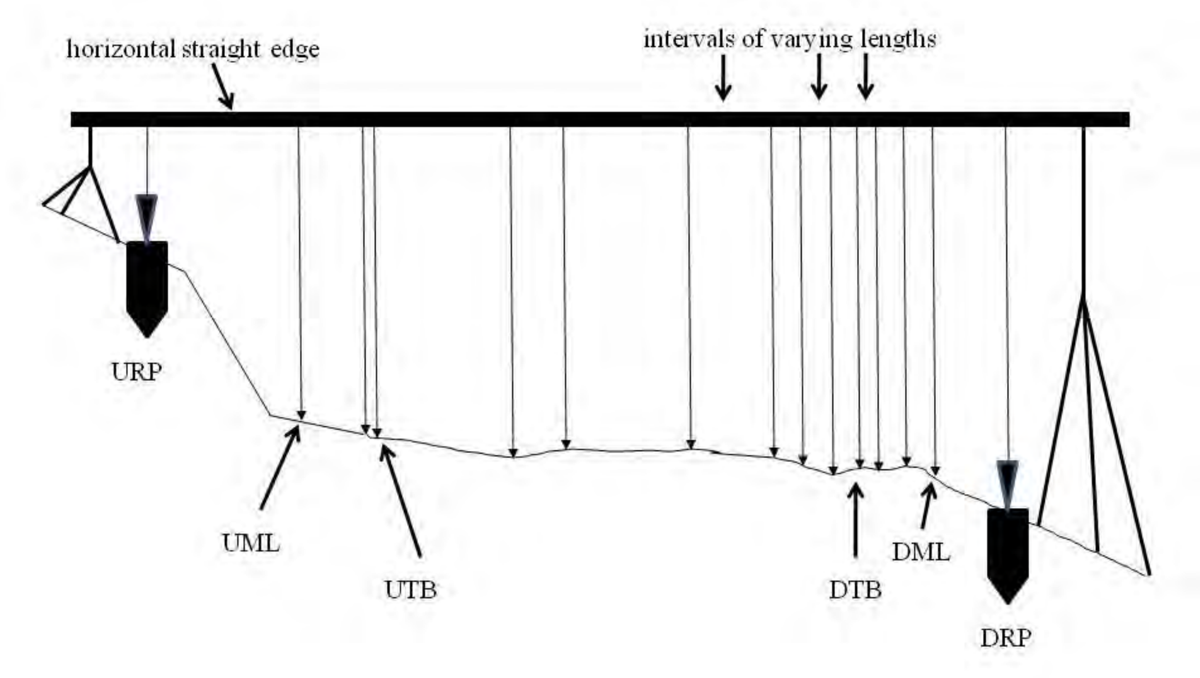

Figure 8.1 Diagram of the variable-interval cross-sectional area method

Counts of users

Commercially-available counters (from TRAFx Research Ltd, Canada) specifically designed to record the passage of mountain bikes were employed to gather user data on each trail over the full year-long study. Two counters were embedded in each trail – one at each end – to enable a cross-check of counts (the trails were chosen for the high likelihood that a rider would pass over the counter at each end).

As a check on the accuracy of all of the counters, several calibration efforts were performed during MTB competition events. During a calibration effort, the time to within a second or so that a rider passed over the counter was recorded manually. This enabled one-to-one matching of the manual record and the counter record. The accuracy of the counters varied considerably but due to the calibration effort, reasonable estimates could be calculated as an indication of use over the course of the study. See Clement (2010) for a complete account of the calibration and counting effort and the methods for estimating use.

Rainfall

Rainfall data were gathered from the Bureau of Meteorology web site listing daily rainfall for the two weather stations closest to the Eagle Mountain Bike Park and the Cudlee Creek Native Forest Reserve. The weather stations are Eagle-on-the-Hill and Stringybark Creek respectively.

Analytical techniques

The study seeks to find any considerable changes between the cross-sectional areas at a particular transect point over the course of the five surveys. The methods for doing this are:

- analysing changes in profile cross-sectional areas;
- graphing the profiles; and
- visual inspection aided by photographic record.

Combining these ensures the best interpretation of any differences to the trail at the transect points: one method is used to back up the other.

At each transect point two cross-section profile areas are calculated. The inner profile extends to the boundaries of the used tread width. The outer profile extends to the boundaries of the measuring limit.

The measure used for comparing cross-sectional areas is the mean change in profile area. This is calculated as the area between the two profiles being compared at the transect point (e.g. Survey #2 c.f. Survey #1), divided by the distance over which the profiles are measured. The unit is given as square centimetres per centimetre (cm^2/cm). A positive mean change means the baseline profile as measured is below the compared profile from the later survey. As an example, if the difference in cross-sectional areas for the width of the used tread is calculated as 10 cm^2 and the width of the used tread (UTB to DTB) is 100 cm, then the mean change is 0.1 cm^2/cm.

An example of a graph of the transect profiles from a transect point that showed no discernible change over the study period is shown in Figure 8.2. This is point #1 on *Tunnel Vision* and the mean change in used tread width profile area values associated with this transect point when Survey #1 is compared with the four later surveys are: 0.7, 0.9, -0.1 and -0.1 cm^2/cm. The corresponding measuring limit profile area values are: 0.8, 1.1, 0.2 and 0.2 cm^2/cm. Even though on first inspection these figures suggest there was some change evident, these figures are typical of a transect point that has not shown discernible change. There are several sources of possible error associated with the method of using a horizontal straight-edge located directly over the reference pegs. The most critical errors are in the following actions:

- the positioning of the straight edge by using plumb bobs over the reference pegs;
- the positioning of the measuring tape on the top of the straight edge relative to the upside reference peg;
- the judgement of ‘level’ by using a builder’s level to set up the horizontal straight edge;
- the judgements involved in reducing the transect profile to a series of straight lines; and
- measuring errors for all vertical distances.

The compounding and confounding factor in performing the measurements for this study is that the measurements are performed more than once. While each of the above sources of error are present when performing a one-off study of a trail, the nature of performing five sets of measurements on each of the transect points of a trail means that the likely range of the error must be considered when drawing conclusions from the analysis of the measurements and subsequent calculations. For these reasons a small change in profile area between one survey and another may well be due to measurement errors and based on a review of the findings in the judgement of the author it is unwise to conclude that there has been either a positive or negative mean change in profile area for absolute values of less than 1.0 cm^2/cm. Improving the accuracy would require a more sophisticated (and more expensive) measuring technique capable of millimetre accuracy.

The most difficult vertical distance to measure was most often the Upside Reference Peg (URP) height. Due to the comparatively short distance between the top of the horizontal bar and the top of the peg, any errors in measurement constitute a higher percentage of the height than the same size error with respect to the Downside Reference Peg (DRP) height. It is the URP height that is used as the height reference for the graphs and the transect cross-section profile calculations. Any variation in this one measure or in the positioning of the measuring tape on the top of the straight edge for any one survey can be seen on the graph of the profiles as a vertical shift in the profile. Where this shift is apparent and the shape of the profile is consistent with other surveys, it can be concluded that there has been minimal change in the profile regardless of the mean change in cross-sectional area.

An example of this vertical shift due to measurement error in the URP of the baseline survey is given in Figure 8.3 where the mean change in used tread width profile area values associated with transect point #5 on *Tunnel Vision* when Survey #1 is compared with the four later surveys are: -1.0, -1.3, -0.7 and -0.8 cm^2/cm respectively. If the measurement for the height of the URP is in error by 9 mm in the first survey then the four compared values become: -0.1, -0.4, 0.2, and 0.1 cm^2/cm and the subsequent graph is more akin to that of Figure 8.2 describing transect point #1 (i.e. the vertical displacement between each profile line on the graph is much smaller than in Figure 8.3).

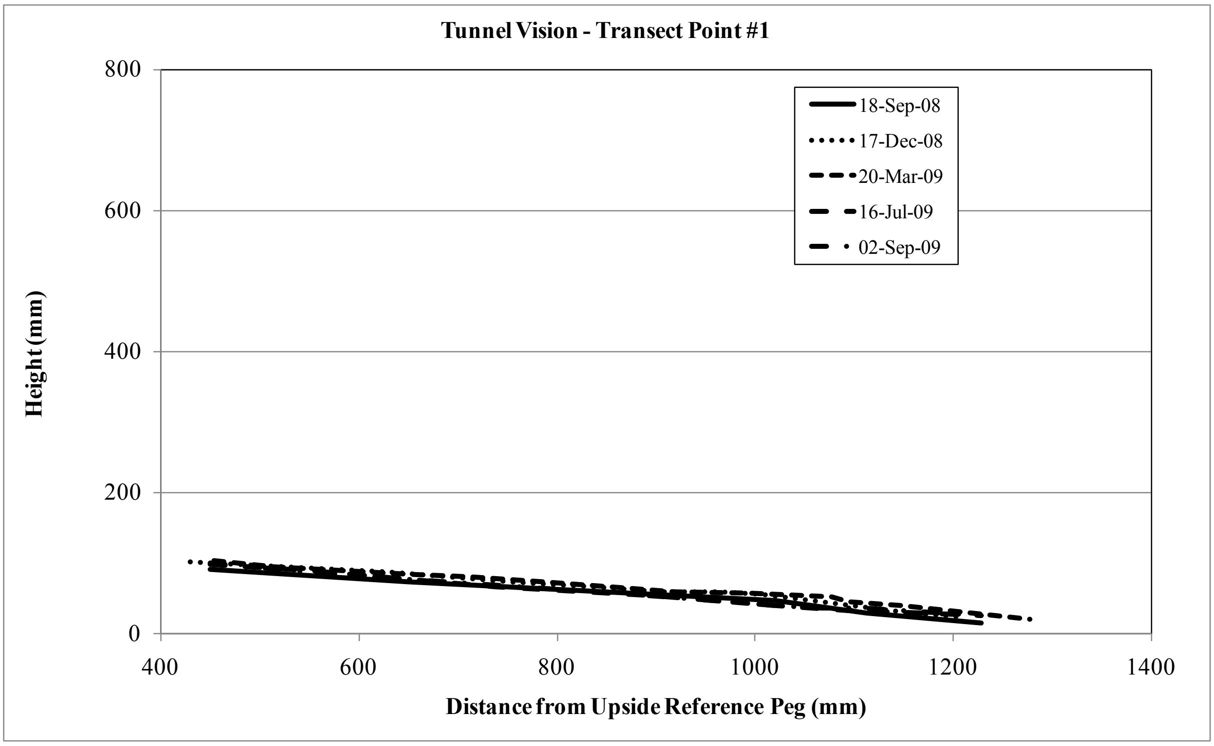

Figure 8.2 Example profile graph of a transect point exhibiting no change in cross sectional areas over the study period

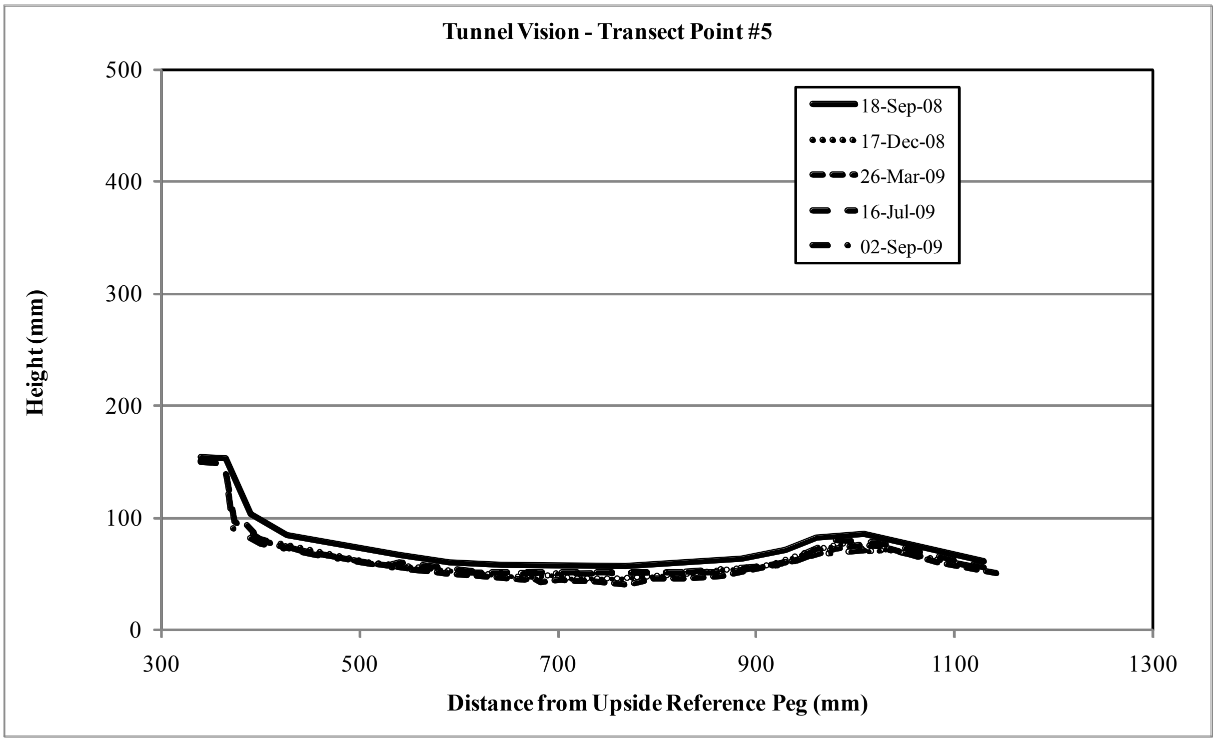

Figure 8.3 Example of a consistent set of transect profiles

Results and discussion

Estimates of daily use

The estimates of daily use on *Dynamic Tension* are shown in Table 8.1 and the estimates of use on *Tunnel Vision* are shown in Table 8.2. Note that in the initial stages of the study, the data were downloaded from the counters on a monthly basis. This was partly to aid the calibration effort, partly because of the mountain bike events that were held on the trails, and partly because the life of the batteries in the counters was unknown at that time.

