Driver and Cyclist Behaviour at Junctions: Who is Really Running Red Lights?

Christopher Russell

40593430

A dissertation submitted in part fulfilment of the requirements for degree of Master of Science in Transport Planning and Engineering

Supervised by Prof Achille Fonzone

School of Computing, Engineering & the Built Environment

Edinburgh Napier University

August 2023

Abstract

The study analysed the behaviour of road users at red lights at five signal-controlled junctions in Edinburgh. Video recordings were taken and used to categorise road users as law-abiding or law-breaking, with the latter being divided into minor (stopping over the line and/or setting off early), serious (running the red light after slowing down and giving way) and very serious (running the red light without slowing down or giving way) offences. 429 observations of road users with an opportunity to run the red light were recorded.

Minor offences were found to be common among all road users while serious offences were rare. No statistically significant difference was found between cyclists and other road users when comparing all illegal behaviour, though they were more likely to commit serious or very serious offences.

More cycling provision at junctions, namely advanced stop lines and early release signals, was correlated with more minor offences by non-cyclists. Fewer minor offences were committed by cyclists at junctions with both advanced stop line and early release facilities.

People driving/cycling for work were found to commit more minor offences, but no statistically significant effect was found for serious and very serious offences.

Acknowledgements

I would like to thank staff at Edinburgh Napier University for their support: in particular, Prof Achille Fonzone for agreeing to supervise the project and Dr Richard Llewelyn for his advice on data recording, analysis and loaning of recording equipment.

Cycling Scotland suggested the topic, for which I am grateful. They also offered support in shaping the project at its early stage; thanks in particular to Rachael Bonds for her advice.

Support for research costs was kindly provided by Cycling Scotland, in memory of founding trustees Sandy Scotland and Brian Curtis.

Finally, thanks to Eric Lesley, who encouraged me to join this course and proofread this dissertation, my partner Sarah who provided both moral support and proofreading, and my mum and uncle, who have always supported me.

Contents

List of Figures

List of Tables

Acronyms

ASL Advanced Stop Line

DfT Department for Transport

ER Early Release

HGV Heavy Goods Vehicle

MV Motor Vehicle

NCF No Cycle Facilities

PC Pedal Cycle
PTW Powered Two Wheeler

TRL Transport Research Laboratory

Chapter 1

Introduction

From tabloid newspapers (e.g. Daily Mail headline “No minister! Jeremy Hunt cycles into more trouble as he risks £3,000 fine by running a red light and ignoring TWO no entry signs as he bikes home (and he didn’t even bother with a helmet)” (Robinson, 2012)) and social media to primetime TV (e.g. Channel 5’s “Cyclists: Scourge Of The Streets?” (MacMichael, 2019)), there is often a perception that cyclists do not follow the rules of the road. Red-light running, in particular, is seen as endemic (e.g. Jenne, 2022). However, comparatively little is commented about drivers who run red lights nor the motivations, rational or otherwise, for cyclists who do so. As investment in cycling has grown in light of increasing congestion and the climate emergency (Hinchcliffe, 2022), a classic argument against doing so relates to a perceived high frequency of illegal or antisocial behaviour by cyclists, including red-light jumping, often dubbed ‘bikelash’ (Sadik-Khan and Solomonow, 2021).

The issue of cyclists jumping red lights was brought up last year in the House of Lords. The notion that cyclists who jump red lights “give us [cyclists] all a bad name” was used by Lord Young of Cookham in a debate around changes to the Highway Code (Hansard, 2022). Rarely is this kind of language used to suggest dangerous drivers give all drivers a bad name. Dr Ian Walker, professor of environmental psychology, provides some insight into the psychology of how cyclists are seen, suggesting they are not only seen as an outgroup (leading to “overgeneralisation of negative behaviour and attributes”), but a minority outgroup and one doing something “deemed slightly inappropriate in a culture that views driving as

Figure 1.1: Photo of a humorous sign about red-light jumping cyclists, seen in London (Image Source: acb, 2007)

normative" (Sutton, 2012). This may contribute to a sense that cyclists jump red lights that is disproportionate to the reality. The wording in a headline in a local newspaper, "Londoners rage against cyclists as they accuse them of constantly breaking the law in a very dangerous way" is an illustrative example, with 'Londoners' and 'cyclists' seen as two distinct groups (as if Londoners themselves could not be cyclists). The sign spotted in London in Figure 1.1, while obviously a joke, does say something about the issue's presence in the zeitgeist.

As transport policy tries harder to nudge people away from driving, especially in urban areas, and towards sustainable modes, including cycling, it seems worthwhile to ask whether this perception is based on reality, whether and to what extent it is something to be concerned about and how to increase compliance if that is deemed desirable.

In the UK, the law is clear that cyclists must stop at red lights in the same way as other road users. The only exceptions are where a cycling-specific light allows them to proceed (generally used in 'early release' style junctions, as shown in Figure 1.2) and that they may proceed beyond the first stopline at a red light to proceed to a second 'Advanced Stop Line (ASL)' where provided, as shown in Figure 1.3.

Figure 1.2: Photo showing traffic lights with early release in Edinburgh (Image Source: Author)

Figure 1.3: Photo showing an Advanced Stop Line for cyclists at a junction in Edinburgh (Image Source: Author)

Internationally, the law differs, with cyclists being permitted to turn right (equivalent to left in a UK context) on red at junctions marked with a “rechtsaf voor fietsers vrij” (“free right turn for cyclists”) sign in the Netherlands and at junctions with a graphic logo in France (as shown in Figure 1.4). Outside of Europe, the ‘Idaho Stop’, whereby cyclists can cycle though red lights after stopping and giving way was introduced in the state of Idaho in 1982 (Bernardi, 2009) and has been extended to seven other states (Kuntzman, 2022).

Figure 1.4: Photo showing a cyclist legally turning right on red in France (Image Source: 13 Comme Une, 2018)

There have been some calls for the law to change in Scotland/the UK so that people cycling could treat red lights as if they signalled ‘stop’ or ‘give way’ (e.g. Glass, 2015, Kinsman-Chauvet, 2023), though there has been no serious move towards legislative change nor support from mainstream cycling campaigns.

Chapter 2

Literature Review

2.1 Scale of the Problem

While red-light running is illegal, it is worth considering how significant an issue it is. Sadly, red-light running is not a victimless crime. The UK's Department for Transport (DfT) publishes summaries of people killed and seriously injured as a result of red-light running ('disobeyed automatic traffic signal') at junctions. This does not include red-light running at dedicated pedestrian crossings, since the code for this ('disobeyed pedestrian crossing facility') includes both signal controlled (e.g. pelican) and non-signal controlled (e.g. zebra) crossings. Only contributory factors recorded by a police officer at the scene of a collision are recorded, which will limit accuracy of data (Department for Transport, 2022).

