CYCLE LANES:
THEIR EFFECT ON DRIVER PASSING DISTANCES IN URBAN AREAS

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ABSTRACT

The current literature in the field of cycle lanes has shown often contradictory evidence as to the benefits and risks of cycle lanes and previous work has specifically shown that on higher speed roads, drivers may pass closer to a cyclist when a cycle lane is present. Utilising an instrumented bicycle, we collected information as to the passing distance demonstrated by drivers when overtaking a cyclist within the urban (30mph/40mph) environment. The presented analysis shows that when a driver encounters a cyclist mid-block (i.e. not at a junction), there are more significant variables than the presence of a cycle lane that determines their overtaking distance. The three most significant variables identified are; absolute road width, the presence of nearside parking and the presence of an opposing vehicle at the time of an overtaking manoeuvre. The analysis also however, demonstrated that there is a larger unknown factor when it comes to overtaking distances. We postulate that this unknown variable is the driver them self and will vary by area, site and even time of day (i.e. different driving cultures, congestion, or frustration during peak times etc.) making it difficult to quantify.

Keywords: cycling, passing distance, instrumented bicycle

1. INTRODUCTION

The benefits of cycling as an effective form of transport are well known for both the individual and the greater population in terms of health, wealth and the environment and this fact is widely recognised and promoted at international, national and local levels of government.

In terms of health, it is widely recognised that obesity is a key risk factor for a number of conditions including heart disease, stroke, some cancers and type-2 diabetes. It is envisaged that without intervention obesity rates could be in the excess of 40% by 2030 (SHS, 2008). In addition to the physical health problems caused by obesity, there can be a reduction in people’s overall quality of life, which can lead to additional mental health problems. Lack of physical activity is seen as a major factor in modern lifestyles that contributes to these health problems and cycling may be part of the answer (Gruer, 2010). Furthermore, cycling has an important role to play in social inclusion; it enables a greater proportion of the population to afford travel to see friends and relatives. Beyond the recognised personal wealth benefits however, cycling also has a significant role in the greater economy. For instance cyclists are generally fitter members of the population and therefore are less of a drain on the economy and are more likely to contribute towards it. Furthermore, cycling has many positive externalities, for example, theoretically the more people that cycle, are less people contributing to road congestion (which itself may be limiting economic activity in some areas) and has low environmental impact (Cavill & Davis, 2007). Currently both the UK and Scottish governments have set the ambitious target of cutting net emissions by at least 80% by 2050 (compared to 1990 levels) (Climate Change Act, 2008 and Climate Change (Scotland) Bill, 2009). The UK government target was raised from 60% to 80% following recommendations set out by the Committee on Climate Change (Ecchinswell, 2008) and the Scottish Government has furthermore, set an interim target of reducing emissions by at least 42% by 2020.

Despite the wholesale recognised positives of cycling and policies aimed at its promotion; cyclists are however, widely perceived as belonging to one of the most vulnerable road user groups, and this may be influencing people's modal choice (Noland, 1995, Parkin et al. 2007a & b). For instance, whilst 15 million people own a bicycle, only 3.6 million use one regularly (Tolley, 2008). This perception unfortunately, may make the benefits and published targets difficult to attain; despite the long established fact that in UK the benefits of regular cycling outweigh the loss of life years in cycling fatalities by a factor of around 20 to 1 (Cavill & Davis, 2007). In attempt to mitigate the perceived risk, council transport departments often automatically investigate the use of cycle lanes. Cycle lanes in the UK are either of the advisory (broken line) or mandatory (solid line) type and may be coloured or uncoloured. Whilst sufficiently designed cycle lanes may be seen to present a degree of visible separation from motorised vehicles; they may also restrict the free movement of cyclists, encouraging them to the left hand side of the road which can be particularly hazardous at junctions where motor vehicles (particularly HGV's) are turning left, placing the cyclist outside the drivers' central area of vision or in a blind spot.

The objective of this research therefore, is to investigate the degree to which the presence of a cycle lane affects the amount of space demonstrated by a driver when passing a cyclist and whether or not the lane being coloured has an additional effect.