The date, trail used and event description of each of the mountain bike events that used either *Dynamic Tension* or *Tunnel Vision* during the course of the study are given in Table 8.3. The organization responsible for each event is given as a footnote to the table.

By far the most concentrated use of either trail occurred on *Tunnel Vision* during the Australian MTB Series of 1–2 November 2008. During the counting period of 17 October to 6 November, daily use was estimated at 360 riders per day. This event attracted many riders from interstate and these contributed to the trail being used for practice for several days prior to the competition.

Table 8.1 Estimates of daily use on Dynamic Tension

Recording Period			Daily Users
#	Start	End	
1	4 September 2008	19 October 2008	12
2	19 October 2008	13 November 2008	8
3	13 November 2008	15 December 2008	11
4	15 December 2008	12 March 2009	9
5	12 March 2009	18 June 2009	26
6	18 June 2009	11 September 2009	7

Table 8.2 Estimates of daily use on Tunnel Vision

Recording Period			Daily Users
#	Start	End	
1	1 September 2008	17 October 2008	30
2	17 October 2008	6 November 2008	360
3	6 November 2008	18 December 2008	43
4	18 December 2008	20 March 2009	27
5	20 March 2009	16 July 2009	26
6	16 July 2009	18 September 2009	20

Table 8.3 MTB event calendar for the study period

Date	Day	Trail	Event
14 September 2008	Sunday	Dynamic Tension	[1] Foxy 1000
21 September 2008	Sunday	Dynamic Tension	[2] Ego Trip
1–2 November 2008	Saturday/Sunday	Tunnel Vision	[3] Australian MTB Series
14 December 2008	Sunday	Tunnel Vision	[1] Summer Series race
29 March 2009	Sunday	Tunnel Vision	[1] Winter Series race
5 April 2009	Sunday	Tunnel Vision	[1] 8-hour race
2–3 May 2009	Saturday/Sunday	Dynamic Tension	[2] Dirty Weekend 24-hour event
26 July 2009	Sunday	Dynamic Tension	[1] Winter Series race

1. Adelaide Mountain Bike Club.
2. Bicycle SA.
3. Adelaide Mountain Bike Club and Inside Line Downhill Mountain Bike Club with Mountain Bike Australia.

The second-most concentrated use of either trail was also on *Tunnel Vision* in the month before, during and for a few days after the Summer Series race held by the Adelaide Mountain Bike Club. During this period an estimated 43 riders per day used the trail. The great majority of the riders were local.

The Dirty Weekend 24 hour event held at Cudlee Creek on 2–3 May 2009 used the *Dynamic Tension* trail. This event attracted some interstate visitors. Over the counting period encompassing the event (12 March to 18 June), 26 riders used the trail daily.

The estimated use (without the peaks caused by large events) of *Dynamic Tension* is a mean of 8 to 12 riders per day and that of *Tunnel Vision* is 25 to 30 per day. The overall use estimates for the full year and including the large use for events is 14 per day on *Dynamic Tension* and 45 per day on *Tunnel Vision*.

Rainfall

The total rainfall over the study period for Eagle-on-the-Hill was 698 mm and for Stringybark Creek was 684 mm. The total rainfall for the 2009 year was close to the historical mean and the distribution was of occasional falls from September 2008 through to May 2009. From then they were regular, continuing through to the end of the study in September.

Transect point changes

Tunnel vision

Of the 20 transect points on *Tunnel Vision*, thirteen showed no discernible change using the measurement and observation techniques of this study. Six showed minimal change and one considerable change. The mean values of changes in transect profile area across the used tread widths of all transect points are -0.2, -0.2, -0.4, and -0.5 cm^2/cm. The values across the measuring limit are similar. Such values are so small that taken together the conclusion is that the trail experienced no discernible change using the measurement and observation techniques of this study under the use and rainfall recorded over the year.

A closer analysis of the point that showed considerable change is now given to determine why it behaves as an outlier. Considerable change is a relative term and in this case is about three times the change evident with compounded measurement errors. Another view of the descriptor is that if the change is due to the loss of soil, then that lost from a strip 1 cm wide across the 73 cm transect could easily fit onto a small garden trowel.

The transect point that showed considerable change, TV-10, did so mostly between the March and July 2009 surveys. During this period the estimated use was 26 riders per day: this includes the riders of two MTB events. Also in this period 48 percent (334 mm) of the rain recorded during the entire study fell. Approximately one third of this rain (109 mm) fell in the five days beginning 24 April with the heaviest day recording 42 mm.

The first MTB event in this period was the AMBC Winter Series race of 29 March. An estimated 360 riders (from the TRAFx counts and not from event records) used the trail on the day of the event. There had been no rain for two days prior to this event (2.8 mm of rain fell from 24 to 27 March) leaving the ground at transect point #10 dry.

The second MTB event was the AMBC Eagle 8 hour Enduro event. From midnight on the day of the event 3.2 mm of rain fell. This cleared about mid-morning. There were about 320 rider passes on the day of the event.

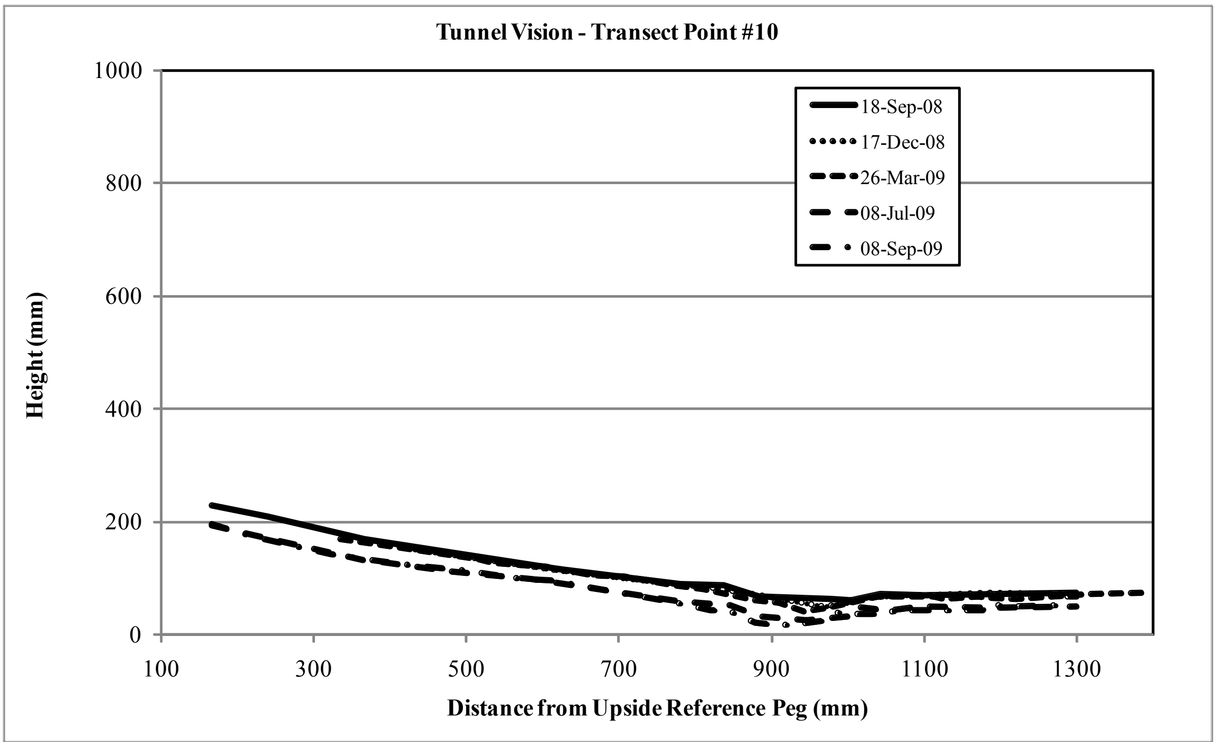

Figure 8.4 Tunnel Vision transect point #10 profiles

The graph of the cross-section profiles of TV-10 is shown in Figure 8.4. Both the July and September 2009 profiles are shifted vertically – probably due to measurement error of the height of the bar above the URP – but their general shapes are largely similar to those of previous surveys. The part of the transect that shows wear is around 900 mm from the URP. Transect point #10 is on a steep part of the trail (approximately 20% grade), is usually traversed in the uphill direction and most users of the park have to walk this section due to its steepness and the relatively bumpy surface that requires considerable effort to traverse. The Eagle 8 hour Enduro event used this section in the downhill direction and a combination of using this direction under race conditions along with the rain that had fallen on the morning of the event is likely to have contributed most to the changes seen over the March to July period. This is an assumption as it is impossible to differentiate between (a) change due to rain, (b) change due to use and (c) change due to rain and use, without doing transect measurements immediately before and after every rainfall event and using much more accurate measuring apparatus than is used in this study.

Figure 8.5 Tunnel Vision transect point #10 in September 2008 and September 2009 showing the effects of soil movement

The trail is constrained by an area of significant vegetation and by the presence of reasonably large trees for about ten metres back from and about thirty metres past this transect point. It is this constraint that probably led to the building of this section of trail outside the recommendations of the guidelines for building sustainable trails. The desirable trail to fall line angle is 90° (the fall line is the line of flow of water down a slope) which when combined with tread outslope induces water to run across rather than along the trail. The relatively low value of trail to fall line angle of 50° at this transect point would result in some water flowing down the trail. Either weather or use or a combination of both has moved soil as can be seen in Figure 8.5. The trail surface is sandy with ash and small stones between large (fist-sized) embedded stones and rocks that have helped anchor the trail. Without these large embedded stones and rocks the trail probably would not have been built through this section of Eagle Park and hence the entire part of the trail would have been much shorter.

Interestingly this part of the trail did not show major change between the July and September 2009 surveys. During this period 32 percent of the rain fell and 7 percent of the total number of riders for the twelve-month study used the trail.

To give the above overall findings more perspective, the highest use of *Tunnel Vision* occurred between the September and December 2008 surveys. Two MTB events were held in this period: the Australian MTB Series was held on 1-2 November; and the AMBC Summer Series Race was held on 14 December. Use averaged over the period 17 October to 6 November (5.2 percent of the study period) that encompassed the Australian MTB Series was estimated at 360 riders per day and the rainfall constituted 3.3 percent of the study total. During the 6 November to 18 December period (11.0 percent of the study) that encompassed the AMBC Summer Series Race, mean use was estimated at 43 riders per day and the rainfall (from 7 November to 18 December) constituted 6.7 percent of the study total. During these periods of heavy use with a small amount of rain, none of the transect points showed more than minimal change.

Dynamic tension

Of the 20 transect points on *Dynamic Tension*, eleven showed no discernible change using the measurement and observation techniques of this study. Seven showed minimal change. The mean values of changes in transect profile area across the used tread widths of all transect points are -0.4, -0.1, -0.6, and -0.3 cm^2/cm. The values across the measuring limit are similar and also within the bounds of experimental error.

Transect point #1 showed considerable change. The point is on a descending section of the trail (12 percent) on a slight curve. It is about five metres short of the entrance to a descending left-hand turn and as such is a braking area for riders. The *Foxy 1000* (October 2008) accounted for approximately 10 percent of the total use estimated over the study period, and the *Dirty Weekend* 24 hour event (May 2009) accounted for approximately 50 percent of use (about 2,200 passes). The trail was dry at the commencement of the *Dirty Weekend* and no rain fell during the event.

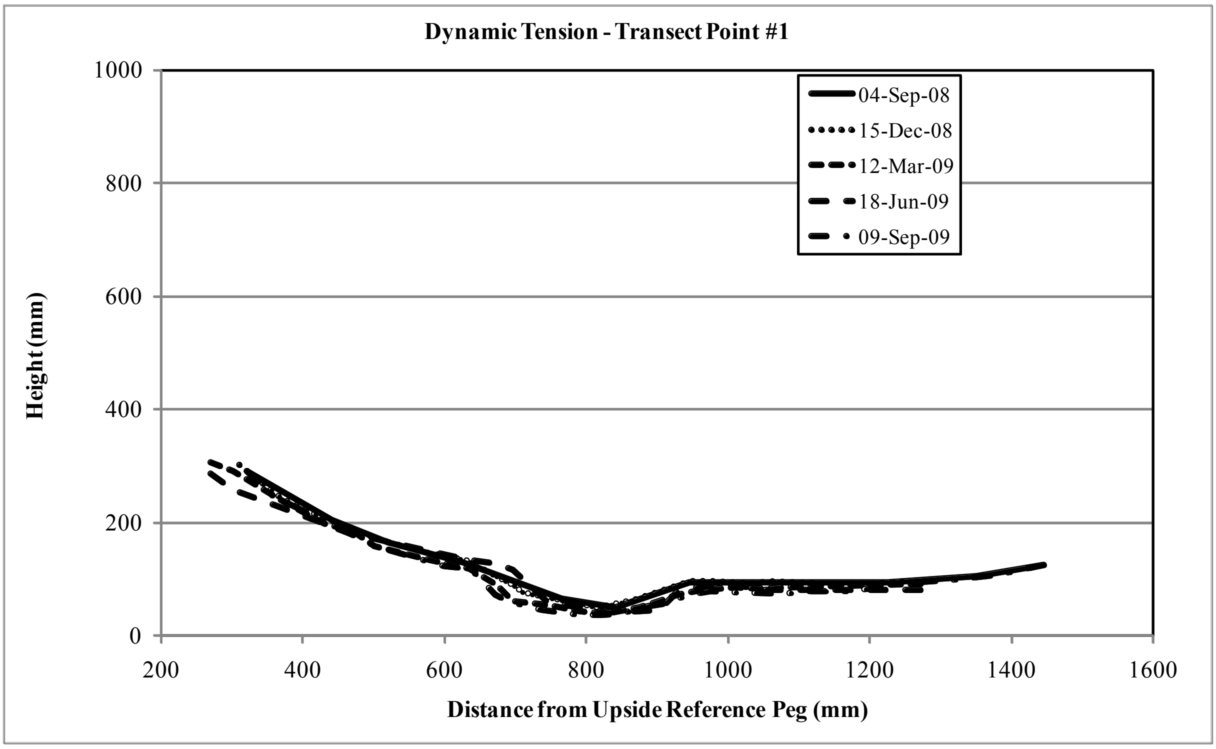

Figure 8.6 Dynamic Tension transect point #1 profiles

The trail to fall line angle is small at about 55° and the distance to the grade reversal when climbing on the trail away from the transect point (the uptrail grade reversal) is about 8 metres. At the first survey in September 2008 there was a noticeable channel where soil loss from the used tread had occurred (Figure 8.6). This deepened and widened slightly between September and December 2008 during which time the trail experienced about 12 percent of the rainfall and its mean use per day was 10 to 11 riders or about 22 percent of total estimated use.

