USING AN INSTRUMENTED BICYCLE TO HELP UNDERSTAND CYCLISTS' PERCEPTION OF RISK

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ABSTRACT

Cycling provides a wide range of benefits compared to motor vehicles. These benefits include health benefits from physical activity, environmental benefits, reduced traffic congestion and associated economic benefits. Not surprisingly, many countries actively encourage people to use bicycles as an alternative mode of transport to the motor vehicle.

The road environment for cyclists affects their safety. For example, the absence of bicycle facilities along roads forces cyclists to travel in the roadway, often leading to a higher cyclist crash risk. In addition, bicycles have a much lower level of protection and stability by comparison with motorized vehicles and therefore cyclists are exposed to a higher level of risk on the road. Decision making (such as modal choice and route choice) and behaviour of road users in different situations are influenced by perceptions of risk.

This research forms part of a doctoral research project currently underway at the University of Auckland which will attempt to understand cyclists' perceptions of risk in relation to cycle safety, through a combination of interviews with cyclists about the perceived risk to their safety on selected routes and the use of an instrumented bicycle on the same routes. The intention is to be able to estimate perceived risk of a route based on objective measures of the surrounding infrastructure and traffic. This paper will discuss the methodology to be adopted in general, followed by a detailed description of the bicycle mounted instrumentation to be used in the research.

INTRODUCTION

Cycling provides a wide range of benefits compared to motor vehicles. These benefits include health benefits from individual physical activity, environmental benefits (less noise and air pollution), reduced traffic congestion and the economic benefits that derive from the previous benefits. For example, the World Health Organisation has found that a person can reduce his or her risk of death from all causes by 30 percent when he or she cycles to and from work instead of using a car (World Health Organization 2014). Consequently, many developed countries encourage people to use bicycles as a mode of transport for short to medium distance trips because of the above stated environmental, health, social and economic benefits that cycling brings.

This is backed up by (Nordback et al. 2014), who stated that a number of concerns such as traffic congestion, health and obesity issues, as well as environmental concerns, have promoted increased cycling internationally. London, New York and Melbourne, for example, had a significant growth in cycling resulting from political leadership paired with infrastructure improvements. Closer to home, Wallis and Lupton (2013) reported that the cost of congestion in Auckland is between $250 million per year and $1250 million per year depending upon the accepted definition of congestion. Cycling has a part to play in reducing the congestion in Auckland and by increasing bicycle usage in the city, as well as reducing the use of private vehicles, the level and cost of congestion will decrease accordingly.

Unfortunately, however, New Zealand has experienced a decline in bicycle usage among school children over the last three decades. This drop in numbers of children cycling to school has resulted in less people cycling to work as these children grow up. Since 1990 the numbers cycling to school have declined by approximately 75 percent (Cycling Safety Panel 2014). This has affected society by missing out on the other benefits that cycling brings. Although there is a lack of strong evidence, it can also be expected that children who often cycle will become safer drivers when they become an adult (Cycling Safety Panel 2014). Recently, however, there has been an increase in adult cyclists - Auckland Transport (2014) reported that automatic cycle counters in Wellington and Auckland showed that New Zealand is experiencing an increase in cycling numbers. However, in order for this positive trend to continue, people's perceptions of cycling safety needs to improve alongside reducing cycle crash rates.

Generally, safety is one of the most important factors in choosing to cycle and in selecting which route to take. However, bicycles have a much lower level of protection and stability in comparison with motorised vehicles and, therefore, cyclists are at a high level of risk on the road. The OECD (2008) states that: "the human body's tolerance to physical force is at the centre of the Safe System approach". Every year there are numerous cyclists involved in road crashes resulting in fatalities, as well as severe and minor injuries. The New Zealand Ministry of Transport (2013) reported that on average over 300 cyclists required hospitalisation each year between 2008 and 2012. On average, during the same period of time nine cyclists died each year in crashes involving motorised vehicles on New Zealand public roads (Ministry of Transport 2013). While cycling is not a dangerous activity in New Zealand *per se*, where one fatality occurs for every two million hours cycling (Cycling Safety Panel 2014), it could be safer when compared with other modes of transport and other countries.