As shown in Figure 2.1, an average of 12.6 people per year were killed in the UK due to red-light running at junctions, with just over half of them (7.7) being vulnerable road users (pedestrians, cyclists and motorcyclists). Meanwhile, an average of 389 people per year were killed or seriously injured, as shown in Figure 2.2.

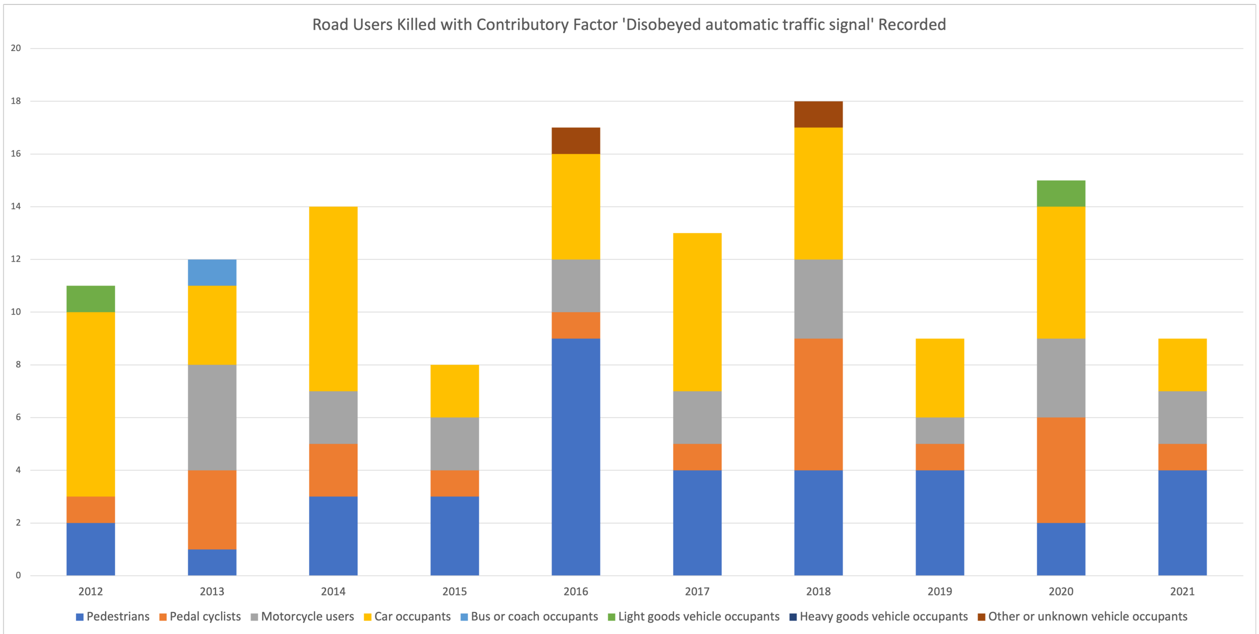

Figure 2.1: Graphical representation of Road Users Killed with Contributory Factor 'Disobeyed automatic traffic signal' Recorded (Data Source: STATS19 RAS07 Table)

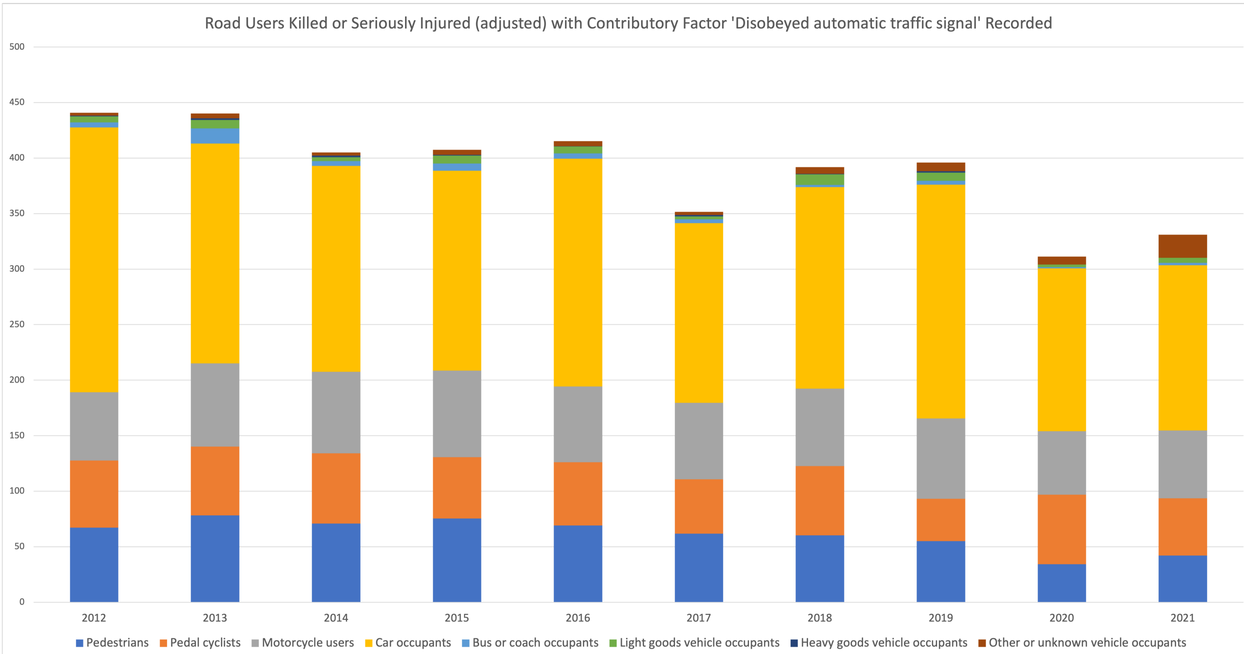

Figure 2.2: Graphical representation of Road Users Killed or Seriously Injured (adjusted) with Contributory Factor 'Disobeyed automatic traffic signal' Recorded (Data Source: STATS19 RAS07 Table)

2.2 Comparing Drivers and Cyclists

Several pieces of research have sought to investigate the prevalence of law-breaking at signal-controlled junctions and factors which influence compliance. These have tended to look at either motor vehicles or cycling modes, rather than both together. When M. Johnson, Newstead, et al. (2011) studied red-light jumping by cyclists in Melbourne, they made a deliberate decision not to compare compliance between cyclists and drivers since they believed their different characteristics meant a direct comparison was not possible; in particular they highlight that opportunities to jump red lights are much more limited for drivers (who cannot generally pass a vehicle in front of them in a queue at a red light) and cyclists, who can filter to the front of the queue and jump the light should they choose to do so. However, even with a very different denominator, a proportion of drivers/cyclists who have the opportunity to jump a red light doing so can be measured.