Figure 8.7 Dynamic Tension transect point #1 in September 2008 and September 2009 showing the widening of the riding channel

The channel further deepened and widened by March 2009 during which time the trail experienced approximately 9 percent of rainfall and about 9 riders per day (about 16 percent of total use). After experiencing some soil loss in the first half of the study the transect point profile now appears to be stable. There was no discernible change in the profile between March and June 2009. This period included the *Dirty Weekend* event when about 51 percent of the usage for the study year occurred.

Transect point #9 is the other point that revealed considerable change over the course of the study: it exhibited both soil loss and gain. The point is at the foot of a descending, right-hand curve of the trail and is at a drainage point on the turn leading into a left-hand descending turn (gradients of 1 and 4 percent either side). The mean change values and the transect profile graphs indicate soil loss from September to December 2008 (about 12 percent of rainfall and about 22 percent of riders over this period) then deposition from June to September 2009 (40 percent of the rainfall occurred in this period and about 12 percent of riders) (see Figure 8.8 for transect profiles and Figure 8.9 for a snapshot taken in June 2009). These changes resulted in a nett zero change in transect profile area over the study period. The surface is soil with embedded small stones that help secure the soil. The used tread width has not changed and the tread started with slight outslope and is now almost flat from sediment deposition at the drain point. The trail to fall line angle is about 60° and the long side uptrail grade reversal distance is 17 m (in this case towards the start of the trail). The shape of the tread for about 10 m on the uptrail side is concave and this, coupled with the low trail to fall line angle would not allow water to run off the trail but induce it to move down to the transect point. The profile measurements, backed by the photographic record and notes taken during the study show that this water does carry some sediment that is deposited at the drain at the transect point.

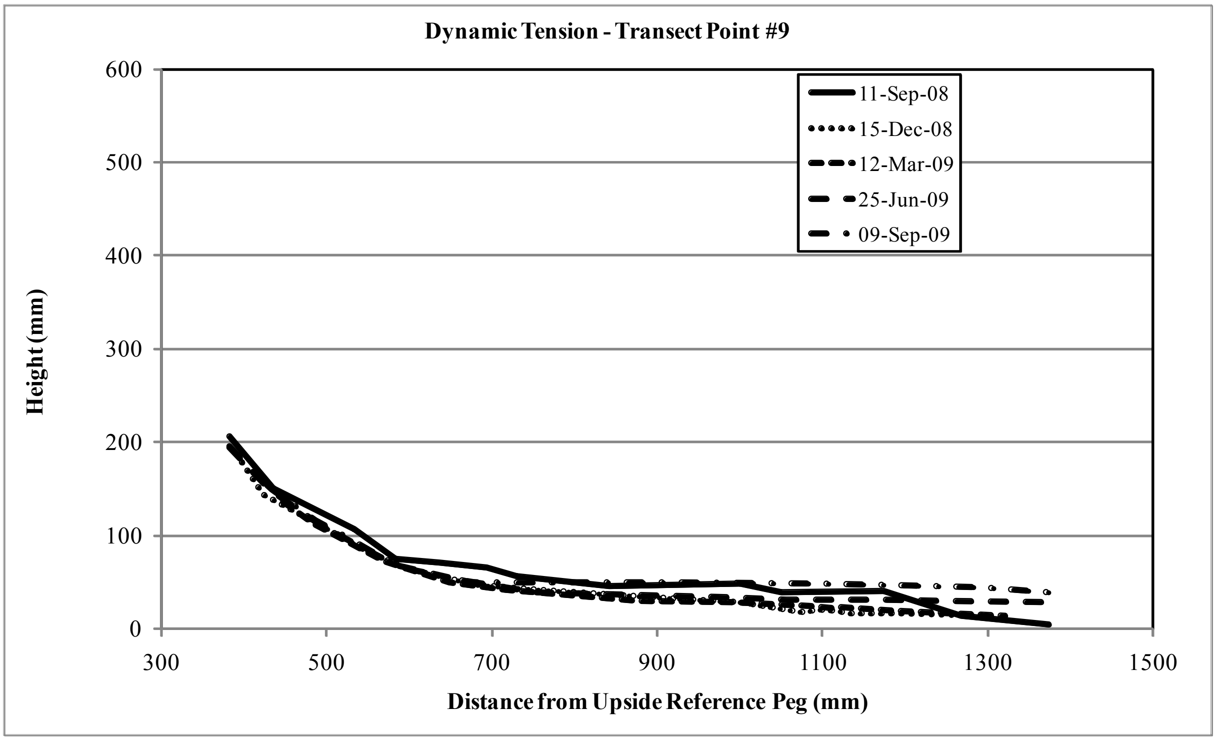

Figure 8.8 Dynamic Tension transect point #9 profiles

Figure 8.9 Dynamic Tension transect point #9 in June 2009

Transect point change summary

Overall, 60 percent of the transect points showed no change and 32.5 percent showed minimal change. The remaining 7.5 percent (three transect points) showed considerable change. The main reason for two of these to exhibit such change is that their related sections of trail arguably deviate too far from the guidelines for sustainable trail building (i.e. the trail to fall line angle is too small and/or the uptrail tread has no outslope to dissipate water and/or there is a considerable distance to the upslope grade reversal). Changes at the third transect are mostly caused by the changes in trailside vegetation affecting the line of riders. There was no evidence at any of the 40 transect points of deep gouging of the type caused by a single tyre. The most soil loss that occurred across a 1cm width on any one of these three transects would fit on a garden trowel.

Used tread width

The used tread width is that part of the tread in which it is estimated that 95 percent of riders will travel. Ascertaining the used tread width is in some cases a somewhat subjective exercise but for the most part, the travel line boundaries are reasonably clear to within a few centimetres across the transect. Evidence for the narrowing of the used tread is the growth of vegetation (usually grasses) further towards the middle of the tread. Part of the study is to see if the used tread widths change markedly over a twelve-month period and if they do, in what manner.

Of the twenty transect points on *Dynamic Tension*, fourteen did not show marked change. All six that changed became narrower; three by ten percent or less, one by eighteen percent and the other two by 23 and 29 percent. The transect point whose used tread width reduced by 29 percent was affected over the course of the study by the growth of a tree next to the trail. The mean used tread widths at the twenty transect points reduced from 51 to 48 cm.

Of the twenty transect points on *Tunnel Vision*, fourteen did not show marked change. Of the six that changed noticeably, four became narrower and two became wider. Of the four that became narrower, two were by ten percent or less, one by eleven percent and the other by 29 percent.

Of the two that became wider, one was by thirteen percent from 37 to 42 cm and the other by 38 percent from 29 to 40 cm. The former of these two became wider on the downside of the used tread. It should be noted here that the surface at this transect point is not a natural surface but is packed stone and the wider tread being used is still totally on this hard-wearing surface. It is very unlikely that the used tread will become wider as the transect point is bordered by bushes close to the trail and observations of riders passing the point during a race showed that the vegetation is not disturbed except for slight movement caused by rider-created wind. The used tread width change of 38 percent is occurring on both the upside and downside at the transect point and the entire width of the new tread is within the boundaries of the tread as it was built. There is no evidence that riders are veering off the trail at this point and the used tread width change indicates that more riders are comfortable on a range of parts of the trail rather than the change occurring due to speed or preliminary alignment by the rider to the next downtrail obstacle/feature/corner.

The mean used tread widths at the twenty transect points remained the same at 43 cm.

In conclusion, 70 percent of the transect points show no change in used tread width, 25 percent have become narrower and 5 percent have become wider but none are wider than the surface of the trail as built. The mean used tread width over the 40 transect points reduced from 47 to 45 cm.

Conclusion

Cross-country mountain bike trails in Australia are increasingly being built following the guidelines for sustainable trail building developed by the International Mountain Bicycling Association and widely promoted by Mountain Bike Australia, the peak body for competitive mountain biking in this country. Two of the trails so built in South Australia are *Dynamic Tension* in the Cudlee Creek Native Forest Reserve and *Tunnel Vision* in Eagle Mountain Bike Park. The entire 600 m of the former and a 1 km section of the latter were subjected to a year-long monitoring and assessment program from September 2008 to September 2009. Rainfall was just under 700 mm at each of the sites over the year and the use on each trail is estimated at a mean 8 to 12 per day on *Dynamic Tension* and 25 to 30 per day on *Tunnel Vision*. At three-monthly intervals (i.e. on five occasions), measurements were taken at 20 randomly-selected points on each of the two trails. The study sought to find changes in tread profile cross-sectional area and changes in the used tread widths (where 95 percent of riders travel). Other data gathered for each transect point were the trail gradient and bearing, the fall line gradient and bearing, the sideslope gradient and bearing and the distance to the upslope grade reversal. These data were helpful in establishing why some transects showed considerable change while others did not.

Overall, 37 (92.5 percent) of the 40 transect points showed no change or showed minimal change (soil movement) over the course of the study. The remaining three transect points (7.5 percent) showed considerable change. The main reason for two of these to exhibit such change is that their related sections of trail arguably deviate too far from the guidelines for sustainable trail building. Changes at the third transect are mostly caused by changes in trailside vegetation affecting the line of riders. The most soil loss that occurred across a 1 cm wide strip at any one of the three transects that showed considerable change would fit on a garden trowel. There was no evidence at any of the 40 transect points of deep gouging of the type caused by a single tyre.

Seventy percent of the transect points show no change in used tread width, 25 percent have become narrower and 5 percent have become wider but none are wider than the tread of the trail as built. This shows that at least at 40 randomly-selected points on a total of 1.6 km of cross-country mountain bike trail built to IMBA guidelines that good design and construction will keep riders to the trail.

In summary, the physical properties (transect profiles and used tread widths) of trails built to IMBA guidelines indicate that for the most part trails can withstand the combination of up to 30 riders per day and 700 mm of rain per annum for at least one year with little impact on the trail surface or the width of the used portion of the trail. Some maintenance is highly likely to be required in those parts of trails that deviate too far from the guidelines.

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Mapping mountain bike trails and associated features

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Abstract

Governments have identified that more information is required with regards to the management of mountain bike trails such as trail location, sustainability and liability. Up to date and accurate maps could aid this need, but currently mapping of such features is limited. To improve this situation, the research identified a multitude of mapping technologies that could be used ranging from Real Time Kinetic Global Positioning Systems (GPS) with centimetre accuracy, to navigational GPS used in recreational activities such as bushwalking with accuracies in the region of 5–10 m. The research in this paper explored mapping technology options and, through the use of a case study mountain bike park in South Australia, determined from these the most suitable for employment in mapping mountain bike trails and associated features such as such as signage, anchor points and obstacles.

Introduction

The sport of mountain biking is rapidly growing and the subsequent management and sustainability of the mountain bike trials is becoming more of an issue. The State Government of South Australia instigated a State Mountain Bike Plan in 2001 that noted a lack of information pertaining to trail design, location, sharing, sustainability and liability. To contribute to an improvement in the management of mountain bike trails including associated features such as signage, anchor points and obstacles, a network of accurate and up to date maps would be of great value. Mapping of such trails and features by authorities in the past has tended to be on an ad-hoc basis using low accuracy, inexpensive survey equipment often supplemented with contributions made from the public e.g. via mountain bike Communities, such as Crankfire in the United States. However, mapping technologies have advanced greatly in the last decade, particularly Global Positioning Systems (GPS) and Geographic Information Systems (GIS). Consequently, providing accurate and up to date base mapping for such management requirements could now be more feasible for stakeholders such as the International Mountain Bike Association (IMBA), Mountain Bike Australia (MTBA) or relevant government agencies such as the Office for Recreation and Sport (ORS) in South Australia (SA).

This paper will begin by introducing a case study mountain bike site in SA that could benefit from more accurate and up to date maps, especially for the purposes of asset management. Current mapping technologies will be explored in order to identify suitable methods to be applied in the case study. The methodology will detail the field mapping undertaken; the subsequent GIS analysis performed and then progress onto the results relating to the most cost effective mapping technology trialled. The paper will conclude with discussion about the results and ideas for further directions.

Study area – Eagle Mountain Bike Park, Adelaide, South Australia

Eagle Mountain Bike Park (EMBP) was created by the State Government of SA with the collaboration and support of many volunteers, mountain bike clubs and local councils during 2006 and is currently managed by the ORS. It is situated in a disused quarry located to the south east of Adelaide

This paper has been subject to peer review.

(Figure 9.1) and contains a variety of trails ranging from easy through to advanced. EMBP also caters for high profile mountain bike events such as the Australian Mountain Bike Championships.