2. BACKGROUND

The European Union (EU) recognises the multiple benefits of cycling in many documents, principally 'Cycling: the way ahead for towns and cities' (EU, 1999) and continues to support policies aimed at promoting cycling across Europe, having established initiatives such as Bike Week, CIVITAS and co-financed the ASTUTE, BYPAD, SPICYCLES and Velo Info projects. The CIVITAS (CIty VITAlity Sustainability) initiative (www.civitas-initiative.org) aims to assist European cities in achieving sustainable, clean and energy efficient transport systems. Within the 2004 White Paper, Scotland's Transport Future (SGov, 2004) the Scottish Executive's Transport Group (now the Scottish Government and Transport Scotland) presented five high level objectives of promoting Economic Growth and Social Inclusion through a Safe, Integrated and Environmentally friendly transport system. Whilst the importance that cycling has in all five of the objectives is recognised, the White Paper specifically considers that cycle lanes and other design and engineering measures can help to achieve the Safety objective 'encouraging more to walk and cycle every day'. The White Paper is light, however on specific details of how the safety objective and other objectives are to be delivered with respect to cycling, other than to say it will be 'encouraged'.

Within the UK the main piece of legislation, concerning the provision for cyclists is the Local Transport Note (LTN) 2/08 (DfT, 2008). This document recognises a clear hierarchy of provision that should be considered by traffic planners and engineers when it comes to providing for cyclists. The fourth consideration on the list is the reallocation of road space (after volume reduction, speed reduction and junction improvement), which may involve cycle lanes. Cycling Scotland also consider that this hierarchy is appropriate for the use for of planning and engineering of cycle routes in Scotland (CS, 2009). LTN 2/08 also recognises however, those items in the hierarchy are not mutually exclusive 'for example reducing the volume of traffic may release carriageway space to provide cycle lanes' and it further recognises that whilst cycle lanes can benefit cyclists, poorly designed lanes can make conditions for the cyclist worse and there is no legal compulsion for the cyclist to use them. Furthermore, the note cites the position identified by Franklin (2007) within the National Cycle Training Standards on Bikeability, that unsuitable cycle lanes may encourage cyclists to adopt inappropriate positioning and therefore, should ideally reflect the movement of cyclists and if necessary be placed in between motorised traffic lanes. Franklin also considers that many cycle lanes are misinterpreted by drivers as defining the space a cyclist needs and where lanes are narrow, this can lead to faster and closer overtakes than if the lane had not been there which agrees with Parkin (2010), which demonstrates that drivers overtake in closer proximity in the presence of a cycle lane on higher speed roads.

Perceived risk (albeit incorrect) is the largest barrier when it comes to those contemplating cycling, or is a major deciding factor in the route choice of existing cyclists. As well as being recognised in current policy this has also been considered in studies by Hopkinson & Wardman (1996), and Wardman et al. (1997 & 2000), etc. The 1996 study by Hopkinson & Wardman involved a general postal return questionnaire, which sought levels on cycle use, and stated preference (home interview) surveys, as part of a review of cycling facilities in Bradford, West Yorkshire. In particular, the study found that safety is more valued than time when it came to route selection by individual cyclists and promotes this as a basis of appraisal of cycling schemes. A stated preference study in the US Tilahun et al. (2007) also suggested that cyclists valued perceived safety over time and would be willing on average to travel an additional 14-19 minutes to cycle on a road with cycle lanes compared to one without, depending upon the presence of car parking. The Wardman et al. (1997) study, again through a stated preference technique, examined the promotion of cycle lanes as and cycle paths as tools to encourage cycling and attain the then government's target of doubling cycle trips by 2002 and doubling them again by 2012. Although these targets have been subsequently abandoned, it is important to note that the report concluded that facilities alone would be insufficient to overcome the perceived barriers and encourage a modal shift. Attitudes towards perceived risks were also quantified by Pearse et al. (1998) in a TRL study; where 51.1% of non cycling adults perceived traffic en route and 43.3% respectively considered, the lack of cycle routes/ lanes to be a barrier to cycling. A similar survey was carried out for the draft CAPS (2009) however, percentages are far lower. Only 29% of participants in the Scottish survey perceived danger from traffic as a reason they don't cycle more, similarly only 13% considered it a reason not to cycle (although 11% also cited driver behaviour as a reason not to cycle). Furthermore, only 7% of cyclists and 10% of non-cyclists in the survey perceived the lack of road space for cyclists to be a barrier. Whilst all these studies suggest (although to a lesser degree in Scotland) that as per the common belief in some circles, that the provision of cycle facilities such as cycle lanes can help to mitigate the perceived risk barrier and encourage cycling, it is postulated that what people say in qualitative studies and what people actually do in practice can be considerably different.

Parkin et al. (2007b) considered both links and junctions in an attempt to establish models of the perceived risk of cycling and its effect upon cyclist route choice. The study involved presenting video clips, observed from the point of view of a cyclist, to both cyclists and non-cyclists. The participants subsequently rated the clips on a scale of 1 to 10 relative to the risk they perceived. In contrast to the views presented by Hopkinson & Wardman (1996) and Wardman et al. (1997 & 2000), the study found cycle lanes only to have a slight effect in reducing perceived risk and did not mitigate perceptions successfully when an entire cycle route was considered. Parkin considered that other factors such as the two-way flows and the number of parked vehicles en route also influences the perceived risk. Parkin also discusses the cyclists' perception to infrastructure and discusses international attempts at establishing a 'bikeability' index.