One other reason to avoid direct comparisons may be the very different potential for harm. A report by Allan (2023), based on a Freedom of Information request, found that in the UK in 2020, cyclists had been responsible for a very small proportion of pedestrian deaths and serious injuries following jumping a red light compared to motor vehicles, as shown in Table 2.1. This indicates that other vehicles, not cyclists, pose much greater danger when jumping a red light (doubtless because of the differences in size, weight and speed). This data provides only limited insight since it only considers the impact on pedestrians and does not consider red-light jumping causing harm to cyclists, other drivers or property damage. It is also worth noting that they do not take into account the distance travelled by each mode.

Table 2.1: Pedestrian Deaths and Serious Injuries following Red Light Violations in the UK in 2020 (Data Source: Allan, 2023)

	Pedestrian Deaths	Pedestrian Serious Injuries
Caused by people cycling	1	17
Caused by people driving/riding motor vehicles	31	368

Unfortunately, only a small snapshot of data for one year is available to compare the impact of red-light jumping by different modes; correspondence with the Department for Transport (DfT) confirms that they do not publish the data on contributory factors which would be necessary for further analysis.

2.3 Drivers

2.3.1 Categorisation of Driver Behaviour

Red-light offending drivers can be categorised by those who run red lights deliberately, those who run them due to distraction (due to, for example, tiredness or mobile phone usage) (Palat and Delhomme, 2012) and those who intend to pass on amber but misjudge and get ‘caught’ by the red light (Konečni, Ebbeson, and Konecni, 1976).

2.3.2 Amber Lights and the Dilemma Zone

When approaching an amber light, drivers must make a decision - can they stop safely before reaching the stopline (and be confident they can stop before the stopline and without braking so suddenly and sharply for the person behind to crash into them) or should they continue through the junction, hoping to pass the stopline before the light turns red (Gazis, Herman, and Maradudin, 1960). This so-called ‘dilemma zone’ was identified by 1960 (ibid.) and has been the subject of research since. The term ‘amber gambler’ for one who decides to go through a junction at amber, gambling on it not changing to red before they pass the line appears to have first been used in a public information film in the UK in 1977 (TVArk, 2007), with a stern voice-over warning that the amber gambler ‘dices with death’ (YouTube, 2011).

In the UK, amber lights are always a fixed three seconds, with a tolerance of 0.25s either way (Department for Transport, 2019). In other countries, the amber duration is not necessarily fixed; for example, in the USA it can be between 3 and 6 seconds, with longer durations typically used on roads with higher speeds (Transportation Research Board and National Academies of Sciences, Engineering, and Medicine, 2012). Similarly, in the Netherlands, different ranges are provided depending on the speed limit (Prinsen, Krol, and Dijck, 2016). This intuitively makes sense, with longer times needed with the higher stopping distances associated with higher speeds.

A Dutch study found that longer amber times did not lead to a change in driver behaviours, but did cut the number of law-breakers considerably (ibid.). However, longer amber times may reduce the overall capacity of the junction, potentially leading to longer waiting times.

2.3.2.1 Compliance

Predicting whether a driver will stop or not when presented with an amber signal has been analysed in a number of studies. Palat and Delhomme (2012) ran a questionnaire aimed at drivers in France with 103 responses. On being given hypothetical scenarios, respondents reported that they were more likely to go through an amber light when specific circumstances including time pressure, a vehicle following closely behind, good visibility, familiarly with the junction and driving at night applied. The study introduced scenarios in a text-based manner, such as:

> Imagine yourself driving the car you usually use. The weather is good. It is 15°C. You need 30 min to arrive at your destination. You are 100 m from a traffic light which is green. You are driving at a speed of 50 km/h. When you are 80 m from the light, it turns yellow. There are no police at the intersection.

This could be hard for participants to visualise and may affect reliability of their answers. Nevertheless, they do give a good guide to the factors that may influence the decision about whether to run a red light or not.

Another study by Jahangiri, Rakha, and Dingus (2016) used simulator and observation data to identify factors leading to passing an amber signal. Their literature review provides a useful summary of factors identified by previous studies, including perception-reaction time, age, gender and time/distance to the junction at the onset of amber, vehicle type, approach speed, mobile phone use and cycle length. Their own study notes the challenge of using observation studies (where demographic data cannot be obtained) and of simulator studies (in which participants may behave differently to outside the simulator). Ultimately, there is no perfect answer to this problem.

2.3.2.2 Techniques to Encourage Compliance

Some techniques have been used to minimise red-light running by drivers. One example is warning signs, which can be passive (as exemplified in Figure 2.3) or active (as exemplified in Figure 2.4). These give drivers a chance to slow down ahead of an imminent change to the traffic signals ahead. However, usage of active signs appears to have decreased in recent years due to an unintended consequence of drivers using the sign as an indication that they can speed up to ‘beat the lights’ rather than slow down and be prepared to stop (The Record-Courier, 2020).

Figure 2.3: Photo of a 'Traffic Signals Ahead' sign in the UK (Image Source: Bridge, 2010)

Figure 2.4: Photo of a 'Prepare to Stop When Flashing' sign in the USA (Image Source: The Record-Courier, 2020)

Enforcement is another method of reducing red light running. For example, in Edinburgh there are 11 cameras which detect red light running and issue fixed penalty notices to drivers who run the red light (Safety Cameras Scotland, 2023a). This is clearly a tiny proportion of the total number of signal-controlled junctions in the city. Safety Cameras Scotland, who operate speed and red-light cameras on behalf of Police Scotland, only consider installing red-light cameras where red-light running has been demonstrated to be a factor in the number and/or severity of collision at a particular location (Safety Cameras Scotland, 2023b).

2.4 Cyclists

2.4.1 Categorising Cyclist Behaviour

Cyclists' behaviour at red lights can be broken down into three categories: risk-taking, opportunistic, and law-obeying (Pai and Jou, 2014). A subsequent study by Fraboni et al. (2018) noted these terms could be seen as subjective or judgemental, so renamed them in more objective terms for their study, namely 'not stopping at red-light', 'violating red-light after an initial stop' and 'stopping for the whole duration of the red-light'.