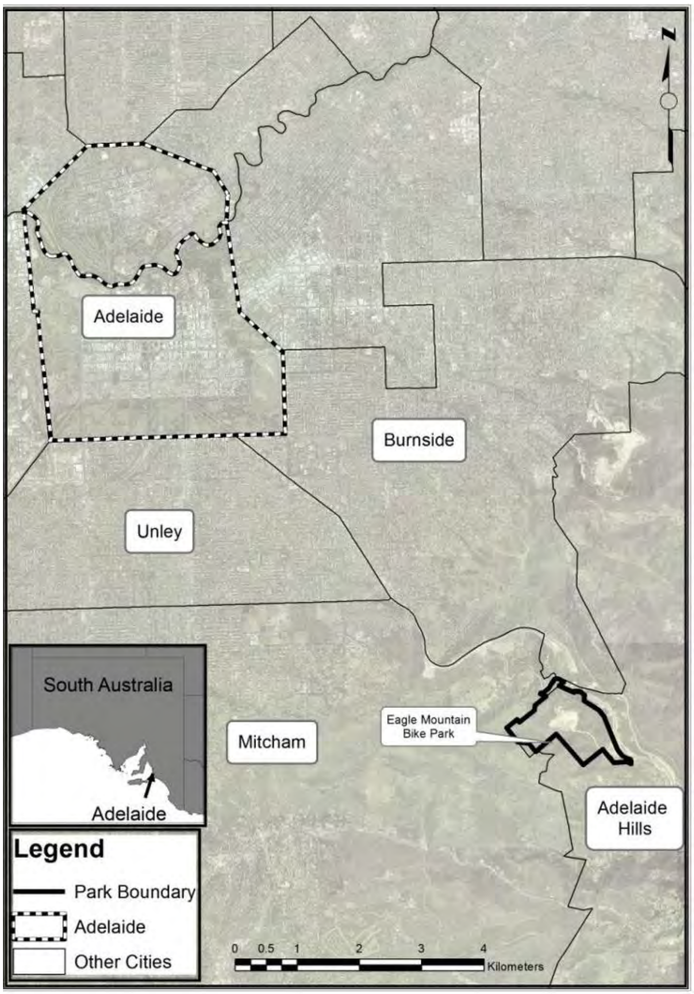

Figure 9.1 Eagle Mountain Bike Park (EMBP) location

EMBP has mapping available for riders to view trails online (Figure 9.2) based on surveys conducted by ORS using hand held GPS, for example the Garmin Handheld etrex that achieves an accuracy in the region of 5–10 m.

To align to the SA State Mountain Bike Plan, ORS would need to collect more data within EMBP such as the location and condition of signage, anchor points and obstacles. However, Vanier (2004) noted, accuracies of the magnitude 5–10 m are insufficient for organizations to manage field assets efficiently and he suggested that using higher accuracy GPS that attain in the region of <1.0 m would be more suitable. This dimension correlates well for application to mountain bike trail features as trails tend to be approximately one metre (1.0 m) wide and signage, anchor points and obstacles could be even smaller. By using more accurate GPS, EMBP features would be much more clearly defined than at present and ambiguity could be avoided, especially if features were closely aligned.

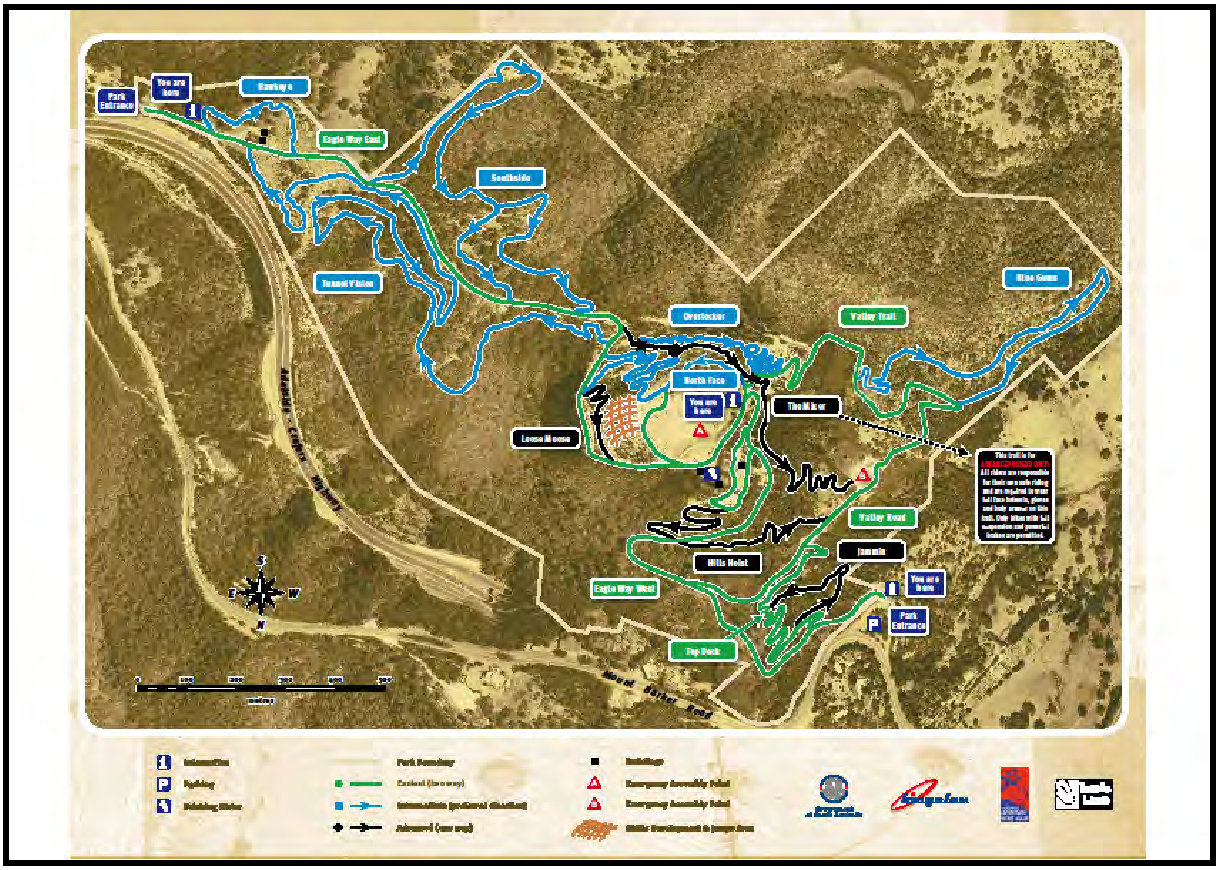

Figure 9.2 EMBP map, source: Government of South Australia, 2010

Mapping techniques

The mapping of trails and associated features could be undertaken terrestrially or from a remotely sensed stance in conjunction with GIS. Indeed, Heywood, Cornelius and Carver (2006) listed many generic operational applications for assets collected in this way ranging from identifying routine maintenance requirements though to more strategic requirements such as identifying new geographical areas in which to expand operations. Terrestrial mapping options exist in the format of Global Navigation Satellite Systems (GNSS) and these include Global Positioning Systems (GPS), total station theodolite traversing, land-based mobile mapping systems/ mobile laser scanners and Inertial Navigation Systems (INS). Remotely Sensed opportunities exist in the format of aerial photography, satellite imagery and airborne Light Detection and Ranging (LiDAR). Many of these options can be coupled with mobile field mapping GIS software such as Environmental Systems Research Institute (ESRI) ArcPad or Trimble® TerraSync™. Each of the mapping systems are discussed below.

Terrestrial

Global Navigation Satellite Systems

GNSS is the overarching term used for satellite navigation systems such as GPS. Van Sickle (2008) lists 3 types of GPS methods namely Static GPS, Differential GPS (DGPS) and Real Time Kinematic GPS (RTK GPS) offering a variety of survey times, accuracies, applications and costs (Table 9.1).

Nevertheless, whichever GPS are used, they are all subject to errors though obstruction to clear skies such as signal degradation due to tree canopies (Li and Rizos 2009) and multipath caused by GPS signals being reflected from close by objects (Ge et al. 2000). An example of the latter with respect to mountain biking could be trails that are located close to cliff faces or within steep valleys.

Signal degradation errors can be minimised, for example static GPS can employ extended times on a survey point to enable multiple estimates of the receivers' position from the satellites to be received in order to calculate a mean position. Conversely DGPS, which is used more for mapping on the move, utilises other GPS receivers at known locations to transmit errors to the mobile DGPS device with the difference calculations carried out in real-time or post processed back at a survey office. The advantage of the former is that the surveyor knows instantly their position whilst post processing involves applying the errors after the survey is complete (Bolstad 2008).

Table 9.1 GPS options (adapted from Van Sickle, 2008)

Method	Description	Computation	Survey time per point of detail (POD)	Accuracy	Application	Cost (approx)
Static	Multi station receivers simultaneously receiving satellite data	Post processed	30 minutes to 2 hours	1/ 100,000–1/5,000,000	High end base survey station infrastructure.	$35,000 per unit (min 2 units required)
DGPS	One base station receiving Satellite 'code' data and sending corrections to roving station	Post processed or real time	1–2 minutes	±1.0 m	Navigation, agriculture.	$4,000–$20,000
RTK GPS	One base station receiving Satellite 'carrier' data and transmitted by suitable communications link sending corrections to roving station	Real time	1 minute	±2 cm	Property boundary surveying	$75,000

Multipath signals have the trait of having longer distances from the satellites and lower power than the direct signals to the receiver. Therefore, some multipath signals can be eliminated by constructing a signal threshold that ignores high noise to mean signal strength (Bolstad 2008).

However, not all errors are noticeable and therefore users need to be aware and check their final product. If there are areas where signals are not received, the gaps could be in filled with more traditional surveying techniques as explained below.

Total Station theodolite: *A total station theodolite* consists of a theodolite that establishes horizontal and vertical angular measurement, an Electromagnetic Distance Measurement (EDM) instrument and an onboard storage device to log the data captured. Through this combination, features can be surveyed as long as a line of sight is maintained between the theodolite and the observed point.

Inertial Navigation Systems (INS): INS combines gyroscopes with measurements of acceleration to determine the speed, and then the distance travelled, of a moving object. From these measurements, a path of travel can be calculated (Aggarwal et al. 2006). They are usually built from an Inertial Measurement Unit (IMU) and custom processing. An IMU requires 3 accelerometers to measure acceleration in each dimension (X, Y, Z) and 3 gyroscopes to measure rotation about each axis (Fong et al. 2008).

Land based Mobile Mapping Systems/ Mobile Laser Scanners: Capturing geographical referenced data on the move has been a recent phenomenon according to DeRen et al (2009). The principle involves the integration of high accuracy GPS, digital stereo cameras (or Laser scanners), INS and a vehicle in order to capture 'drive-by' objects. An example of a laser option is the 'StreetMapper 360' product created by 3D Laser mapping and Ingenieur-Gesellschaft für Interfaces mbH (IGI) which offers positional accuracy to 300 mm (3D Laser Mapping 2009).

Remote Sensing

Cracknell and Hayes (2007) suggest that the ability to gather information about a subject using images from a device that is physically separated from any object is termed remote sensing. Thurston et al. (2003) noted that remotely sensed images (e.g. aerial or satellite images) were used in GIS for both analysis and as backdrops to other datasets. Campbell (2002) indicated devices that collect this data can be either passive or record energy emitted by the Earths' surface (e.g. SPOT (Satellite Pour l'Observation de la Terre)), or active where energy is emitted by a sensor (e.g. Light Detection and Ranging (LiDAR)). These different methods are briefly explained below.

Aerial Photography: Mikhail et al. (2001) defined the use of aerial photographs (photogrammetry) as the process of deriving measurement information of an object through the use of an aerial photograph thus establishing a fundamental relationship between the two at a particular time. The process can be analog i.e. using optical, mechanical and electronic equipment or analytical utilizing a combination of mathematics and digital processing.

Satellite Imagery: Imagery satellites collect electromagnetic energy emitted from a sensor and in doing so do not disturb the target entity it is observing (Jensen 2007). Elachi and van Zyl (2006) emphasised that such imagery allows the collection of global information such as the dynamic of clouds but also smaller scale detail such as vegetation cover. Satellite imagery can be acquired in stereo format enabling 3D position to be established. Currently the highest spatial resolution from commercial satellites is 0.41 m from GeoEye1 (GeoEye 2009)

Light Detection and Ranging: LiDAR works by emitting pulses of light toward objects (even through tree canopy) and from the return signal builds a 3 dimensional image. Costs for users are decreasing but the main problem is that signals maybe polluted by hitting objects that are not needed by the survey e.g. telephone poles, buildings and that these features may have to be filtered from the required data. Even so, LiDAR use is becoming more widespread (Liu 2008).

Which mapping technique to choose?

Wolf and Brinker (1994) suggested that factors relating to map use, equipment cost, equipment availability and survey personnel skill levels are particularly important when undertaking a mapping project. With regards to map use or, in other words the accuracy required for the project, McCormack (1999) asserted that surveyors like to obtain better accuracies than is required and to that extent a mapping technique for mountain bike trails and associated features would seem to equate to using RTK GPS with accuracies in the region of ±2 cm. However, Wolf and Brinker's second factor, namely cost, precluded this option as mountain bike stakeholders have only used cheap alternatives in the past and consequently purchasing, or even hiring, such equipment was not an option i.e. RTK GPS was too costly to use. The third factor related to the equipment at the disposal of the surveyor. From the remaining terrestrial mapping alternatives previously described, static GPS was discounted due to slow speed of survey, Total Station theodolites were eliminated though a combination of lack of speed and the tendency to use 2 operators, MMS/ MLS were removed due to their emerging technology status and time needed to adapt the equipment from a vehicle to a mountain bike and INS due to time constraints generated by late delivery of equipment for testing purposes. As for the Remote Sensing choices, Photogrammetry/ satellite imagery were rejected as substantial tree canopy obscured the tracks and obstacles whereas LiDAR was discarded, even with its capability of penetrating tree canopy, as it would be difficult to distinguish between the bare earth that may constitute a trail and other areas of bare earth that were not. The final factor related to personnel had two issues namely the researchers were trained surveyors, and secondly their remit was to have a technique that could be used by a relative novice. Therefore, the methodology that was chosen to explore for the purpose of this project was DGPS.