The implication of cycle lanes on the lateral positioning of both bicycles and motor vehicles has been considered for some time, although until recently has not been reflected in the aforementioned standards. Kroll et al. (1977) carried out a study which involved the filming of several urban streets, both with and without cycle lanes in the United States of America and this was supplemented by data from three additional sites both prior and post construction of cycle lanes. The results in both parts of the study indicated that when cycle lanes are present, whilst the extremes in driver overtaking behaviour were reduced, with fewer close overtakes and wide swerves resultant; the average overtaking distance did not vary. In contradiction to this, it was however found that on certain streets, a cycle lane reduced the overtaking distance demonstrated by drivers.

Also in the United States (Florida), Harkey et al. (1997) in an evaluation of cycle facilities videoed 13 sites, which had either a cycle lane, a paved hard shoulder or a wide curb lane (i.e. no cycle lane but wider inside lane, WCL) facility, whilst also taking still pictures when a driver overtook a cyclist. The collected data, was subsequently used to establish a model, a Bicycle Compatibility Index (Harkey et al., 1998) which could be used by planners and engineers so as to determine the suitability of a road for cycling. The study found that the main variables affecting the separation distance between the cyclist and the overtaking vehicle were: the facility type, vehicle presence in the adjacent lane, the presence an open drainage gulley, the number of lanes, the speed limit and the total width of the road. Significantly where the facility was a wide curb lane as opposed to a cycle lane the mean separation distance increased; however it was also noticed that cyclists tended to be closer to the kerb at these sites. The study also found that the extent to which a driver deviated on encountering a cyclist appeared to be dependent upon the area, rural or urban, deviation being greater in rural settings rather than by facility.

Walker (2007) carried out a study with an instrumented bicycle, which recorded the proximity of a motor vehicle to a cyclist, and this was statistically compared to the position of the cyclist on the road. The study found that contrary to common belief within the cycling community, drivers gave less room when overtaking a cyclist positioned further from the kerb. The study also proved that a driver gave the cyclist less room where, the cyclist was male or wearing a helmet or the driver was in a bus or heavy goods vehicle. The observed results suggested drivers' tended to act on a preconception of cyclists and brief visual assumptions. The work does not however, appear to take account of the available carriageway width or link the data to speed or flows. The study also recommends that further investigation into the effects of cycle lanes on overtaking distances is required; perhaps relevant to the width of the lane.

Parkin et al. (2010) also collected quantitative data regarding the passing distances drivers demonstrate when encountering a cyclist. The Parkin study however, was relative to the presence or not of a cycle lane. The study examined three sites in Lancashire (two rural and one urban); whilst simultaneously reporting the recorded Annual Average Daily Traffic (AADT) flows at the sites. All cycle lanes used in the experiment were advisory and uncoloured. The analysis demonstrated that in rural environments (40mph and 50mph zones), given a 9.5m wide road, drivers demonstrated statistically greater overtaking distances in the absence of a sub standard 1.45m wide cycle lane (the DfT note recommends 2.0m). The findings were not replicated however, for a similar width road within an urban environment (30mph zone), where there was found to be no significant difference between passing distances relative to the presence of 1.3m (once more substandard) cycle lanes. Parkin suggests that where cycle lanes are present, drivers may be driving within the confines of their own marked lane, with less recognition being afforded to the cyclist.

The current design standards, whilst recognising the complications, which may be associated with cycle lanes, in terms of the cyclist's position and substandard widths, etc., as presented by Franklin (2007), Parkin et al. (2010) and others; mainly address the perceived benefits of cycle lanes. It is however theorised by this paper, that as suggested by the US studies, there are more significant factors affecting driver passing distances than the presence of cycle lanes. The current study will expand on the previous research in analysing cycle lanes of different colours and widths. Furthermore, it is considered that, given the aforementioned contradictions, further research is required into driver passing distances in order to gain a better understanding of the manoeuvre.

3. METHODOLOGY

3.1. Equipment

An instrumented bicycle was the main item used in the recording of vehicle overtakes of a pedal cycle (Ridgeback Velocity hybrid bicycle). Subsequently a AT1 wireless helmet camera was attached to the rear rack of the bicycle and was situated at a right angle to the direction of travel (as shown in Photo 1) so as to capture vehicle overtakes.