Clearly, therefore, bicycle infrastructure is an important part of a road network requiring road authorities to plan, design, build, and maintain a street for all road users, and not just for motor vehicles. The environment for cyclists along existing roads affects cyclists' safety. This impacts on whether parents permit their children to cycle to school, whether people use bicycles for local trips (i.e. shopping), and most importantly whether people cycle for general health. During the period 1960's - 1980's, almost exclusive emphasis was placed on automobile facilities.

To increase the numbers of cyclists, they need to feel safer on roadways. This is achieved by minimising their risk of being involved in a crash. Decision making and behaviour of road users in different situations are influenced by perceptions of risk (Lam 2005). Studies have shown that high levels of perceived risk affects the potential cyclists' travel mode choice, as cycling appears more dangerous than other modes of transport (Møller and Hels 2008). In addition, Reynolds et al. (2009) highlighted the lack of studies on cyclist route choice. In other words, what type of routes are more attractive for cyclists to choose. This raises questions for transport agencies and planners such as where to put a cycle route, which route is safer and how to encourage cyclists to travel on that route. To encourage people to increase their bicycle usage, there is a need to have safe cycling provisions, have a better understanding of all factors that impact cycle safety and concentrate on measures that would encourage bicycle usage.

However, even more so than vehicular accidents, cycling crashes are rare events in statistical terms. Conflicts, however, occur on a much more regular basis and such information would be very useful in a proactive assessment of site risk. Unfortunately, these go currently undetected and are not recorded. In an effort to address this issue, this research intends to instrument a bicycle in order to collect conflict data using a naturalistic cycling study. This paper describes the methodology to be adopted in collecting conflict data, followed by a detailed description of the bicycle mounted instrumentation to be used in the research.

LITERATURE REVIEW

A number of researchers studying bicycle safety have used information from hospital or police records and statistics (Angel-Domenech et al. 2014). They provide data from actual reported crashes, a subset of the real population of crashes, however no data is recorded about the more frequent cycle conflicts or near misses that occur on a daily basis. There are many more conflicts that occur between cyclists and other road users (e.g. motor vehicles and pedestrians) that are not reported. Based on bicycle facility characteristics, other road users may occupy bicycle tracks and this might increase the potential risk of crashes. These incidents are generally not reported and therefore not recorded.

Several recent studies have adopted naturalistic cycling data to see how this method can develop crash countermeasures to increase bicycle safety. In this method an instrumented bicycle is used to observe interactions between bicycles and other road users. Dozaa et al. (2012), for example, conducted a naturalistic methodology on bicycles. Instrumented bicycles were used in this study for collecting naturalistic data in Gothenburg. They concluded that collection of naturalistic data can be executed in a similar fashion to naturalistic driving data. By considering the increasing number of cyclists and the cycling safety issues, this method of data collection on bicycles can help to improve safety.

In earlier research by Walker (2007a), a naturalistic experiment examined the proximity from overtaking vehicles passing the instrumented bicycle. This study showed that, contrary to that generally believed, overtaking vehicles pass closer to a cyclist when the cyclist wears a helmet, cycles away from the edge of the road, and if the cyclist is a male. Bus and heavy goods vehicles also pass closer to cyclists (Walker 2007b). A study by Chuag et al. (2013) investigated the vehicle, infrastructure and cyclist related factors affecting cyclists' behaviour and proximity of passing vehicles. The authors used an instrumented bicycle riding in real traffic. They concluded that the passing distance was smaller when motorcycles passed a cyclist compared to cars and small trucks. Cyclists appeared unstable when a bus (longer passing time) passed them. Road surface hazards made the cyclists reduce the passing distance that the passing car driver has chosen. Moreover, vehicles passed female cyclists with larger passing distance compared to male cyclists.