Methodology

Field mapping

Three types of DGPS were trialed, the first was a GPS Pathfinder® Pro XRS GPS receiver, mounted in a back pack with an external antennae attached (Figure 9.3). This DGPS was used in conjunction with a Trimble Nomad G series handheld data logger and TerraSync™ GIS software. By combining this particular DGPS receiver with the services of a real-time correction service known as Omnistar the stated accuracy mentioned by Van Sickle (2008) could be improved to an accuracy of sub-metre.

The second and third DGPS methodology employed was a Trimble® GeoXM™ that had an inbuilt antenna, a stated accuracy of 1–3 m and was similarly coupled with GIS software known as Environmental Systems Research Institute (ESRI) ArcPad. The difference between these two techniques was that the latter utilised a post processing service that would reduce the errors inherent in DGPS observations.

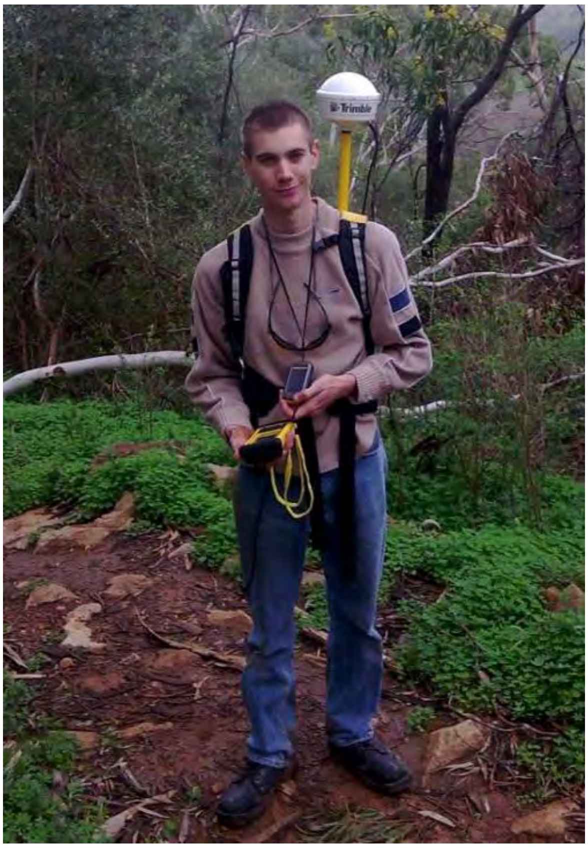

Figure 9.3 A. Billiau using the Trimble Pro XRS at EMBP

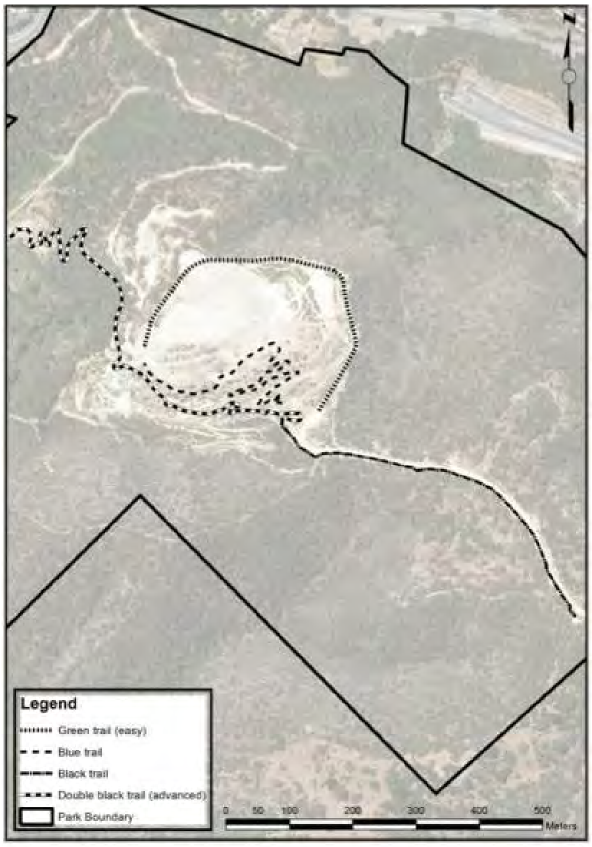

Figure 9.4 EMBP trails

Data input

Each of the four trails identified in Figure 9.4 were surveyed using the three DGPS techniques and the horizontal values of Eastings and Northings were recorded. Even though the DGPS receivers had the ability to determine vertical values of height, this value was discounted as the accuracy of height values is approximately twice the accuracy of the horizontal (Thurston et al. 2003) so in this case, the height would be accurate to approximately 2 m. It was decided by the research team that if height values were deemed necessary for asset management in the future, these could be more accurately determined by using a Digital Elevation Model (DEM) sourced from high resolution aerial photography. In addition to the horizontal coordinate values, attribute data was collected pertaining to the name of the trail being surveyed. The recorded observations were transferred into ESRI ArcGIS software to enable analysis to be conducted.

Analysis

To enable judgment to be made with regards to the accuracies of the 3 DGPS systems, a comparison with a previous survey of EMBP undertaken by Karas (2008) that utilised RTK/ GPS and Total Station theodolite was used. Visual interpretation could be used to determine deviation from the Karas survey, but it was more scientific to use an ArcGIS functionality known as ‘Near’ (Figure 9.5) to mathematically compute the differences. This enabled the Euclidean distance between an input feature (in this case the newly surveyed DGPS routes) and a near feature i.e. Karas (2008) to be calculated.

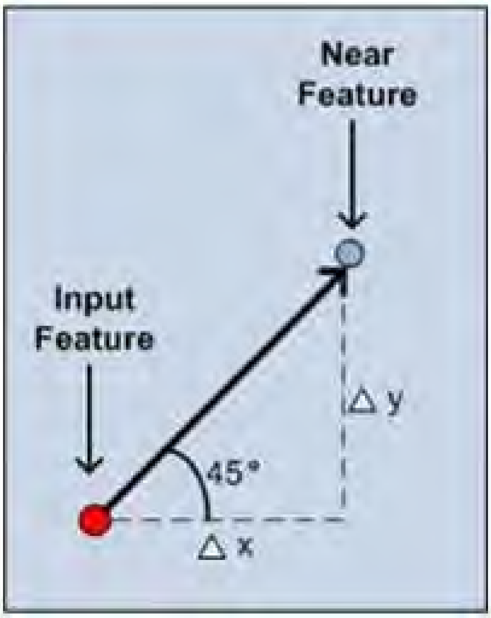

Figure 9.5 Near Diagram (ESRI, 2009)

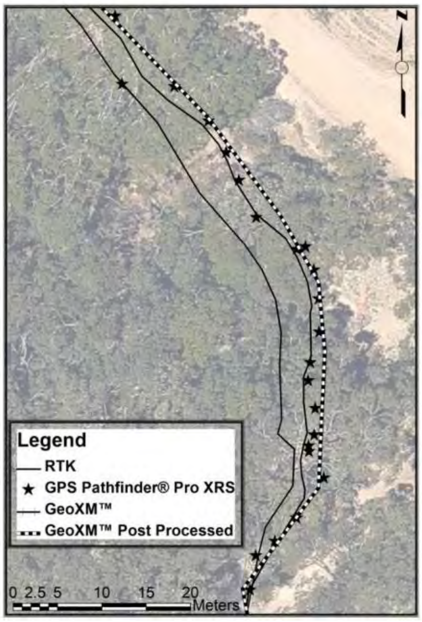

Figure 9.6 DGPS results selection for a section of the Double Black trail overlaid on an orthophotograph of the area

The calculated data was then exported into Minitab, collated into groupings, descriptive statistics were generated and frequency histograms created.

Results

Figure 9.6 illustrates a sample from the observations made though particularly dense vegetation i.e. the most extreme conditions within EMBP for the DGPS to operate within. The map indicates that the GPS Pathfinder® Pro XRS GPS obtained the nearest position to the bench mark Karas (2008) survey, with the GeoXM™ post processed next, and latterly the uncorrected GeoXM™.

The ESRI ArcGIS Near functionality created a new column in the trail GIS database and assigned values for each point (Figure 9.7). The calculated data was then exported into Minitab, collated into groupings, descriptive statistics were generated and frequency histograms created (Figure 9.8). The overall results based on the survey of all trails are shown in Table 9.2.

Attributes of OSR_Point_Blue

FID	Shape *	NAME	CLASS	LENGTH	length1	ORIG_FID	NEAR_FID	NEAR_DIST
0	Point	Overlocker	Blue	734	84.35	0	0	2.667665
1	Point	Overlocker	Blue	734	84.35	1	0	0.834277
2	Point	Overlocker	Blue	734	84.35	2	0	0.986736
3	Point	Overlocker	Blue	734	84.35	3	0	0.751897
4	Point	Overlocker	Blue	734	84.35	4	0	0.198769
5	Point	Overlocker	Blue	734	84.35	5	0	0.14092
6	Point	Overlocker	Blue	734	84.35	6	0	0.348096
7	Point	Overlocker	Blue	734	84.35	7	0	0.356459
8	Point	Overlocker	Blue	734	84.35	8	0	0.068191
9	Point	Overlocker	Blue	734	84.35	9	0	0.156465
10	Point	Overlocker	Blue	734	84.35	10	0	0.37911
11	Point	Overlocker	Blue	734	84.35	11	0	0.260376
12	Point	Overlocker	Blue	734	84.35	12	0	0.473052
13	Point	Overlocker	Blue	734	84.35	13	0	0.177647
14	Point	Overlocker	Blue	734	84.35	14	0	0.198119
15	Point	Overlocker	Blue	734	84.35	15	0	0.264596
16	Point	Overlocker	Blue	734	84.35	16	0	0.35402
17	Point	Overlocker	Blue	734	84.35	17	0	0.170776
18	Point	Overlocker	Blue	734	84.35	18	0	0.073053
19	Point	Overlocker	Blue	734	84.35	19	0	0.139723
20	Point	Overlocker	Blue	734	84.35	20	0	0.068955

Record: 0 Show: All Selected Records (0 out of 453 Selected) Options

Figure 9.7 Sample result of undertaking the 'Near' functionality

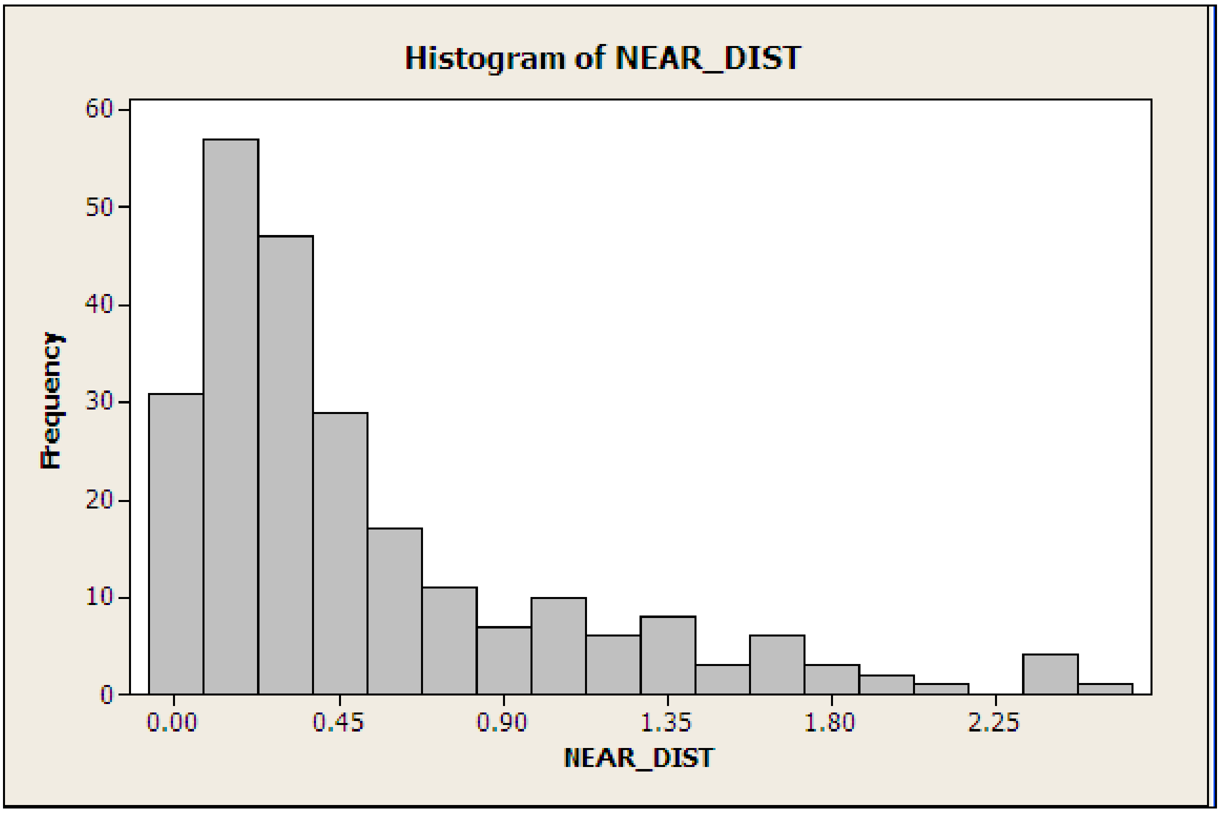

Figure 9.8 Frequency Distribution Histogram for the Double Black Trail surveyed by GPS Pathfinder® Pro XRS GPS

Table 9.2 Results and comparison of case study mapping techniques

DGPS	Accuracy		Equipment Cost (approx)		Time (average)	Restrictions
	Expected	Median	Hire	Purchase		
Trimble GPS Pathfinder ProXRS/ Nomad	Sub metre	0.38 m	$500 per week (including Omnistar access fee)	$15,000	0.5 min per point 70 mins per trail	Minimal interference from tree Canopy
GeoXM	5 metres	2.28 m	$200 per week	$5,000–6,000	0.75 min per point 80 mins per trail	Internal low quality antennae leads to increase in time to access satellites
GeoXM (post processed)	1–3 m	1.07 m	$200 per week $40 post processing fee	$5,000–6,000	0.75 min per point 80 mins per trail	Internal low quality antennae leads to increase in time to access satellites especially though obscures sky e.g. tree canopy

Discussion

Accuracy

The most accurate of the investigated mapping options was the backpack Trimble GPS Pathfinder® Pro XRS GPS/ Trimble Nomad G series handheld data logger with Omnistar correction service which attained an accuracy well within the stated accuracy identified in Table 9.1 of ±1.0 m. The GeoXM™ had two echelons of accuracy, the higher one being achieved through the employment of the post processing of collected data but just outside the stated accuracy in Table 9.1. The tracks surveyed at EMBP tended to be <1.0 m in width and obstacles were of a similar magnitude. Therefore, it can be inferred that a suitable mapping option needs to be at least as accurate as these dimensions and, as is the norm with survey, exceed these requirements. Therefore, according to the results displayed in Table 9.2, the only viable option available was the Trimble GPS Pathfinder® Pro XRS GPS.