The camera initially recorded footage of a graduated board (scale) marked in 50mm intervals from 0.5m (from the bicycle tyre) to 2.5m, and to ensure consistency the scale was integrated into a specially constructed stand, which also held the rear wheel of the bicycle and a spirit level was utilised to level the bicycle.

A second camera was also attached to the handle bar of the bike (ATC 5K helmet camera). The ATC 5K camera, shown in Photo 2, faced forward (the direction of travel for the bike) and was angled slightly towards the right so as to capture information such as the current flow conditions and the presence of parking (nearside or opposite) or other factors that would cause a temporary reduction in width (an opposing vehicle or traffic island). Furthermore, the second camera also recorded all overtakes, including those that were greater than the 2.5m scale and were not recorded by the first, sideways facing camera. The forward facing camera also clearly established vehicle types. Furthermore, the camera was also used to determine the time at which the cyclist passed fixed locations and hence the cycle speed.

Photo 1 – Instrumented Bicycle, AT1 Camera/ Receiver, Mount, Cycle Stand and Graduated Board

Photo 2 – ATC 5K Bar Mounted Camera

The cyclist wore the same trousers, jacket, and helmet at all times, and a small black pannier bag was attached to the left side of the bicycle rack to carry a notebook and a small digital camera. Whilst it was considered, that this presented the image of the typical cycle commuter/ utility cyclist; it was also considered that this consistent image would remove appearance as a possible variable.

3.2. Survey Sites

Between 4th October and 12th November 2010, between the hours of 10:00 and 16:00, 14 sites were surveyed of varying width and either without or with cycle lanes. The purpose of the data collection was twofold; to identify sites that were similar in nature in terms of width and traffic flow (both without and with cycle lanes, uncoloured and coloured) so they could be statistically compared and to collect data from range of sites in order to establish a Generalised Linear Model (GLM) of the overtaking process. Initial tests were also undertaken during the traditional AM (08:00-09:00) and PM (17:00-18:00) peak hours; however this information was discarded as traffic conditions meant the collection of flow data, was impossible (i.e.

dense traffic obscured the forward facing camera) and the cycle speed could not be consistent. Furthermore, traffic conditions were more unpredictable during this period and dangerous to the cyclist positioned only 500mm from the kerb. As noted previously and in contradiction to the findings of the Walker (2007) study; the more experienced cyclist considers that vehicles give them more space when they are further from the kerb and more visible, a view supported by Franklin (2007), Parkin et al. (2010) and others.

Primarily sites were chosen so as to be straight and level as possible, so that these variables could be eliminated from the analysis and furthermore, this facilitated consistency in the data gathering (a constant cycle speed, etc.,) and both sites without and with (advisory) cycle lanes, coloured and uncoloured were selected. Sites were also chosen that were reasonably free of congestion, as this allowed efficient data gathering (at congested sites as previously stated, little or no data could have been reliably collected with the forward facing camera). Furthermore, sites were selected that were of continuous width, although individual sites were of various individual width so that this variable could be modelled. Sites were also selected with different traffic flows, observed speeds, and with and without car parking, so these variables could also be modelled although the prime requirements mainly dictated these variables.

The basic procedure involved the cyclist travelling a consistent speed (in the region of 10mph) between two fixed points at the selected sites. Runs were captured in both directions as it was considered that this was more efficient and would provide more balanced data with regards to vehicle flows. The forward facing camera capturing the aforementioned variables and corresponding still images extrapolated from the sideways facing, rack mounted camera in order to determine vehicle overtaking distances.

4. ANALYSIS

4.1. Statistical Comparisons

Three statistical comparisons were undertaken at;

1. a site without cycle lanes to a similar site with uncoloured cycle lanes;
2. a site with uncoloured cycle lanes and a site with coloured cycle lanes; and
3. a site without cycle lanes and a similar site with coloured cycle lanes.

An ‘F’ test was carried out in order to determine if there was a statistical difference in the variance of overtakes at such sites. A ‘z’ test (for $n>30$) or a ‘t’ test (for $n<30$) was then carried out to explore if there was a statistical difference in the means. A univariate ANOVA (Analysis of Variance) was also subsequently carried out to check the validity of the t/z tests and to allow comparison with the previous reported tests, by Parkin et al. (2010) and Walker (2007). Vehicles observed overtaking by the front facing camera but not captured by the sideways facing camera (i.e greater than 2.5m) were conservatively defined as 2.51m overtakes and all tests were undertaken at a 95% Confidence Level.

Selected sites were utilised for the comparisons (rather than an aggregate of all sites of a particular type) in order that similarities in terms of width, alignment and traffic flows could be maintained. Analysis was conducted for “all vehicles” and separately for cars, LGVs and HGVs separately. Whilst tests could be conducted for LGVs and for HGVs at some sites, low numbers make these results inconclusive relative to cars and hence only all vehicles and car statistics will be reported.