An Australian study identified three different types of non-compliant cyclists - namely 'racers' who tried and failed to beat an amber light, 'impatients' who stopped and waited but then went on to violate and 'runners' who rode through without stopping (M. Johnson, Charlton, and Oxley, 2008).

Of course, these descriptors are relevant only to an observation of one specific cyclist at one junction. Research has noted that prevalence of red-light jumping varies significantly between different junctions and manoeuvres. In other words, a law-abiding cyclist at junction A may well act as an opportunistic cyclist at junction B.

2.4.2 Safety Implications of Obeying Red Lights

While drivers may break red lights because of a misjudgement or due to distraction, many cyclists justify jumping red lights on safety grounds, claiming that getting ahead of motor traffic is actually safer than waiting for green (Marshall, Piatkowski, and A. Johnson, 2017). Some data indicates that this may be well founded, at least in some cases.

The fact that female cyclists tend to obey red lights more than male cyclists (e.g Transport for London, 2007) has been blamed for the higher prevalence of collisions where a female cyclist is struck by a Heavy Goods Vehicle (HGV) (Leach, 2010). Since three-quarters of motor-vehicle/cyclist collisions happen at junctions (Walker, 2011), perhaps it is understandable that cyclists want to get away from a junction as quickly as possible. Of course, outwith the well-known risk that HGV blind spots pose (hence it often being safer to get away from them, regardless of traffic laws), it is not clear to what extent red-light jumping is one of the causes or one of the consequences of the relatively high risk to cyclists at junctions.

Blogger Mark Treasure's description of the unpleasant consequence of obeying a red light is rather illuminating. He writes about a typical junction with a pinch point just after it (Treasure, 2013):

> [As] the lights turned green, I pedalled off as fast as I could, a small mammal pursued by a horde of angry bears, all heading into this narrowing gap. Of course they all wanted to get ahead of me before this gap, so I had to fight my out into the stream of bears coming past me.
>
> It was unpleasant. To avoid it, I could (and probably should) have trundled my way across the junction, through a red light (gasp!), while the lights were green for pedestrians. I would have escaped from the junction, and been far away, a good distance down the road at the moment the lights turned green and all the hard acceleration and revving occurred.
>
> This is why so many people jump red lights; a desire for subjective safety, to be away from the fast angry bears, rather than stuck right in front of them waiting for the signal that will release them from captivity behind you.

As well as the discomfort of leaving a junction with a queue of drivers behind, there are risks to cyclists who obey traffic signals as drivers may not expect to encounter a cyclist and so may not look for them, resulting in so-called 'failure to see' errors (Walker, 2011). These may be particularly common in areas with low cycling rates. Again, this suggests the strategy of carefully moving away from the junction before the lights change may be a rational, albeit illegal, act of self-preservation.

Some studies appear to recommend measures to encourage higher compliance without necessarily justifying why this is desirable. For example, Fraboni et al. (2018) and Pai and Jou (2014) suggest running public education programs to tackle the issue, while Richardson and Caulfield (2015) go further, stating there is an "urgent need" for the police to act to "deter illegal cyclist behaviour and punish offenders". It is perhaps surprising that studies tend not to recommend that cities could adopt an 'Idaho Stop' style law, as discussed in Section 1.

2.4.3 Non-Safety Justifications for Running Red Lights

Saving energy is also a factor for cyclists that does not apply to drivers in the same way, with more physical exertion required to start from a complete stop compared to just slowing down (Marshall, Piatkowski, and A. Johnson, 2017, Schleinitz et al., 2019). Other justifications include that an inductive loop did not detect their bike (hence not triggering the needed green light phase) or that there were no other road users present (M. Johnson, Charlton, Oxley, and Newstead, 2013).

2.4.4 Compliance Rates

Compliance with red lights by cyclists has been studied in a number of cities and junctions, with very significant variation in the results obtained.

Transport for London (2007) found 84% compliance with red lights during a study of five junctions in London during weekday AM and PM peak periods, with male cyclists around 30% more likely to offend than females. They also found cyclists less likely to offend when turning right than other manoeuvres.

Some differences were seen in compliance rates across the junctions surveyed and even different arms of the same junction. Compliance rates varied between 79% and 87%.

Unfortunately, driver behaviour was not recorded and no distinction was made between cyclists who ran the red light cautiously (after giving way) and those who did so in a more reckless way. Similarly, only weekday peak periods were monitored. It is also not clear if all junctions were monitored on the same day - other potential factors like weather may have contributed if not. The five sites were seemingly chosen arbitrarily and the report admits that this is a small sample and may not provide statistically reliable results.

A study in Bologna, Italy found much lower compliance rates across 4 sites observed during morning and afternoon peak periods. Just 37% of observed cyclists fully complied, with 30% violating after an initial stop and 33% not stopping at all (Fraboni et al., 2018). It is not clear why such a difference is seen relative to the London study discussed above, though it may be that the larger and more complex junctions in the London study and/or cultural differences may have contributed. Like in London, males were more prone to violate than females. They also found that older cyclists are more likely to follow the rules. No association was found with headphone usage.

Another factor seen in the Italian study was that cyclists are less likely to violate the red light when other cyclists are present and waiting. They speculate that this may be due to social influence, which certainly seems plausible.

In Melbourne, Australia, a study of red-light running focused on peak periods, with the authors choosing to target commuter cyclists through their choice of locations. Overall compliance was high at 97% in the morning and 89% in the afternoon (M. Johnson, Charlton, and Oxley, 2008). The reason for the difference between violations in the morning and afternoon is not clear; perhaps different arms of the junction were more heavily used at different times with different characteristics, different manoeuvres more typical or some demographic differences existed between the cyclists using the junction at the different times. It does further highlight that a large number of independent variables may influence compliance.

A comparison between personal bike riders and those using shared bikes was conducted in China, finding incidences of red-light running to be significantly higher among those riding personal bikes (46% vs. 15%) (Gao et al., 2020). This could be due to different demographics of those groups and/or different amount of cycling experience. If many bike-share riders are newer to cycling, they may be more cautious. The heavy slow nature of the bikes themselves could also contribute to riders not having the confidence to get through gaps in traffic in time, preferring to wait for green.

Marshall, Piatkowski, and A. Johnson (2017) note that many existing studies focus on law-breaking as a binary, whereas in reality there are grades of illegal bicycling behaviour. For example, stopping to check an intersection is clear and continuing carefully if so is rather different to completely ignoring a red light and going through the junction at speed regardless of the presence of other vehicles. They sought to fill that gap through their survey, though self-reported studies have their own limitations compared to observational studies (and vice-versa).