Another study by Parkin and Meyers (2010) used an instrumented bicycle to examine the proximity of vehicles overtaking cyclists on roads with and without cycle lanes. The results of this study showed that vehicles on roads without a 1.45m cycle lane chose significantly greater passing distances. This study suggested that vehicle drivers tend not to provide a comfortable passing distance to cyclists in the adjacent cycle lane.

Kay et al. (2014) studied the effects of a bicycle warning sign on driver behaviour as they overtook cyclists. The results showed that the presence of signs were effective in keeping vehicles away from the edge line of the road, however the sign treatment didn't significantly affect the proximity between vehicles and cyclists. Larger vehicles, such as buses and trucks, tended to pass closer to cyclists compared to motorcyclists passing cyclists. The treatment sign reduced vehicles speed by 4 km/h. Overall, they concluded that vehicle speeds reduced as the distance between cyclists and vehicles decreased (Kay et al. 2014).

Walker et al. (2014) studied the proximity between overtaking vehicle drivers and cyclists considering cyclists' skill and appearance. They concluded that the passing distance of vehicles was not related to the cyclist's appearance wearing different outfits. Only cyclists with high-visibility vests that had "police" and "camera cyclist" name printed affected drivers' behaviour. Among all passing drivers, a small percentage of drivers (1-2%) passed cyclists within 50cm. The authors suggested that cyclists cannot change drivers' passing behaviour by changing their appearance, instead safer infrastructure, better education and legislation helps cyclists to be passed safely by vehicles.

In research by Chapman and Noyce (2012), a naturalistic experiment was conducted to examine the driver behaviour of vehicles passing the instrumented bicycle in rural roads. The authors collected 1151 observations of interactions between drivers and cyclists. They observed only 0.5% (6 out of 1151) of drivers passed closely (in this study, less than 1.0 m was considered close). By measuring the average distances between the passing vehicles and the cyclists, they found the average to be 1.95 m for locations with a bicycle lane and 1.92 m without a bicycle lane.
A recent study by Dozza and Werneke (2014) showed how naturalistic data from 16 cyclists can be used to estimate cyclist safety risk. The results of this study revealed that cycling near an intersection and an intersection with sight distance problems increased the risk by 4 and 12 times respectively. Poor road surface condition increased the risk by 10 times.

METHODOLOGY

This section describes the methodology for the identification and classification of conflicts, and the setup of an instrumented bicycle to observe and measure conflicts between the cyclist and other road users.

Classification of conflicts

This method classifies conflict data based on the definition given by Hunter et al. (1999). They defined midblock and intersection conflicts as: "an interaction between a bicycle and a motor vehicle, pedestrian, or other bicycle such that at least one of the parties had to change speed or direction to avoid the other."

The DOCTOR (Dutch Objective Conflict Technique for Operation and Research) conflict observation method has been chosen to classify traffic conflicts. This method was developed in the Netherlands and applied in several traffic safety studies (van der Horst and Bakker 2004; van der Horst, A Richard A et al. 2014; Angel-Domenech et al. 2014). The DOCTOR method consists of conflict severity categories from 1 to 5 and, in case of a conflict, the cyclist is requested to rate the conflict from 1 to 5. For rating a conflict, the risk of a collision and its potential seriousness if a collision had actually happened are considered. A combination of factors, including various speed, the available and required space, the angle of approach and the types of road users are taken into account.

Bicycle Instrumentation Setup

The following sections describe the chosen "standard" bicycle to be used in the study, as well as the instrumentation attached to the bicycle, the purpose of said instrumentation, the data logger and power source adopted.

Bicycle: An Avanti Giro F1 hybrid bicycle has been chosen for this study. This is a general-purpose bicycle that is able to tolerate a wide range of riding conditions. It is a comfortable and easy to handle bicycle that make it popular with beginner cyclists, casual riders, commuters, and children. A comparable "standard" bicycle has also been chosen in similar studies overseas. A schematic of the instrumented bicycle is included in Figure 1. The location of the instrumentation on the bicycle is detailed in the schematic in Figure 1, and described in the following sections.