Comparison 1: No cycle lane vs uncoloured lane

For the first of these comparisons, the overtaking distances observed on the 9.3m wide section of Ferry Road, (without cycle lanes) were statistically compared with the overtaking distances that were observed on the 9.4m Buccleugh Street site (with 2x 1.4m wide uncoloured advisory cycle lanes). Other than similarities in width and alignment however, both sites were also considered similar in terms of traffic flows (1256vph, 7% heavy compared to 1066vph, 5% heavy).

The results showed that whilst there was no statistical difference in the variances of overtakes between the two sites, for all vehicles and for car drivers alone, there was a statistical difference in the demonstrated mean overtaking distance (ANOVA: P=0.0003 for all vehicles and P=0.0002 for cars, respectively). Wherein the mean overtaking distance for all vehicles and cars alone were greater (by 0.16m) when a cycle lane was present.

The findings for car drivers, are contrary to the findings of Parkin et al. (2010), which suggested that there was no difference at 30mph sites. It was noted however, that 54% of vehicles were directly opposed by another vehicle travelling in the opposite direction at the Ferry Road site (without cycle lanes) compared to only 32% at the Buccleugh Street site (with cycle lanes). This variable was not recorded in the Parkin et al. (2010) study. Tests therefore were rerun removing this variable, so as to investigate its importance.

A reduced but still statistically significant difference in the mean overtaking distance remained (0.12m), (ANOVA: P=0.0310 for all vehicles P=0.0138 for cars). It is postulated that in an urban (30mph zone) that there are additional factors when a motor vehicle overtakes a cyclist which are more important than the presence of cycle lanes and one of these may be the presence of an opposing vehicle (which can be much more variable in the urban setting).

Comparison 2: Uncoloured cycle lane vs coloured lane

Similar statistical tests were undertaken comparing Buccleugh Street (9.4m wide) with uncoloured cycle lanes (2x1.4m wide) and Dalry Road (9.8m wide) with coloured cycle lanes (1.6m and 1.5m wide). Flows are similar on average at the two sites (1066vph as oppose to 807vph) and importantly the percentage of opposing vehicles encountered by overtaking drivers is similar (32%, as oppose to 30%).

The results of this test revealed a slight absolute difference in mean overtaking distance (0.02m more at the coloured site), but this was not a statistically significant difference for any vehicle category. The variances likewise showed no statistical difference.

The level of opposing traffic directly at the time of overtaking movements was similar at both the Buccleugh Street and Dalry Road sites (32%, as opposed to 30%), however in the interests of consistency the tests were also repeated, removing that percentage of opposed traffic, so as to determine the effect of the colour of the cycle lane alone. No change in any of the statistical tests was observed.

Comparison 3: No cycle lane vs coloured lane

To further understand the effects of coloured cycle lanes upon overtaking distances, data gathered from the Muirhouse Parkway site (9.8m wide with no cycle lanes) was statistically compared to data collected from the aforementioned Dalry Road site (also 9.8m wide, with 1.5m and 1.6m cycle lanes). Whilst there was, a difference in traffic flows at the two sites on average (469vph, as oppose to 807vph), both flows similarly consisted of a large proportion of heavy vehicles (9% compared to 12%) and most of which were buses, with both roads being located on busy bus routes.

Similar to the Parkin et al. (2010) study (albeit with coloured cycle lanes in this instance), the results demonstrated that there was no statistical difference in any vehicle categories in the urban, 30mph environment, when it came to the mean distances (0.02m less at cycle lane site) that drivers presented when overtaking a cyclist, regardless of the presence of a cycle lane. However, for this comparison a statistically significant difference in the variance of overtaking distance was observed opposite to that of Kroll et al. (1977) (s.d. = 0.26 for no-cycle lane vs s.d. = 0.35 for cycle lane (F-test: P-value = 0.0008). It is postulated that this variance was more likely due to the difference in vehicle flows, rather than the presence of the cycle lane.

Although both sites were considered low in terms of the percentage vehicles directly opposing the overtaking vehicle (18%, as oppose to 30%), for consistency statistical tests were also carried out removing these proportions. The results did not change in any notable manner.