The research provides some useful insights, especially since the questionnaire was completed more than 18,000 times thanks to snowball sampling. They asked people who cycle to tell them what they would do at certain concrete scenarios (supported by photos), with granular options. For example, if approaching a pictured junction at a red light, would they wait for green, slow down and continue if no traffic, stop then continue if no traffic or continue without slowing down. They also asked demographic questions and questions about their experience as a cyclist and driver.

They found that while almost all cyclists (95.87% of respondents to their survey) do break the law at least occasionally, very few do so in a reckless way, as shown in Figure 2.5. This is based on the responses to the seven scenario questions. Of course, this data has its limitations - it is hard to know how representative the sample was or that how they answered the questions reflects reality. The coding of the answers as 'minor infringement', 'major infringement' or 'reckless endangerment' is also a subjective process. Nevertheless, it does provide an insight into the way in which many cyclists do break the law - largely in relatively minor ways.

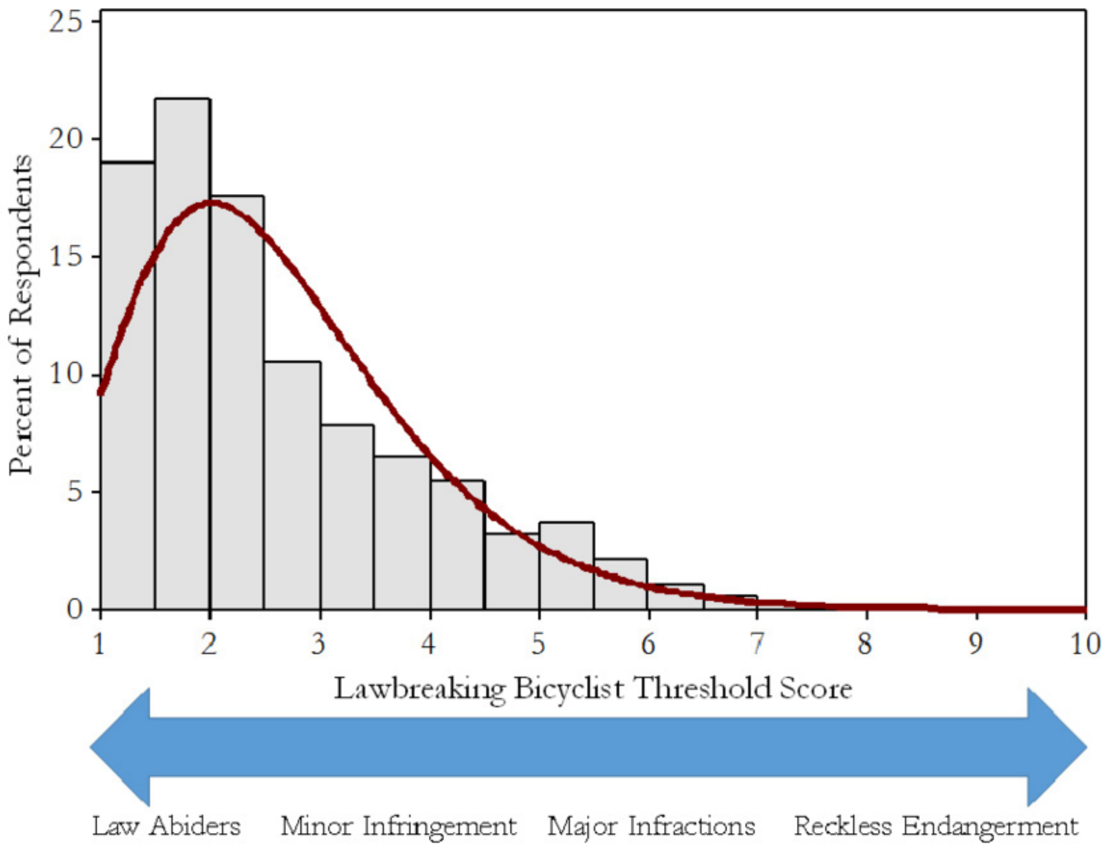

Figure 2.5: Histogram showing Lawbreaking bicyclist threshold scores and distribution (Image Source: Marshall, Piatkowski, and A. Johnson, 2017)

Notably, the same research found that almost all respondents (99.97%) also admitted to breaking the law when driving, at least occasionally (Marshall, Piatkowski, and A. Johnson, 2017).

2.4.5 Factors Influencing Red-Light Running by Cyclists

Various factors have been found to affect the propensity for cyclists to jump red lights. These are summarised in Table 2.2.

Table 2.2: Factors Found to Influence Red-Light Running by Cyclists

Factor	**Description**	**Source**
Gender	Males are more likely to offend	M. Johnson, Charlton, Oxley, and Newstead (2013)
Age	Younger people are more likely to offend	M. Johnson, Charlton, Oxley, and Newstead (2013)
Helmet usage	People not wearing helmets are more likely to offend	Pai and Jou (2014)
Bike share users	Bike share riders are less likely to offend	Gao et al. (2020)
Number of other cyclists stopped	Cyclists more likely to stop where other cyclists are stopped	Fraboni, Marín Puchades, De Angelis, Prati, et al. (2016)
Crash involvement	Cyclists who have not been in a crash are more likely to infringe	M. Johnson, Charlton, Oxley, and Newstead (2013)

E-bike users were found more likely to infringe in Taiwan (Pai and Jou, 2014), but this was not found to be the case in Germany (Schleinitz et al., 2019). The finding that bike share users were more likely to infringe was not replicated in a study in Dublin, Ireland (Richardson and Caulfield, 2015).

2.5 Junction Design

As well as the cyclists themselves, the junction has also been seen to affect propensity to go through a red light. Junctions with a short red-light duration and T/Y intersections were found to have more red-light jumping by cyclists in Taiwan (Pai and Jou, 2014).

One blog about cycling in the Netherlands presents an interesting case study of two junctions in Utrecht, one which has very high compliance with the red light and the other very low. The author speculates that low traffic volumes at the latter means cyclists have learned that the lights are unnecessary, whereas obeying the former is needed to keep them safe (Treasure, 2015).

The effect of junction design, in particular cycle facilities provided, on red-light running by different road users has been investigated by several studies.

2.5.1 Advanced Stop Line

Advanced Stop Lines allow cyclists to position themselves at the front of a queue of traffic, improving their visibility. While they have been implemented at many junctions across the UK, the latest guidance from Transport Scotland and the Department for Transport notes their limitations (Transport Scotland, 2021, Department for Transport, 2020).