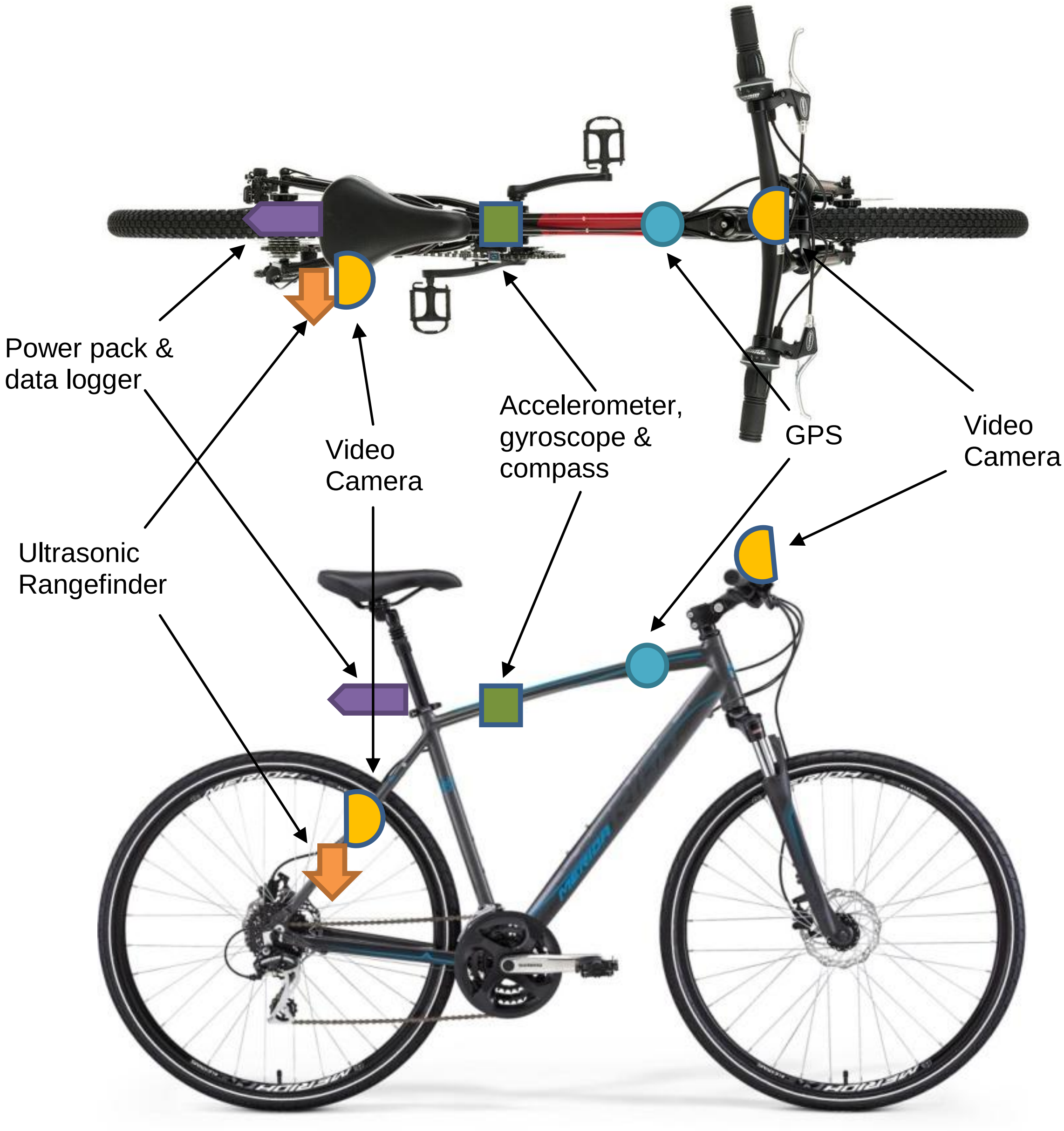

Figure 1 Schematic of Instrumented Bicycle

Video Cameras: The bicycle has two compact video cameras of the type shown in Figure 2. One of the video cameras is installed on the handlebar of the instrumented bicycle facing the direction of travel to record video information on conflicts. A second video camera is rear facing, directed towards the traffic to record passing vehicles.