Summary of Statistical Comparisons

ALL Vehicles						P-values		
Comparison	opposing traffic	Mean overtake (m)		S.D. (m)		F-test	t/z-test	ANOVA
1	with	**1.84**	**2.00**	0.34	0.32	0.2676	**0.0001**	**0.0003**
	without	**1.97**	**2.09**	0.32	0.30	0.2743	**0.0264**	**0.0310**
2	with	2.00	2.02	0.32	0.35	0.2277	0.7253	0.7270
	without	2.09	2.09	0.30	0.35	0.1173	0.9943	0.9944
3	with	2.04	2.02	**0.26**	**0.35**	**0.0008**	0.6310	0.6022
	without	2.06	2.09	**0.26**	**0.35**	**0.0042**	0.5969	0.5600

Table 1: Summary of comparisons

The presented results demonstrated in contrast to the previous study by Parkin et al. (2010) that at the investigated urban sites, overtaking distances were significantly increased when uncoloured cycle lanes were present compared to sites with no cycle lanes. (Comparison 1)

However, when uncoloured cycle lanes were compared to coloured cycle lanes there was found to be no statistical difference in the mean overtaking distance. (Comparison 2)

Furthermore, when a site with no cycle lane was compared with a site with coloured cycle lanes there was found to be no statistical difference in the mean overtaking distance, which is in agreement with the previous Parkin et al. (2010) study. (Comparison 3)

This study however examined wider cycle lanes (1.4m uncoloured cycle lanes and 1.5-1.6m coloured cycle lanes as opposed to 1.3m wide in the Parkin Study). It could be suggested, from the analysed sites that drivers feel more certain as to the position of a cyclist on a road with coloured cycle lanes, where as uncoloured lanes are less defined and hence drivers may be giving some additional space when the cycle lane is less clear. The analysis however, also demonstrated that by removing the presence of opposing vehicles (those coming from the other direction and hence potentially limiting overtaking width) from the study, and therefore considering the effect of the cycle lanes individually, the results were unchanged, although the strength of the significance level was decreased.

Whilst the mean overtaking distance was not shown to be statistically different when comparing no cycle lane to a coloured cycle lane (comparison 3), there was however a significant difference in variance with a higher standard deviation in overtaking distance being observed in the presence of a coloured cycle lane.

4.2 Generalised Linear Modelling (GLM)

The contrasting results of the statistical tests and previous literature suggests that within an urban area, at least there are variables more important than the presence of cycle lanes, affecting the distance a driver presents when overtaking a cyclist. The second part of this analysis, therefore investigates these possible variables in a Generalised Linear Model (GLM): where the overtaking distance (tyre to tyre) was the dependent variable and data collected concerning: the absolute road width (m), lane width (m), vehicle type (Car, Taxi, LGV, HGV or Bus), the provision for cyclists (no cycle lane, cycle lane or cycle lane colour), cycle lane width (m), factors temporarily reducing width (parking nearside/ opposing, traffic islands or opposing vehicle), speeds (posted, cycle, relative or absolute, mph) and traffic flows (opposing and 2 way average, vph) at the time of each individual overtake were analysed as independent variables.

GLM-1	coefficient	t-stat	P-value
Absolute Road Width (m)	0.058	13.07	1.92E-37
Opposing Vehicle (binary)	-0.139	-8.057	1.37E-15
Vehicle Speed (mph)	0.015	3.923	9.05E-05
Relative Speed (mph)	-0.012	-3.06	2.20E-03
Nearside Parking (binary)	-0.235	-8.703	6.88E-18
Opposite Parking (binary)	-0.093	-2.505	1.23E-02
Colour of Cycle Lane (binary)	-0.036	-2.298	2.17E-02
Presence of a Bus (binary)	-0.127	-3.096	2.00E-03
Opposing Flow (vph)	-6.56E-05	-3.34	9.00E-04
intercept	1.236	26.08	1.90E-128

Table 2 – Generalised Linear Model (GLM), Constructed On Recorded Overtakes

The resultant model utilising 1908 measured overtakes (i.e. those overtakes <2.5m), shown in Table 2, determined that the three most significant variables influencing the demonstrated overtaking distance were:

- **Absolute road width (m),**
- **the presence of Parking (binary), and**
- **the presence of an Opposing Vehicle (binary).**

Where an increase in absolute road width increased overtaking distances, and conversely the presence of parking or an opposing vehicle reduced distances.

Vehicle Speed and Relative Speed were also discovered to be critical variables. Suggesting that faster motor vehicles tend to allow more room when overtaking a cyclist but conversely, the larger the separation in the relative speeds of the bicycle and motor vehicle reduced the overtaking distance. The Opposing Flow (vph) at the time of the overtaking manoeuvre was also discovered to be critical, suggesting that logically as the opposing flow increases the overtaking distance decreases. It is hypothesised, that this may be because when the road becomes busier, visibility is reduced and hence time for the driver to consider deviating from their path is reduced.