Equipment Cost

However, the Trimble GPS Pathfinder® Pro XRS GPS option did incur greater costs due to the Omnistar subscription and the purchase price. The GeoXM™ options on the other hand, both were cheaper to buy/ hire and also had the option to increase the accuracy of the observed results through post processing. The short duration nature of the work, where a whole park could be mapped in a short intense period, and a long interval time with no need to alter the map, makes post processing in batches much cheaper then maintaining a subscription to a correction service such as Omnistar. Therefore, it can be deduced that the most cost effective and accurate solution would be to combine the Trimble GPS Pathfinder® Pro XRS GPS with post processing of surveyed data.

Personnel

The DGPS, regardless of which type, proved to be a straightforward technology to use for data capture and one that could be relatively easily learnt as a novice from a zero knowledge starting point. The TerraSync™ GIS software proved to be user friendly in terms of startup time and navigation through the differing menu options and, as experience rapidly increases, other options to spur on the rate of capture could be explored such as the use of data dictionaries that alleviate the need to manually key in data. The ESRI ArcPad software was more intricate and less intuitive and needed more of a working knowledge of GIS to be efficiently utilised. It also tended to be a little more unstable than the TerraSync™ GIS software, requiring several reboots. The Trimble GPS Pathfinder® Pro XRS GPS was slightly quicker to observe points of detail along the route.

Restrictions

There were no real restrictions evident with the GPS Pathfinder® Pro XRS GPS apart from a slight increase in waiting time to connect to satellites under the tree canopies. There is a facility within the GPS Pathfinder® Pro XRS GPS to alter the settings to try and determine a reading, but this tends to decrease the accuracy as the receiver's parameters are widened to accept weaker satellite signals. The GeoXM™ suffered more with the loss of satellite connectivity due to its antennae which was low in quality and also located within the GeoXM™ itself. Additionally, the hand held method of capturing data inherently blocks access to satellites due to be in close proximity to the surveyor's body (conversely, note the position of the Trimble GPS Pathfinder® Pro XRS GPS in Figure 9.3 above the surveyor's head).

Conclusion and further directions

Currently, for the purposes of managing assets within EMBP, the mapping of trails and associated features is insufficient. The research presented in this paper identified a number of mapping technologies and investigated each with a view to using on mountain bike trails. From these options, three types of GPS were selected for further examination at a case study site south east of Adelaide known as EMBP. The technologies were compared in terms of accuracy, cost, time and restrictions. From the fieldwork it was found that the DGPS system Trimble GPS Pathfinder® Pro XRS GPS, combined with a Trimble Nomad G series handheld data logger and subsequent post processing of the survey data provided the most cost effective solution to meet the needs of mapping mountain bike trails and associated features.

The mapping options at EMBP were restricted to the use of DGPS due to the terrain and the extent of tree canopy coverage but with more time and resources 3 more avenues of research could be pursued. First, applying the MMS/ MLS to a bike would enable both the trail and obstacles to be mapped but also produce a video that could be made accessible to potential riders, possibly through a mountain bike club website. Secondly, the LiDAR alternative could also be explored, especially as the Airborne Research Australia (ARA) facility is based within Adelaide and potentially provides LiDAR for research purposes. Thirdly, new GPS trajectories, as GPS would still seem to be the solution for mountain bike trails based on accessibility, training requirements and cost. As mentioned previously, GPS is but only one of a number of GNSS. As Dempster and Rizos (2009) noted, others include the Russian 'Global'naya Navigatsion-naya Sputnikovaya Sistema' (GLONASS), European Galileo, and China's Compass and within 5 years these GNSS may be all fully operational. Whilst initially the receivers for these systems may be expensive and consequently be used by high accuracy applications, based on the experience of GPS and its high accessibility to the novice users, it could be interpreted that multi constellation receivers will eventually percolate into mass use by the public the same way as GPS only have, making applications such as mapping mountain bike trails accessible.

As Li and Rizos (2009) pointed out, that to be able to establish a position reliably and cost effectively in all terrains and environments is the 'Holy Grail' for researchers and engineers and, in pursuit of this, they indicate that the School of Surveying and Spatial Information Systems (University of New South Wales) has already trialed a method that combined GPS, INS and Radio Frequency (RF) and obtained centimeter accuracy in the test site.

This research highlighted a number of mapping technologies that could be useful for the efficient recording of asset location within mountain bike parks. However, the DGPS Trimble GPS Pathfinder® Pro XRS GPS system could also have uses beyond asset management needs. The accuracy attained could aid the collection of information that could be useful to riders such as the length of the trail, height profile, the nature of the trail surface, sharp turns, drops and, as the information would be a digital format, it could easily be uploaded to websites so riders could download information, possibly onto their own GPS units. As for other mapping technologies discussed, further developments could, for example, see Mobile Mapping Systems progress from being located on vehicles to bikes and thus enable mountain bike information to progress into animated 3D format giving riders a virtual ride down a mountain bike trail. The question now remains as to whether or not mountain bike authorities deem these types of mapping technologies worthy of investment.

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The evolution and dynamics of bicycle design

Leon Arundell

Boreel Pty LTd, Downer ACT

Introduction

This paper explores how the evolution of bicycle design progressively opened up new ways to apply mechanical principles to bicycle travel. It explains a range of design developments from 1820 to the present, beginning with balance and steering. The paper draws on a wide range of references and includes a range of insights into the historical context. The paper evaluates the claim of Hards (2009) that 'the technological advances of the past two decades far exceed those of the previous 200 years.'

Balance, steering and pedals – From the hobby-horse to the tricycle

The hobby-horse

No assessment of the bicycle's technological development is complete without the contribution of Karl von Drais. About 1820, von Drais developed a device with a steerable wheel located directly in front of a second wheel. Without von Drais' steerable wheel, the modern pedal bicycle would be vastly inferior to an 1880s pedal tricycle. It would be unsteerable. The rider would have to cease pedalling every few seconds, to stabilise the bike by pushing his feet against the ground. To accommodate this, the saddle would have to be low enough for the rider's feet to touch the ground - too low for efficient pedalling.

Figure 10.1 The hobby-horse – dynamic balance

Source: Canberra Bicycle Museum

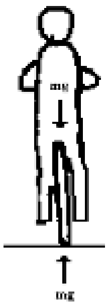

Figure 10.2 Hobby horse – balanced and upright

Source: Author's collection

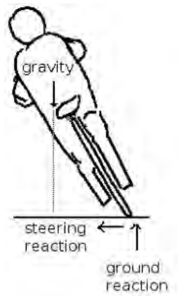

Figure 10.3 Leaning to the left

Source: Author's collection

Von Drais' hobby-horse (Figure 10.1) had a wooden frame with wood-spoked wheels and steel tyres. Its in-line wheels gave it an inherent tendency to fall over. This problem was addressed by having the seat low enough for the rider's legs to reach the ground, and thus prevent the hobby-horse from falling. Steering allowed the rider to balance the Hobby Horse while in motion, without needing to push against the ground with his or her feet.

A balanced hobby horse (Figure 10.2) has its centre of gravity directly over its wheels. The stability of a hobby-horse can be upset by a side wind, a rock on the road, or a slight movement of the handlebars that moves the wheels sideways and out from under the centre of gravity (Figure 10.3). If the hobby horse (or bicycle) leans left, the gravitational force and the reaction force of the ground are out of line. This creates a torque that causes the hobby-horse to tilt farther to the left.

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The rider can regain balance in a static fashion, by pushing against the ground with his or her left foot. The rider can also regain balance dynamically, by steering to the left. The reaction of the ground against the steering turns the hobby-horse and brings the wheels back under the centre of gravity. If the rider steers too sharply to the left, the wheels will overshoot and the hobby-horse will lean right. The rider can then correct this by steering to the right.

If on the other hand, the rider does not steer sharply enough to the left, the hobby horse will continue to fall to the left – albeit less strongly than if the rider had not steered to the left. The rider can correct this by steering more sharply. In this way, the hobby horse can progress, in a more-or-less forwards direction, without the rider's feet touching the ground.

The steerable front wheel made it possible to keep a moving hobby-horse upright, by dynamically balancing a complex range of forces. The process is essentially achieved by continually steering the hobby-horse under the centre of gravity of the combined hobby-horse and rider.

Dynamic steering

It is also possible to steer a hobby horse dynamically, using the same complex forces that allow it to be balanced dynamically. To understand how a hobby horse steers dynamically, it is important to recall Sir Isaac Newton's laws of motion. Imagine the left leaning hobby horse in Figure 10.3, in outer space, above the earth and acted on by gravity. The hobby horse accelerates towards the earth. Its centre of gravity and its centre of mass are the same point, and so there is no rotational force around its centre of gravity. As it falls, the hobby horse continues to lean at the same angle, neither leaning towards the left nor becoming more upright.

A balanced hobby horse standing on the ground has no vertical acceleration because its downward gravitational force mg (mass times gravity) is balanced by an equal but opposite upward force, exerted on the wheels by the ground (Figure 10.2). If the hobby horse is perfectly upright, the upward and downward forces act in the same line, resulting in no net turning force.

If the hobby horse leans and steers to the left (Figure 10.3), the gravitational force and the reaction force from the ground are no longer in line with each other. The vertical reaction force exerted by the ground, and the opposing vertical force of gravity, create a net torque that causes the bicycle to rotate anticlockwise.

The net torque can be counteracted by putting the hobby horse into a left turn. In a left turn the tyres exert a rightwards force on the ground, and the ground reacts with an equal leftwards reaction force on the tyres. So the hobby-horse accelerates leftwards. The leftwards reaction force exerts a clockwise torque about the bicycle’s centre of mass. This counteracts the anticlockwise torque of the gravitational reaction force, resulting in a stable turn. The rider can restore straight-ahead balance by steering farther to the left, so that the wheels return to directly beneath the centre of gravity.

In summary, an initial steering action in the “wrong” direction causes an instability that, in turn, permits the rider to perform the desired turn without falling over. Over-steering allows the rider to end the turn and return to an upright and straight-ahead trajectory.

Macmillan and boneshaker – Pedal propulsion

Steering paved the way for the next great advance in cycling – pedal propulsion – because it freed the rider's feet from the task of holding the hobby-horse upright.

Figure 10.4 Macmillan

Source: Canberra Bicycle Museum

Figure 10.5 Boneshaker

Source: Canberra Bicycle Museum

A Scottish blacksmith named Macmillan is believed to have fitted pedal lever drive to a hobby horse in 1839 (Figure 10.4). In the 1860s, the boneshaker (Figure 10.5) – essentially a hobby-horse with cranks and pedals on the front wheel – popularised pedal drive. The seats of some boneshakers were mounted on a flat spring-shaped steel frame that probably provided more comfort than the term "boneshaker" suggests.

The gearing of a Macmillan or boneshaker depended entirely on the size of the front wheel. One turn of the pedals meant one rotation of the front wheel. 'The Barb,' a boneshaker with a 33 inch diameter front wheel, won a two mile race in 11 minutes 29.5 seconds (*The Argus* 22 June and 12 July 1869), at an average speed of 17 km/h.

The advent of pedal propulsion meant that the speed of the bicycle was no longer directly tied to the speed at which the rider could move his or her feet. This set the scene for a pursuit of speed that continues to the present day.

Tricycle – Practical transport

The next major development in cycling was the tricycle (Figure 10.6). It was heavier, more complex and more expensive than a boneshaker, but it was stable, could carry luggage, and could be safely ridden by women in skirts.

The first person to cycle all the way from Sydney to Melbourne, in 1884, rode a tricycle. He then tricycled back to Sydney, averaging 85 km per day (Pearson 1896:10). George Broadbent, an 'elderly' grandfather, traveled over 28,000 km on his tricycle between 1883 and 1885. In 1885, '…a Miss Bouchier and two other young ladies, of Ballarat, rode their tricycles to Melbourne, nearly [160 km] in a single day' (Kron 1887: 562, 564–565). For many people the tricycle was the original 'horseless carriage'. It permitted a freedom of travel that was previously unavailable.