Figure 2 Video Camera

GPS (Global Positioning System): A Phidget GPS tracker, shown in Figure 3, is used to continuously record location, as well as providing timestamps and speed of the instrumented bicycle. The Phidget GPS provides the longitude and latitude of the board's position in signed decimal degree format. The position accuracy is 2.5m CEP (Circular Error of Probability).

Figure 3 Global Positioning System

Accelerometer/ Compass/ Gyroscope: A PhidgetSpatial Precision 3/3/3 (High Resolution), shown in Figure 4, provides a 3-axis compass, a 3-axis gyroscope, and a 3-axis accelerometer all in one package. It has enhanced precision in the accelerometer when measuring less than ±2g, and enhanced gyroscope precision at angular speeds less than a hundred degrees per second (100°/s).

Figure 4 Combined Accelerometer, Compass and Gyroscope

Ultrasonic Rangefinder: An ultrasonic distance measuring sensor is used to examine the proximity (passing distance) between motorized vehicles and cyclists when the motorized vehicles are overtaking the cyclist. The chosen device, a Maxbotix HRUSB-MaxSonar-EZ0, shown in Figure 5, has a wide and sensitive beam pattern and is installed facing overtaking vehicles.

Figure 5 Ultrasonic Rangefinder

Single Computer Board: A small size single board computer, the Intel Compute Stick, shown in Figure 6, is used in this study as a data logger to store the data from the variety of the sensors including the GPS, ultrasonic rangefinder, gyroscope, compass and accelerometer.

Figure 6 Single Board Computer

Power Source: Two portable Lenmar Mutant power packs are used as battery sources for all of the electronic sensors, as shown in Figure 7. This power pack contains 4 USB ports. This device can be charged with its AC power adaptor.

Figure 7 Power Pack

FUTURE RESEARCH

The ongoing doctoral research programme will attempt to understand cyclists' perceptions of risk in relation to cycle safety, through a combination of interviews with cyclists about the perceived risk to their safety on selected routes and the use of the instrumented bicycle on the same routes. Participants will be asked to assign a perceived level of risk to sections of a range of cyclist commuting routes. Volunteers will be required to participate in this “Rate my Route” part of the research. The intention is to be able to estimate perceived risk of a route based on objective measures of the surrounding infrastructure and traffic. The long-term goal is to develop a cycle risk safety index (CRSI) which will provide a relative indicator for cyclist safety, thereby helping to inform cyclists of safer route choices.

CONCLUSION

The built environment for cyclists affects their safety. For example, the absence of bicycle infrastructure and provisions along roads forces cyclists to travel in the roadway - often leading to a higher cyclist crash risk. In addition, bicycles have a much lower level of protection and stability by comparison with motorised vehicles and, therefore, cyclists are exposed to a higher level of risk on the road. Decision making (such as modal choice and route choice) and behaviour of road users in different situations are influenced by perceptions of risk.

Previous research has demonstrated the value of naturalistic cycling data in understanding the behaviour of drivers in relation to cyclists for a number of scenarios. This research also intends to adopt a naturalistic cycling methodology and, to that end, an instrumented bicycle has been developed which will collect information on the location, direction of travel, gradient, acceleration in 3 axes, proximity to traffic, as well as video footage. Coupled with information of the surrounding transport infrastructure provision it is hoped to increase our understanding of cyclists' perception of risk.