As discussed in Section 1, drivers must stop at the first stopline if their signal is at red, but cyclists may pass that and instead stop at a second stopline.

Whether ASLs have an impact on red light running was examined by Transport for London (2006), who found a higher propensity for cyclists to violate red lights was higher when ASLs were present (17% vs 13%). However, the study also noted that the rate varied significantly (from 3% to 36%), presumably due to factors other than the presence or absence of the ASL, making it hard to draw any firm conclusion.

They also found that where ASLs were not provided, 54% of cyclists waited beyond the stopline (effectively breaking the law to create their own ASL); this is particularly problematic if they wait in the pedestrian crossing area. Perhaps unsurprisingly, this was less when an ASL was provided (40%), though the reduction might have been expected to be greater.

Drivers were found to routinely encroach onto the space reserved for cyclists; 36% of cyclists experienced this issue when using an ASL in the study. The authors suggest further research with a longitudinal study comparing before an after an ASL is implemented at a sample of junctions, which would mean site-specific features would be controlled for; however, it does not appear that any such research has been published.

2.5.2 Starting Amber and Early Release Cycle Lights

In the UK, all green aspects are preceded by a two-second ‘starting amber’ period where both the red and amber aspects are displayed simultaneously. The significance of this is to indicate to road users that the lights are about to change to green; however, they must remain stopped until the green light is shown. Time to prepare was particularly important when driving older cars, for example those with manual chokes. This phase does not exist in many other countries (including France, Spain, Ireland and the USA), where the light changes directly from red to green (Maxwell, 2006).

A 2006 study (ibid.) found that at junctions, 39% of vehicles crossed the stopline before green at the five UK junctions studied. Across junctions and signalised pedestrian crossings, the mean time to cross the start line was 1.75 seconds after the onset of starting amber, i.e. 0.25 seconds before the green. The study suggest that there are limited safety concerns with this type of minor red light jumping since drivers tend to cross the stopline during the starting amber phase cautiously and only when the junction is clear and that doing so increases the capacity of the junction. A reduction in the length of the phase to 1s or 1.5s is suggested (mirroring similar reductions in Finland and Sweden), though the cost may be prohibitively high for the expected benefits.

Early release cycle lights are a relatively new innovation in the UK, with the first implemented in York in 2010 (Department for Transport, 2016). They allow cyclists to start a few seconds ahead of motor vehicles, reducing risk of left hook type collisions (where a left-turning vehicle hits a cyclist, perhaps in its blind spot). The signal timings for junctions with and without early release can be seen in Tables 2.3 and 2.4 respectively. However, they bring a new opportunity for law-breaking behaviour, as some drivers may move off during the cycle-only phase while their own light is red or be more likely to set off during the starting amber phase.

Table 2.3: Signal Timings - Junctions with Early Release

Lights shown	**Duration**	**Traffic that may proceed**
Red light + green cycle light	3 seconds[1]	Pedal cycles only
Red and amber lights + green cycle light	2 seconds	Pedal cycles only
Full green light	*varies*	All traffic
Amber light	3 seconds	No traffic, unless unable to stop safely
Red light	*varies*	No traffic

[1] This is not a fixed time at all junctions with early release, but appears to be the typical duration used in Edinburgh

Table 2.4: Signal Timings - Junctions without Early Release

Lights shown	**Duration**	**Traffic that may proceed**
Red and amber lights	2 seconds	No traffic
Full green light	*varies*	All traffic
Amber light	3 seconds	No traffic, unless unable to stop safely
Red light	*varies*	No traffic

Two major studies have been conducted, both by the Transport Research Laboratory (TRL), one on a track and the other after these signals were introduced on some junctions in London. The track-based study (Ball et al., 2015) found variation in how much drivers tended to set off before their green signal depended on the length of the early release - longer early release times led to higher proportions of drivers setting off too early. For example, with a 4 second early release, between 4 and 6% of drivers moved off before the main signals changed to starting amber, but around 40% would set off before the full green aspect.

Figure 2.6: Photo of the approach to the junction of Burdett Road and Mile End Road in London, showing the early release signals for cyclists (Image Source: Google Maps Street View)

Similarly, cyclists tended to set off during their starting amber period when early release lights were provided to them with a cycle-only red and amber; this phase is not used at all early release lights (contrast Figures 2.6 and 1.2; the former has red, amber and green cycle-only lights, the latter only has green).

Justifications given by car drivers and motorcyclists for starting during the cyclist-only phase included "it can be easy to glance at the green cycle and just take off if you are not concentrating" and "motorcycles need space and safety".

There are several limitations - firstly, that behaviour during a trial may not reflect real-world behaviour. Secondly, the report focuses on drivers setting off during the cyclist-only period with the main signals at red and only touches upon motorists setting off during their own starting amber - a violation of the law and an action that reduces the effectiveness of the cycle early release.

A subsequent study of real-world observations (Clifford et al., 2018) looked at four London junctions with 4-second early release for cyclists with low-level cycle signals. It found that between 64 and 93% of drivers proceeded on the main green light, with between 0 and 33% proceeding on starting amber and between 0 and 7% proceeding during the early release phase. Interestingly, results differed significantly across the four junctions studied. The authors do not speculate as to why this may have been the case.

2.5.3 Other Cycling Infrastructure

There is clearly a wide range of cycling infrastructure, all of which may affect compliance rates. An observational study in Dublin found cyclists more likely to offend where there was a cycle track and bicycle traffic lights compared to a cycle lane and regular traffic lights (Richardson and Caulfield, 2015).

2.6 Gig Economy

The prevalence of people driving, riding motorbikes and cycling due to work in the 'gig economy' has risen significantly in recent years; in fact, the proportion of people in England and Wales doing delivery/driving work through platforms is estimated to have quadrupled between 2016 and 2021 (Trades Union Congress, 2021). Since these workers are paid per job (or 'gig') rather than per hour, they may have more incentive to bend and break road rules in order to earn a better hourly rate. In a study by Christie and Ward (2019), one person who delivers food by motorbike sums up how he maximises his earnings:

> You ignore all the road signs and you just speed all the time. I got 2 tickets for running through a red light.

Similarly, someone who delivers parcels by car reported 'amber gambling':

> There are times where yes, you will, go faster than the speed limit, or you will gamble on an amber light just to get through it. Just to save that bit of time, so yes, most definitely

Of a sample size of 138 car drivers, 66 pedal cyclists and 27 two-wheeled motor vehicle gig economy workers, around 15% of drivers agreed with the statement “I have driven/ridden through a red light when I’ve been under pressure” compared to 55% of pedal cyclists and 35% of powered two wheeler riders.