Figure 10.6 Tricycle

Source: Canberra Bicycle Museum

Figure 10.7 Pennyfarthing

Source: Canberra Bicycle Museum

Faster gears – from the penny farthing to multiple gears

Pennyfarthing

In the search for greater speed, the driving wheel of the boneshaker grew into the large driving wheel of the 'ordinary' bicycle, which we now know as a pennyfarthing (Figure 10.7). Rear wheels – needed only for fore-and-aft stability – became smaller.

A 1,600 mm diameter front wheel would permit a top speed approaching 40 km/h. At this wheel size, not everyone had legs long enough to reach from the saddle to the pedals. So a person's leg length became the factor that limited how fast they could cycle. The limitations of the penny-farthing also included safety – it was a long way to fall, from a saddle almost 1.5 metres above the ground – and braking ability – the high and forward riding position meant that anything more than gentle braking could send the rider over the handlebars.

On 20 May 1883 George W Burston rode a pennyfarthing 161 km from Ballarat via Geelong to Melbourne, at an average speed of 16 km/h (Kron 1887: 559).

Kangaroo – freeing the pedals from the front axle

By the mid 1880s (Hepher 2003), the kangaroo (Figure 10.8) used either a hub or chain gear to achieve a similar overall gearing to a penny-farthing, but with a smaller, safer front wheel. The hub gear version used pedals connected to a large cog, driving a smaller cog on the front axle. The chain drive version used pedals connected to a large chain ring, which drove a smaller sprocket connected to the front axle.

Chain drive allowed high gearing to be obtained without a very large drive wheel. The speed of a bicycle was no longer limited by the length of the rider's legs.

The chain driven kangaroo was more technologically sophisticated than an 'ordinary' which has only eight bearings (two in each wheel, two in each pedal, two for the steering and two for the brake). Because the Kangaroo's pedals were located away from the wheel hub, an axle connecting directly between the pedals would block the spokes and prevent the wheel from turning. So the pedals had to be on separate mounts, driving separate chains. Each of the two chains had more bearings than could be found in an entire 'ordinary.'

The chain-driven kangaroo not only broke the nexus between pedal speed and wheel speed. It also broke the need to locate the pedals at the front axle. Pedals could now be mounted in a range of locations, provided that they could be connected to an axle by a chain.

Figure 10.8 Kangaroo

Source: Author's collection

Figure 10.9 Safety bicycle

Source: Canberra Bicycle Museum

The Rover Safety was a breakthrough design because it successfully combined several existing innovations. Like the hobby-horse, it had two mid-sized wheels. It used the kangaroo's chain drive, but driving the rear wheel and outside its radius. Locating the pedals so far from the wheel axle required a frame extension forwards from the rear axle to the pedal axle. It also introduced torques beyond those for which the boneshaker and kangaroo frames were designed. The solution was to also extend the frame down from the saddle to the pedal axle, and upward and forward from the pedal axle to the bottom of the steering head. This formed the "diamond" frame that still dominates 21st century bicycle design.

The safety bicycle was lighter and cheaper to make than the 'ordinary'. Both of its mid-sized wheels could be made stronger and/or lighter than the large wheel of an 'ordinary'. It could have taller gearing, which could be changed to suit the rider's preference. With its lower centre of gravity, located midway between its front and back wheels, it could be ridden up and down hills, or braked hard, without tipping off the rider. Its lower saddle made it easier to mount and dismount, meant that a falling rider had less distance to fall before hitting the ground, and meant that a stopped rider could remain on the saddle and use his legs for support.

One of the interesting developments of the safety bicycle is that its straight front forks soon evolved a curve that placed the axle well forward of the steering line (see Figure 10.9). When such a bicycle is tilted to the left of right, the force of gravity acts at the wheel's centre of gravity – the axle. Because the centre of gravity is forward of the steering line, the wheel falls downwards and leftwards, towards the direction of the tilt. A cyclist walking beside such a bicycle, holding it only by the saddle, can steer it by tilting it left to turn left, or right to turn right. This is the basis of hands-free steering.

Hands-free steering becomes counter-intuitive when riding the bike rather than walking on the ground beside it. The reason for this is that, when riding the bike, the rider can't push against the ground to make the bicycle tilt. Without using the handlebars, the only way to make the bicycle lean to the right is to lean the body to the left. Newton's laws of action and reaction mean when the rider leans to the left, the bike leans to the right. This causes the front wheel (and hence the bicycle) to steer to the right. Meanwhile the rider, with no external force acting on them, continues forward. The rider and the bicycle are on divergent paths, and the bicycle moves to the right of the rider's centre of gravity. If at this point the rider tilts their body back to the right, this can cause the bicycle to lean left, so that the front wheel turns to the left. In this way a skilled rider can achieve a continuing meta-stable left-hand turn, as was shown in Figure 10.3. To end the turn, the rider tilts their body farther to the right, so that the bicycle steers farther to the left, becomes unstable and tips upward to the right. If the rider straightens up at just the right moment, the bicycle returns to an upright and straight-ahead course. As with steering the hobby-horse, an initial turn towards the right has resulted in a turn to the left. The difference with hands-free steering is that an the initial turn to the right is caused by the rider shifting his balance towards the left.

Gearing

Nineteenth century bicycles generally offered only a single gear ratio, even though two speed gears arrived in New Zealand by 1873 (Tricyclist 1883) and may have arrived in Australia at the same time. Gears became more common with the development of the three speed hub gear at the start of the 20th century. A low gear made it possible to pedal up hills that would otherwise require the rider to dismount and walk; a high gear enabled the rider to maintain higher speeds on flat terrain or downhill, without the cadence limitations of a single gear.

Kyle and Berto (2001) found hub gears to be generally 2% less mechanically efficient than derailleur gears. Primitive derailleur gears appeared in racing in the 1930s. In the 1950s the derailleur evolved into its modern form, with tension wheels integrated into the gear-change unit. In the 1980s Shimano developed a successful “index” derailleur system, that offered simple and precise gear shifting (Berto 2009).

A modern wide-range close-ratio multi-gear system, with up to 33 gear combinations, makes it possible to maintain an almost constant cadence and pedalling effort in a wide range of circumstances. The author’s experience indicates that two-speed gears reduce travel times by five percent, compared with a single gear, and that eighteen speed gears reduce travel times by a further ten percent.

The pursuit of speed

Following the introduction of chain and cog gearing, the principal factors that limited a bicycle's speed over a given distance became wind resistance, rolling resistance, weight and reliability. Another factor is wheel size.

Figure 10.10 Racing bicycle

Source: Canberra Bicycle Museum

Figure 10.11 Recumbent bicycle

Source: Canberra Bicycle Museum

Wind resistance

Wind resistance becomes increasingly significant as speed increases. Racing cyclists travel in pelotons because this reduces wind resistance for all riders except the leader. Racing bicycles (e.g. Figure 10.10) use aerodynamic frames to minimise wind resistance, and can sustain speeds up to 71 km/h (Matthews 1995: 114).

Another way to reduce wind resistance is to reduce the swept area of the spokes. The wind resistance of a spoke is proportional to the cube of its speed through the air. At the top of its stroke a spoke travels almost twice as fast as the bicycle frame, and has close to four times the wind resistance that it would have if it was simply fixed to the frame. The swept area of a bicycle's spokes can be reduced by eliminating them (Figure 10.10) or by using smaller diameter wheels that permit the use of shorter spokes (Figure 10.11). A bike with seventeen inch wheels requires 6% less power at 24 km/h than a conventional racing bike with 27 inch wheels (Hadland 1981: 121).

Speed can be increased by placing an aerodynamic fairing in front of and/or around the rider. This increases the potential speed of an upright bicycle to 83 km/h and of a recumbent bicycle to 133 km/h (Figure 10.12).

Figure 10.12 Recumbent bicycle with fairing

Source: Ian Sims Greenspeed

Figure 10.13 Tyre under low pressure, showing flattened bottom tread section

Source: Author’s collection

Placing the rider in a recumbent position (e.g. Figure 10.12) could in itself be expected to reduce frontal area, and hence increase speed. This does not appear to be the case for un-faired recumbents. The speed record for an un-faired recumbent bicycle is only 67 km/h (Recumbent and Human Powered Vehicle Information Centre 2009), which is 4 km/h slower than an upright racing bicycle.

Rolling resistance

Rolling resistance can be minimised by using well maintained good quality transmission bearings (pedals, bottom bracket, chain and wheel). Early bicycles used solid steel or rubber tyres which were puncture-free and had low rolling resistance. 1890s cushion tyres offered a softer ride, but at the expense of greater rolling resistance. In 1893, Percy Armstrong rode a bike with cushion tyres 3,200 km from Croydon in Queensland to Sydney in six weeks, at an average of 76 km per day. Armstrong then switched to a new bicycle with Dunlop pneumatic tires, and set a Sydney to Melbourne record of four days 4.75 hours, averaging 222 km per day (Driver and Arundell, 2007).

Tyre rolling resistance is primarily a product of hysteresis, a process in which energy is absorbed and returned, but with some of the energy converted to heat in the process. It depends on the stiffness of the tyre tread, and the size of the contact patch where the tread meets the ground.

The contact patches of a pair of bicycle tyres (i.e. the parts that touch the ground, Figure 10.1) transmit an upwards force equal to the combined weight of the rider and the bicycle. On a bike with a laden weight of 90 kg, with tyres inflated to 7 bars, the size of the contact patch on each tyre is about six square centimetres.

As a tyre rotates, a progressing area of the tyre flattens to become the contact patch, and then resumes its normal rounded shape. As it flattens, some of the kinetic energy of the bicycle deforms the tyre casing and is partially converted to heat. As the tyre resumes its rounded shape, not all of the original kinetic energy is recovered. The rolling resistance of pneumatic tyres decreases as inflation pressure increases, because at higher inflation pressures the contact patch is smaller and there is less tyre deformation.

Weight

Weight increases rolling resistance and increases gravitational force. Increased gravitational force means faster descents and slower ascents. Weight also reduces acceleration and increases braking distance.

Weight can be minimised by making the bicycle from lighter materials, and by using less of them. It can also be reduced by using smaller wheels. Smaller wheels use less material for the rim and for each spoke. They require fewer spokes. Shorter spokes are less likely to flex. Wheel forks and frame stays are shorter and lighter, and less likely to flex.

In cycling, there is a rule of thumb that a gram of rotating mass is equivalent to two grams of non-rotating mass. This is because energy is proportional to the square of speed. The bottom section of a rolling wheel is stationary, and has no kinetic energy. Each gram of mass at the top of a wheel is travelling at twice the speed of the bicycle, and thus has four times the kinetic energy of a gram of non-rotating mass. So a rotating wheel has more kinetic energy than an equal non-rotating mass. It takes more energy to accelerate a large wheel to a given speed.

The author's conventional alloy front wheel with a 622 mm diameter rim weighs 1,440 grams complete with hub, spokes, 23 mm tyre and tube. His comparable wheel with a 369 mm diameter rim and 32 mm tyre weighs 950 grams.

The effort required to steer a bicycle wheel is proportional to its angular momentum, which in turn is proportional to its rotating mass. The greater angular momentum of a larger wheel means that the bike responds more slowly to steering input. This allows the rider more time to react, but requires greater steering effort, especially as speed increases.

Hadland (1981: 121) reports that adding an 11.4 kg (12%) weight to a 13 kg bicycle and an 82 kg rider increases a bicycle’s power requirement by six percent on flat ground and ten percent on a one in eight grade, and that 349 mm diameter wheel rims provide a ten percent advantage in acceleration compared with 630 mm diameter rims.

The ability of a wheel to survive an impact without buckling is largely determined by the spacing of spokes around the rim. A 349 mm diameter rim with 36 spokes has its spokes spaced at 30 mm intervals, while a 622 mm rim has its spokes spaced at 50 mm.

In 60,000 km of commuting on wheels with 349 diameter rims, the author ‘trued’ (that is, removed buckles) his wheels three times and did not experience a broken spoke. With larger wheels, he has experienced a more frequent need for wheel truing and replacement of broken spokes.

For a given hub width, the spokes of a larger wheel are more closely parallel than those of a smaller wheel (Figure 10.14). This gives the smaller wheel greater rigidity.

The spokes of a smaller wheel have a shorter lever arm from the hub to the rim, and can produce the same driving force with less torque at the wheel hub. This places less strain on the hub and spokes, contributing to longer transmission life. The hub gears in the author's sixteen inch rear wheel required no internal servicing during 60,000 km of commuting.

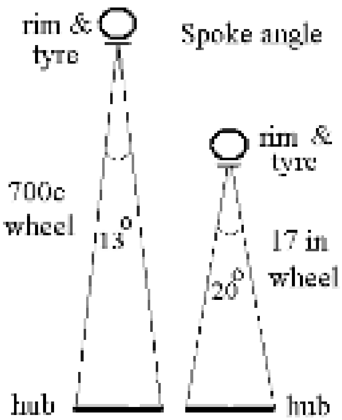

Figure 10.14 Spoke angle

Source: Author's collection

Figure 10.15 'Double Gees' embedded in Dunlop Tyres

Source: Fitzpatrick 1980 p139

Reliability 1 – Rim Protection

The improved rim and wheel protection that pneumatic tyres provide allows lighter wheels to be used without loss of reliability. The rim of a wheel with a solid steel or rubber tyre must be strong enough at each point to absorb the full impact of a bump. Cushion tyres provided better rim protection by spreading bump impacts over a larger section of rim. An air-filled pneumatic tyre normally has no direct contact between the wheel rim and the tread of its tyre. When the tyre tread hits a bump, the impact is distributed around the entire rim by air pressure. A rim used with a pneumatic tyre does not need to be strong enough to survive a point impact. So it can be made lighter than a wheel designed for use with cushion tyres and much lighter than a wheel designed for use with a solid tyre.