A surprising finding was that the binary variable representing the presence of buses was also critical. It is theorised that because the vast majority of buses in Edinburgh, Lothian Buses are extremely consistent when it comes to overtaking a cyclist that this variable was identified as significant. The presence of Opposite Parking was also found to be significant within the model and was logical in terms of its influence, i.e. when it is present it results in a reduced effective width and less room for the driver to deviate when overtaking a cyclist.

Considered the least critical of the critical variables, was the presence of a Coloured Cycle Lane; the multiplier suggests that this actually has a slight negative effect in reducing overtaking distances. Although, the previous significance tests showed this to be non-statistical when examining mean overtaking distances other tests did however, find that in some instances (e.g. comparison 3) that drivers tended to vary their overtaking distances more when a coloured cycle lane was present. It is however, considered important what the final model did not include, the variable concerning the presence of any Cycle Lane (including coloured and uncoloured); this variable was found to be non-significant and was removed during the model building process.

The overall fit of this model was poor however (R^2=0.275), and the intercept of which was more significant than the independent variables, suggesting that there are other more important variables that were not recorded. Whilst one item which may have resulted in an improved fit was to have recorded overtakes greater than 2.5m, it is postulated that more significant variable is the driver them self; i.e. if somebody is going to give the cyclist lots of room/ pass close they will do so regardless of the facilities in place (cycle lane or no cycle lane).

To examine the unmeasured overtakes (i.e. those >2.5m) a second model was built based upon all of the 2837 overtakes observed (those >2.5m were again conservatively assigned as 2.51m). As the relative speeds and hence vehicle speeds of these overtakes were not known (33% of the total) it was considered better to construct the model without these variables; the resultant model is shown in Table 3.

GLM-2	coefficient	t-stat	P-value
Absolute Road Width (m)	0.063	11.795	2.22E-31
Posted Speed Limit (mph)	0.009	5.165	2.58E-07
Opposing Vehicle (binary)	-0.156	-9.544	2.87E-21
Effective Lane Width (m)	0.095	9.432	8.11E-21
Cycle Speed (mph)	0.014	3.58	3.00E-04
Nearside Parking (binary)	-0.262	-11.066	6.79E-28
Presence of Traffic Island (binary)	-0.065	-2.936	3.40E-03
Cycle Lane Width (m)	0.107	6.739	1.92E-11
Colour of Cycle Lane (binary)	-0.067	-4.123	3.84E-05
Presence of a Bus (binary)	-0.124	-3.515	4.00E-04
Opposing Flow (vph)	0.00009	-5.263	1.53E-07
intercept	0.585	9.64	1.17E-21

Table 3 – Generalised Linear Model (GLM), Constructed On All Observed Overtakes

It is considered significant that this model (including overtakes >2.5m) was identical in what was considered to be the most significant factors. The three most critical variables in this model were again:

- **Absolute road width (m),**
- **the presence of Parking (binary), and**
- **the presence of an Opposing Vehicle (binary)**

The Relative Speed and Vehicle Speed variables (not recorded for +2.5m overtakes) were replaced within this model by the Posted Speed and Bike Speed variables. This however, is consistent with the previous model wherein faster drivers generally provide more space when overtaking a cyclist, however the faster the cyclist is (i.e. the lower the relative speed) the overtaking distance also tends to increase. Opposing Flow, vph remains a critical variable within the model also and again suggests logically as this value rises, overtaking distances tend to reduce.

The presence of a Bus was again found to be the only significant vehicle during analysis of the overtaking manoeuvre and as with the previous findings it was found to reduce the overtaking distance. The presence of the Opposite Parking variable however, became non-critical when data relating overtaking distances greater than 2.5m was included and was subsequently removed from the model.

As with the previous model, the presence of coloured cycle lanes on a road of consistent alignment, width and gradient (circa 0%) was also found to be significant, whereby coloured cycle lanes actually reduce overtaking distances slightly. As previously noted it could be hypothesised that drivers consider cyclists to be more defined in coloured cycle lanes and do not feel the need to give them further space and hence pass more closely.

However, new critical variables were also introduced in this model, which included the significant proportion of overtakes that were greater than 2.5m. The effective Lane width became statistically important (this is the effective width of a road lane where a cycle lane or hatching reduces it or the half width of the road where there is no cycle lane or hatching). Wherein the wider a road lane is, the greater the overtaking demonstrated by drivers. However, conversely to this the Cycle Lane width variable (which reduces lane width) also became statistically significant. This appears to suggest that cycle lanes are only effective in increasing overtaking distances, as one would expect when they are wide but the road is also. This finding appears to correlate with the current DfT guidelines, that when a road is too narrow for standard cycle lanes, cycle lanes should not be installed. The variable regarding the presence of a width restriction such as a Traffic Island also became statistically significant when overtakes greater than 2.5m were included in the model, resulting in a slight reduction in predicted overtaking distances. On site it was observed that drivers often would pass at two extremes when a traffic island was present, either close to the cyclist (to avoid the island) or close to island and further from the cyclist (presumably using it as a defined edge to drive beside).