This suggests that among gig economy workers, pedal cyclists are most likely to violate red lights. This may be due to the greater opportunity they have to do so (since they can filter to the front of a queue), a sense that they are less likely to face consequences (in legal and/or safety terms) or other reasons.

Chapter 3

Research Aims and Questions

Following the identification of gaps in the literature, the following research questions have been identified, alongside the relevant null (H_0) and alternative (H_a) hypotheses.

3.1 Research Question 1

What proportion of people driving and cycling run red lights at a given junction and with what severity?

- H_0: There is no significant difference in the rate at which cyclists and motor vehicle drivers run red lights at a given junction
- H_a: There is a significant difference in the rate at which cyclists and motor vehicle drivers run red lights at a given junction

3.2 Research Question 2

How does the presence of cycle facilities at a junction influence law-breaking behaviour?

- H_0: There is no significant difference in the rate at which cyclists and motor vehicle drivers run red lights at junctions with different cycle facilities
- H_a: There is a significant difference in the rate at which cyclists and motor vehicle drivers run red lights at junctions with different cycle facilities

3.3 Research Question 3

Do people driving/cycling in the ‘gig economy’ offend more than the average driver/cyclist?

- H_0: There is no significant difference in the rate at which cyclists and motor vehicle drivers who are driving/riding for work run red lights compared to those not driving/riding for work
- H_a: There is a significant difference in the rate at which cyclists and motor vehicle drivers who are driving/riding for work run red lights compared to those not driving/riding for work

To compare behaviours by drivers and cyclists, it is necessary to determine what we mean by ‘severity’ in terms of law breaking. As discussed in Section 2.4.1, red-light running should not necessarily be viewed as a binary but with more granularity. A classification, influenced by that of Fraboni et al. (2018) is introduced in Table 3.1.

Table 3.1: Categorisation of Behaviour at Red Lights by Cyclists/Drivers

Severity	Description
Law Abiding	Stopping at a red light before the relevant stopline and remaining stopped for the duration of the red light
Minor Offence	Stopping at a red light after the relevant stopline but before entering the junction and/or setting off during the cycle-only or starting amber period
Serious Offence	Entering a junction through a red light after slowing down considerably or stopping and giving way to other road users
Very Serious Offence	Entering a junction through a red light without slowing down considerably or stopping and giving way to other road users

Ultimately, the classification of activities is subjective. As a result, after compiling an initial classification, consultation was sought from Cycling Scotland's Cycle Road Safety Manager (a former police superintendent) and the final version above is the one made taking his input into consideration.

Due to the limitations of monitoring, the focus is purely on red-light related offences and will not cover other offences at junctions (e.g. use of mobile phones, illegal turns at green lights).

Chapter 4

Methodology

4.1 Data Gathering

Data was gathered by recording footage of the approach to various junctions in Edinburgh using portable video cameras (GoPro Hero 5 Black devices recording at 1080p50) mounted on appropriate fixed points (e.g. lamp posts). The cameras were positioned so that the stopline(s) were visible on all lanes of approach to the junction and the state of the traffic light (e.g. red, green) captured. In order to minimise personal data captured, vehicles were filmed from behind so that, as far as possible, faces of drivers and cyclists are not captured. Two cameras were used simultaneously so that both the stopline and the signal heads were clearly visible. An example can be seen in Figure 4.1.

Figure 4.1: Photo of two GoPro video cameras recording a stopline (Image Source: Author)

The two videos were synchronised to within approximately one-hundredth of a second by recording a stopwatch on an iPhone while filming both videos and synchronising those frames in DataVyu as shown in Figure 4.2.

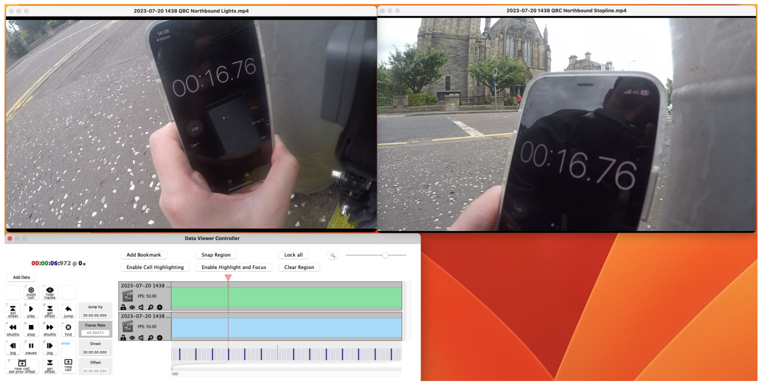

Figure 4.2: Screenshot of software being used to synchronise videos from two cameras (Image Source: Author)

The cameras were left running for one to two hours at a time while the author stayed in the vicinity of the area to record information about any noteworthy conditions outwith the view of the camera and ensure the cameras remained in place. A sign was put up next to one of the cameras to explain its purpose (transport research) and the contact details of the person to contact with questions (the dissertation supervisor). This ensured the data collection complied with all measures addressed in the ethics approval.

4.1.1 Junctions

There are countless junctions in Edinburgh which could be analysed. Due to time constraints, only a small proportion of them could realistically be included in this research. In order to answer research question 2 (as defined in Section 3.2), it was necessary to monitor junctions with different cycle facilities.

It is clear from the literature review that there are a large range of factors that influence propensity to run a red light. As an observational study (rather than, for example, using a simulator), there will be limits in the ability to draw firm conclusions. For example, one junction may see more violations than another, but it will not be possible to say with certainty whether this is down to the cycle time, busyness of junction, number of approach lanes etc, since multiple independent variables will inevitably be different across junctions analysed.

To minimise this effect, junctions chosen were all in central Edinburgh, with relatively similar traffic volumes (all main roads), same posted speed limit (20mph). Initially, it was planned to limit junctions to those without left or right turns (since turning traffic may be banned); in the end, this was true of four of the five junctions and at the fifth, proportion of turning traffic was very low.

4.1.2 Description of Each Monitored Junction Arm

4.1.2.1 Mayfield Road (Northbound at Fountainhall Road)

The junction is in the Newington area of Edinburgh, just south of the city centre. Mayfield Road is used as a through route for north-south traffic. It forms part of a cycle route connecting Edinburgh University's main campus to its King's Buildings site. Bollards were added to parts of the route as part of the Spaces for People program during the COVID-19 pandemic and remain in place. Early release lights for cycles were installed at some time between March 2021 and October 2022 (range of dates established using Google Maps Street View). Other than the early release for cycles, it is a fairly typical junction - all approaches are two-way for all traffic and there are no banned turns nor specific facilities for turning right. An all-pedestrian phase is provided when requested via a push button.