REFERENCES

Angel-Domenech, Antonio, Alfredo Garcia, Fernando Agustin-Gomez, and Carlos Llorca. 2014. Traffic conflict analysis by an instrumented bicycle on cycle tracks of Valencia. Paper presented at International Cycling Safety Conference, .

Chapman, J., and Noyce, D. *Observations of driver behaviour during overtaking of bicycles on rural roads.*2012.

Chuang, K. -H, C. -C Hsu, C. -H Lai, J. -L Doong, and M. -C Jeng. 2013. The use of a quasi-naturalistic riding method to investigate bicyclists' behaviours when motorists pass. *Accident Analysis and Prevention* 56 : 32-41.

Cycling Safety Panel. 2014. *Safer journeys for People who cycle.* New Zealand: Cycling safety Panel, NZ Transport Agency.

Dozza, Marco, Julia Werneke, and Andre Fernandez. 2012. Piloting the naturalistic methodology on bicycles. Paper presented at Proceeding ot the st International Cycling Safety Conference, Helmond NL, Nov 7-8 2012.

Dozza, M., and J. Werneke. 2014. Introducing naturalistic cycling data: What factors influence bicyclists' safety in the real world? *Transportation Research Part F: Traffic Psychology and Behaviour* 24 : 83-91.

Hunter, William, J. Stewart, and Jane Stutts. 1999. Study of bicycle lanes versus wide curb lanes. *Transportation Research Record: Journal of the Transportation Research Board*(1674): 70-7.

Kay, Jonathan J., Peter T. Savolainen, Timothy J. Gates, and Tapan K. Datta. 2014. Driver behaviour during bicycle passing maneuvers in response to a share the road sign treatment. *Accident Analysis & Prevention* 70 (0) (9): 92-9.

Lam, Lawrence T. 2005. Parental risk perceptions of childhood pedestrian road safety: A cross cultural comparison. *Journal of Safety Research* 36 (2): 181-7.

Ministry of Transport. 2013. *Cyclists crash facts.* New Zealand: Ministry of Transport, .

Møller, M., and T. Hels. 2008. Cyclists' perception of risk in roundabouts. *Accident Analysis and Prevention* 40 (3): 1055-62.

Nordback, K., W. E. Marshall, and B. N. Janson. 2014. Bicyclist safety performance functions for a U.S. city. *Accident Analysis and Prevention* 65 : 114-22.

OECD. 2008. *Towards Zero: Ambitious road safety targets and the safe system approach.* OECD.

Parkin, J., and C. Meyers. 2010. The effect of cycle lanes on the proximity between motor traffic and cycle traffic. *Accident Analysis and Prevention* 42 (1): 159-65.

Reynolds, C. C., M. A. Harris, K. Teschke, P. A. Cripton, and M. Winters. 2009. The impact of transportation infrastructure on bicycling injuries and crashes: A review of the literature. *Environmental Health* 8 (47): 1-19.

van der Horst, A Richard A, Maartje de Goede, Stefanie de Hair-Buijssen, and Rob Methorst. 2014. Traffic conflicts on bicycle paths: A systematic observation of behaviour from video. *Accident Analysis & Prevention* 62 : 358-68.

van der Horst, ARA, and P. Bakker. 2004. Safety measures at railway level crossings and road user behaviour. Paper presented at 8th International level crossing symposium Sheffield, UK, 14-16 April 2004.

Walker, I. 2007a. Drivers overtaking bicyclists: Objective data on the effects of riding position, helmet use, vehicle type and apparent gender. *Accident Analysis and Prevention* 39 (2): 417-25.

Walker, I., I. Garrard, and F. Jowitt. 2014. The influence of a bicycle commuter's appearance on drivers' overtaking proximities: An on-road test of bicyclist stereotypes, high-visibility clothing and safety aids in the united kingdom. *Accident Analysis and Prevention* 64 : 69-77.

World Health Organization. 2014. *Health economic assessment tools (HEAT) for walking and for cycling.* European Union: World Health Organization.