Reliability 2 – Punctures

Despite their other advantages, pneumatic tyres are subject to punctures. Wheels designed for use with pneumatic tyres can suffer permanent damage if they are ridden with flat tyres. Tyres that are more puncture-resistant tend to have heavier treads, and therefore more rolling resistance. Frank White (1898) reported one puncture per 7,500 km on a ride from Fremantle (WA) to Rockhampton (Qld) and return. In 1910 round-Australia cyclist Francis Birtles averaged one puncture per 3,200 km (Figure 10.15) (Fitzpatrick 1980: 139).

Modern bicycle tyres exhibit a very large range of puncture resistance. On a 1,500 km trip along the Murray River in 2008, six bicycles with standard tyres averaged 400 km between punctures, while seventeen bicycles with puncture-resistant tyres averaged 6,300 km per puncture (Tozer 2008).

Bicycle design and wheel size

Overview

Wheel size is strongly linked to bicycle design. The evolution of the boneshaker into the ‘ordinary’ was marked by a dramatic increase in the size of the driving wheel, and a reduction in the size of the following wheel. These changes were both reversed, equally dramatically, when the ‘ordinary’ evolved into the safety bicycle.

Two subsequent developments in bicycle design have been associated with relatively small wheels. The first was the development of the small-wheeled full suspension Moulton bicycle in 1962, and the second was the development of the BMX bicycle in the 1970s.

Small vs large wheels

This paper has identified that smaller wheels are lighter and offer less wind resistance than larger wheels. On the negative side, they offer shorter tyre life because they rotate more times for a given distance travelled. There are also differences in ride quality and performance on different surfaces.

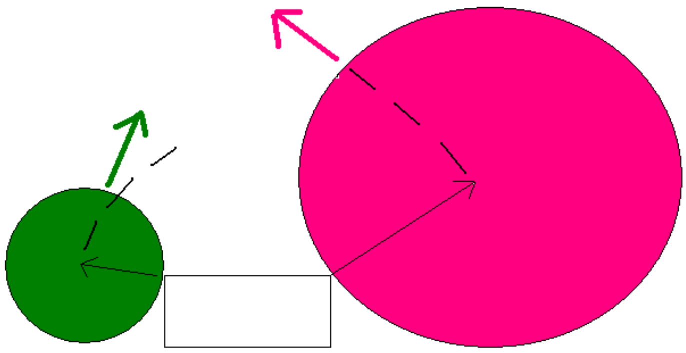

Figure 10.16 Small and large wheels hit an obstacle

Source: Author’s collection

Figure 10.17 Momentum transfer under braking

Source: Author’s collection

A large wheel a hits a given obstacle earlier, and rolls over it with a shallower angle of rise. Figure 10.16 shows a small and large wheel encountering the same obstacle. As it begins to roll over the obstacle, the hub of the small wheel in Figure 10.16 travels almost vertically, while the hub of the larger wheel travels at around 45 degrees from horizontal. Smaller wheels penetrate deeper into soft ground (Hadland 1981). This explains the author’s experience that large wheels experience less resistance when travelling on soft surfaces such as grass and sand.

Because they occupy less space, small wheels allow more design possibilities. Compared with a bike with 700 mm diameter wheels, a bike with sixteen inch wheels has more potential luggage space available between its wheels. It can mount its luggage racks up to 260 mm lower, for greater stability. A bike with 700 mm diameter wheels can carry luggage mounted low on either side of its front wheels, but this luggage adds to the weight that turns when steeering. A small-wheeled bike can carry front luggage low on a frame-mounted rack above the front wheel, without affecting its steering.

For a given wheelbase, a bicycle with sixteen inch wheels is eleven inches shorter overall than a bicycle with twenty-seven inch wheels. In team pursuit races, smaller wheels allow riders to form a more closely-packed peloton to minimise wind resistance. Bikes with sixteen inch wheels are not permitted in normal bicycle racing. Demonstration team pursuit races were held in 1963 and 1965, between bicycles with sixteen inch wheels and conventional racing bicycles with larger wheels. Both races were won by the bicycles with sixteen inch wheels (Hadland 1981).

Extreme braking can flip a bike rider over the handlebars. This effect is exacerbated by angular momentum transfer from the braking wheels. The angular momentum of a wheel is proportional to both its speed and its rotating mass. So a larger wheel is more likely to flip its rider over the handlebars (Figure 10.17).

Suspension

Suspension aids comfort, reduces fatigue, and assists control by keeping the wheels in contact with the ground. Some people appear to believe that suspension reduces bicycle performance. However, if the impact of a bump is not absorbed by the bicycle, it can be absorbed by the rider's spine and internal organs. Some suspension systems absorb less than 1% of the bicycle's energy (Hadland, 1981). Full suspension bikes have set the speed record for fastest upright bicycle, held the Cardiff-London record, and won time trials, a criterium, triathlons and HPV races (Moulton Bicycle Company 2009).

'The Barb', a race-winning Australian velocipede, featured a seat that was 'made to rest on a steel spring' (*Argus* 1869).

Since the invention of the Rover Safety Bicycle in the 1880s, suspension has mainly been offered in the form of springs directly supporting the saddle.

In the 1890s Pedersen, a Danish engineer living in Dursley in England, designed a suspended saddle and a bicycle (Figure 10.18) to carry the saddle. The three-dimensional space frame was made of small-diameter thin-walled metal tubing. Being fully triangulated, it was stiff in all three dimensions.

Figure 10.18 Dursley-Pederson

Source: Canberra Bicycle Museum

Figure 10.19 Moulton

Source: Author's collection

The 20th century

The Moulton

In 1962 Alex Moulton launched a bicycle (Figure 10.19*)* with rubber suspension that softened the potentially harsh ride of its small (and therefore stiff) wheels. In the late 1970s he redesigned his bicycle, using a frame similar to that of the Dursley Pedersen.

Bicycle suspension became mainstream in 1990s, mountain bikes. "Seat post" suspension also became common on "hybrid' or "city" bikes.

BMX and its descendants

The 1970s “bicycle moto-cross” or “BMX” bicycle (Figure 10.20) revolutionised 20th century cycling. Unlike previous bicycles, the BMX was designed for fun rather than for transport. Its speed was limited by its single gear and knobbly tyres, but those tyres enabled it to negotiate the dirt mounds and corners of a BMX circuit.

Figure 10.20 BMX

Source: Canberra Bicycle Museum

When BMX riders outgrew their BMX bikes, they graduated to mountain bikes – larger versions of the BMX. These have a wide range gears, to allow them to ascend steep hills and also travel at reasonable speeds on flat ground.

1990 to the present

Hards (2009) claimed that, “the technological advances of the past two decades far exceed those of the previous 200 years.” She identified these advances as an expanded range of bicycle styles, featuring aluminium and carbon fibre frames, and improvements in suspension and braking. Lighting improvements included improved batteries, HID headlights, and LED tail-lights and headlights. She compared 1990 and 2009 road bikes, noting improvements such as replacement of downtube-mounted shift levers with integrated brake/gear levers, an increase from manual eight speed rear gears to electronically controlled eleven speed gears and a 1.9 kg decrease in weight.

Conclusion

The technological advances listed by Hards (2009) were incremental advances, that had less impact on the nature of cycling than the BMX bicycle. Even so, the BMX is dwarfed in significance by the cycling advances of the 19th century, which included steering, pedal propulsion, chain drive, pneumatic tyres and multiple gears.

Without the benefit of these advances, the modern bicycle would offer excellent lights and a wide range of lightweight, rigid, un-steerable aluminium or carbon fibre frame styles, propelled by pushing the rider's feet against the ground.

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North Terrace, Adelaide

Day One: Monday 18 January, 2010

08:30 – 09:00	Registration, Foyer, Architecture Building *Pre-conference refreshments sponsored by Sustainable Transport Consultants, NSW*
09:00 – 09:05	Welcome and preliminaries: Main Conference Room, Flentje Lecture Theatre, Architecture Building Stu Clement, Convenor, ACC 2010
09:05 – 09:25	**Official Opening** Honourable Patrick Conlon, Minister for Transport, Minister for Infrastructure, Minister for Energy, Member for Elder, Legislative Assembly South Australia
09:25 – 10:35	Session 1: Chair – Jennifer Bonham
Guest Speaker	**Future cycling in Australia: from TODs to BOSs** *Ineke Spapé* (SOAB Consultants and Breda University, The Netherlands) Ineke's visit sponsored by the University of Adelaide
	Concepts for a cycle network upgrade for Adelaide *Stephen Russell* (Defence and Systems Institute, University of South Australia)
10:35 – 11:00	Morning refreshments, Foyer, Architecture Building
11:00 – 12:15	Session 2: Chair – Leon Arundell
	Cycling, tourism and online technology *Dennis Puniard* (University of Canberra, Australian Capital Territory)
	Limitations on the use of the term "cyclist" to describe people who ride bicycles *Russell Greig* (Bikewest, Department of Transport, Western Australia)
	Reporting of cycling in the Australian newspaper media Chris Rissel (University of Sydney, New South Wales), *Adrian Emilsen* (MacQuarie University, New South Wales), Ben Smith (Monash University, Victoria) and Catriona Bonfiglioli (University of Technology, Sydney, New South Wales)

12:15 – 12:25	*Address by the sponsor of lunch:* *City of Charles Sturt*
12:25 – 13:15	Lunch, Foyer, Architecture Building
13:15 – 15:15	Session 3: Chair – Graham Bradshaw
	Changes in cycling for everyday purposes in the past decade – epidemiological application of the Household Travel Survey Data, NSW *Grace Corpuz* (Transport Data Centre, New South Wales), Dafna Merom, Hidde Van der-Ploeg and Adrian Bauman (University of Sydney, New South Wales)
	Cycling to school – practical and legal considerations *Leon Arundell* (Canberra, Australian Capital Territory)
	Roundabouts and cycling: an Australian perspective *Fay Patterson* (Hub Traffic and Transport, South Australia) Signing cycle networks – showing the way to more cycle trips *Warren Salomon* (Sustainable Transport Consultants, NSW)
15:15 – 15:25	Pre-roundtable instructions – Peter Lumb, Moderator
15:25 – 15:45	*Afternoon refreshments sponsored by:* *infraPlan (Aust) Pty Ltd*
	Foyer, Architecture Building Move to tutorial rooms in Napier Building
15:45 – 17:15	Session 4: Conference Roundtable Moderator – Peter Lumb Tutorial Rooms, Napier Building
19:00 –	**Conference Dinner** (optional) *Spices on Rundle*

Day Two: Tuesday 19 January, 2010

08:30 – 09:00	Pre-conference refreshments, Foyer, Architecture Building *Pre-conference refreshments sponsored by Sustainable Transport Consultants, NSW*
09:00 – 10:40	Session 5: Chair – Peter Watts
Distinguished Speaker	**The role of cycling in a sustainable future** *Ian Lowe, AO* (Griffith University, Queensland)
	Ultralocal cycling *Bob Perry* (SCAPE Strategy, New South Wales)
	Sunshine Coast Regional Council's TravelSmart Program *Jo Ferris* (Sunshine Coast Regional Council, Queensland)
10:40 – 11:00	Morning refreshments, Foyer, Architecture Building

11:00 – 12:45 Session 6: Chair – Ian Lowe

Mapping mountain bike trails – Eagle Mountain Bike Park, South Australia
Adrian Billiau and Paul Corcoran (School of Natural and Built Environments, University of South Australia)

Tunnel Vision and Dynamic Tension – quantitative outcomes from monitoring and assessing mountain bike trails
Stu Clement (Stuart Clement Solutions, South Australia)

The evolution and science of the bicycle
Leon Arundell (Canberra, Australian Capital Territory)

New approach to narrow highway bridge cycle safety
Peter Kortegast (Opus Consultants, New Zealand) and Tim Selby (Opus Consultants, Western Australia)

12:45 – 12:50 *Address by the sponsor of lunch:*
Bicycle Institute of South Australia (Jeremy Miller)

12:50 – 13:40 Lunch, Foyer, Architecture Building

13:40 – 15:40 Session 7: Chair – Ineke Spapé

The application of a naturalistic driving method to investigate on-road cyclist behaviour
Marilyn Johnson, Judith Charlton and Jennie Oxley (Monash University Accident Research Centre, Victoria)

Build it so they want to come: a study of how the aesthetic and experiential aspects of bicycle paths can influence usage
Tony Stephens (Department of Transport, Western Australia)

Disciplining the deviant traveller: a Foucauldian critique of cycleways
Jennifer Bonham (University of Adelaide, South Australia) and Peter Cox (University of Chester, UK)

Ways to improve the on-road relationship between cyclists and motorists
Adam Bachmayer (Flinders University, South Australia)

15:40 – 15:55 *Afternoon refreshments sponsored by Adelaide City Council*
Foyer, Architecture Building

15:55 – 17:25 Session 8: Chair – Ian Radbone

Utilising local government to deliver State government funded cycling infrastructure using a Variable Grant Mechanism
Colin Ward (Bikewest, Department of Transport, Western Australia)

CRISP (Cycle Route Implementation and Stakeholder Plan): lessons learned from examples in the UK and Australia
Richard Jones and *Nathan Parish* (Complete Urban, Queensland and New South Wales) and *Nigel Coates* (Launceston City Council, Tasmania)

The "Tour de Work" Cycling Challenge: implementation and results from the Adelaide project
Zoe Drechsler (Adelaide City Council, South Australia), *Thomas Stokell* (Challenge for Change, UK) and Jake Bugden (Sustainable Focus, South Australia)

17:25 – 17:35 Conference close: *Stu Clement, Convenor*