Whilst this model had a slightly better fit (R^2=0.424) than the previous model and the intercept is statistically less important there still remains a large residual error, suggesting once more that there are one or more important variables that have not been recorded when it comes to demonstrated overtaking distances. Once more, it is postulated that this variable is the individual driver.

5. CONCLUSIONS AND RECOMMENDATIONS

This paper has presented the actual benefits of cycling in terms of health, wealth and the environment, both to the individual and to the greater population and has reviewed current policy and standards. Previous research in the field of cycle lane provision has also been researched, and whilst limited, was also found to be contradictory in parts. For instance users of roads with cycle lanes reacted more positively towards them when asked about them in qualitative studies; while in some cases drivers demonstrated ‘more risky’ behaviour (speeding and closer overtakes) at sites with cycle lanes when it came to quantitative data gathering. Furthermore, the Parkin et al. (2010) study suggests that whilst at 40mph & 50mph, statistically significantly reduced overtaking distances are resultant at sites with cycle lanes compared to sites without; there was no statistical difference at 30mph sites. In this work we that there were important variables, especially in the urban (30mph) area that could influence results.

Results of initial testing, through statistical comparison, confirmed that variables other than the presence of a cycle lane in the urban area would influence the distance a driver demonstrates when overtaking a cyclist. For instance whilst the analysis demonstrated that there could be a difference in overtaking distance between sites without cycle lanes and sites with (i.e. comparison 1), at other sites there was none (i.e. comparison 3). These results were both contradictory and complimentary of previous studies, hence suggesting that in the urban area at least, there are more significant variables present than the presence of a cycle lane. It was postulated that one of these variables may have been the presence of an opposing vehicle at the time of an overtaking manoeuvre and results demonstrated that this highly variable factor would be significant in the urban area.

Further testing investigated through the construction of a Generalised Linear Model what these variables were most likely to be and investigated a wide range of physical variables. It was found that overtaking distances increased most significantly relative to the Absolute width of a road and reduced relative to the presence of width restrictions such as Parking or the aforementioned Opposing Vehicle. Furthermore, cycle lanes, unless sufficiently wide were shown to have little statistical effect and only when overtakes greater than 2.5m were included in the analysis. In fact coloured cycle lanes appeared to reduce predicted overtaking distances slightly and it could be suggested that drivers consider cyclists to be more defined in coloured cycle lanes and do not feel the need to give them further space and hence pass closer.

The modelling process also however, demonstrated that there were more significant variables than the extensive physical variables explored. It is postulated that one of these variables is the driver them self and it is recommended that further qualitative research is required to investigate this. Previous 3rd party research however, demonstrates that there is often an observed discrepancy in what people say in qualitative studies and what they do in practice, and any further research needs to consider this. Furthermore, it is hypothesised that human nature will vary from area to area, site to site and even by time of day (i.e. different driving cultures, congestion, or frustration during peak times) making it difficult to quantify on a basis that can be generalised.

Further research could also compare cyclists' perceptions of passing distances on sites with and without cycle lanes to actual recorded overtaking distances, utilising the procedure established in this report. It is recognised however, that cyclists are not a homogeneous group and the beginner/ leisure/ commuting/ touring/ cyclist etc., are likely to have different perceptions and this will also require careful consideration. However, where similar studies have been undertaken at public transport stops/ stations investigating perceived and actual passenger waiting times, both prior and post the implementation of a Real Time Passenger Information (RTPI) system; it has been routinely found that passengers can overestimate waiting times by circa 20% prior to installation of RTPI compared to post, despite actual times remaining constant.

It is therefore, concluded that in the urban environment at least, there are more significant factors encountered when a driver overtakes a cyclist mid-block than the presence or not of cycle lanes. However, as identified in the literature review one of the problems of cycle lanes is that they may wrongly influence the position of a cyclist at junctions; further quantitative research is required to determine the scope of this potentially fatal problem. Therefore, in line with the more recent standards (LTN 2/08 & Cycling by Design) there should be a presumption against the automatic provision of cycle lanes when widths will be substandard. Furthermore, and again in line with the recent standards, in order to reduce perceived risk and encourage more cycling, it is recommended that reducing or calming of existing motorised traffic must be explored first, creating an attractive and welcoming environment. It is also recommended that this be done parallel to training for both motorists and cyclists alike.

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