The arm of the junction being monitored has one lane on its approach for general traffic with a semi-segregated cycle lane, as shown in Figure 4.3 (note the white car in the foreground is parked in a floating parking bay). It is on a slight uphill gradient.

Figure 4.3: Photo of Mayfield Road (Northbound at Fountainhall Road) (Image Source: Author)

4.1.2.2 The Mound (Northbound at Princes Street)

The Mound forms one of the main north-south routes in central Edinburgh, with one general traffic lane in each direction and a paint-only advisory cycle lane. As it crosses Princes Street, all traffic must proceed straight ahead as both left and right turns are banned. The banned turns facilitate parallel (also known as walk-with-traffic) pedestrian crossings; while north-south traffic proceeds, north-south pedestrian crossings have a green man. The east-west arm along Princes Street operates in the same way, with all turns being banned and parallel pedestrian crossings utilised. The junction has a large yellow box in the centre, which traffic must not enter unless their exit is clear. However, the yellow paint is quite faded and may not be obvious.

The only exception to the banned turns is that cycles can turn left from the Mound onto Princes Street by using dropped kerbs just before the junction to access a small section of shared use pavement. However, the markings for this are very faded and the shared use sign turned around, so there may be limited awareness of this facility (the markings as they were in 2013 and in 2023 are shown in Figure 4.4).

(a) Photo of left-turn bypass for cycles at The Mound/Princes Street junction in 2013 (Image Source: Robson (2013))

(b) Photo of left-turn bypass for cycles at The Mound/Princes Street junction in 2023 (Image Source: Author)

Figure 4.4: Photos contrasting original and faded markings and turned sign indicating that cyclists can turn left before the signal-controlled junction at The Mound

Early release cycle lights were installed as part of Edinburgh Council's Tram Cycle Safety project in 2021 since trams run east to west through the junction along Prince Street.

4.1.2.3 Lothian Road (Northbound at Morrison Street)

Lothian Road forms part of the A700, one of the major through routes for traffic in Edinburgh, running north-south just to the west of the city centre. The number of lanes of traffic provided varies along the road; at the point observed there is a part-time bus lane and general traffic lane. During the observations the bus lane was not active and there were vehicles parked in it for most of the time, effectively reducing the road to one lane.

The junction in question is a rather complicated one in a sense, with filter lights and banned turns used to facilitate parallel pedestrian crossings, presumably to maximise capacity. On the northbound approach at Morrison Street, both turns are banned for all road users; the left-turn since Morrison Street is one-way and turning into it would be turning into oncoming traffic, the right turn into Bread Street is banned to protect a pedestrian crossing. The junction can be seen in Figure 4.5.

An ASL is provided for cyclists, but no early release signals. No cycle lanes are provided on approach.

Figure 4.5: Photo of Lothian Road (Northbound at Morrison Street) (Image Source: Google Maps Street View)

Lothian Road was also chosen in order to capture people cycling for food delivery, since there are many restaurants and takeaways in the area, as shown in Figure 4.6 (the Subway restaurant highlighted in the screenshot is at the junction monitored).

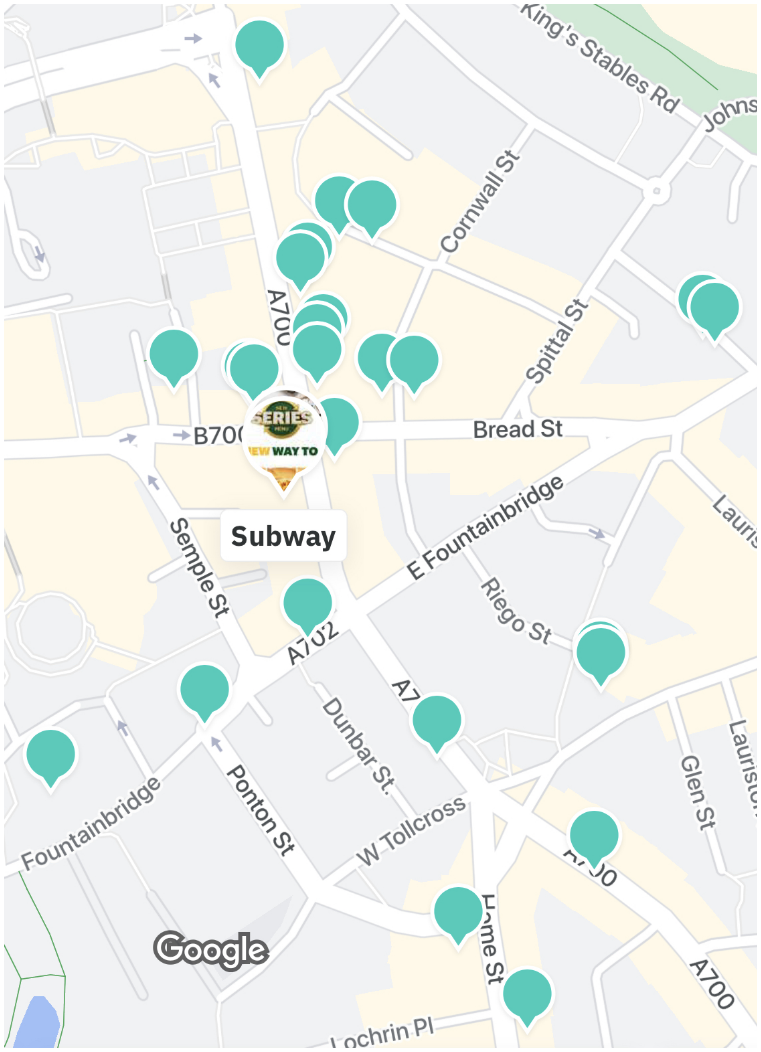

Figure 4.6: Screenshot showing restaurants and takeaways on Deliveroo near Lothian Road (A700 running top to bottom in image) (Image Source: Deliveroo App)

4.1.2.4 Torphichen Street (Westbound at West Maitland Street / Atholl Place)

Torphichen Street forms a through route for traffic in Edinburgh going between the north-west and south parts of the city. It is particularly important for private motor vehicles, since various streets and turns are banned around Princes Street in the city centre and the detour to avoid them often involves passing through Torphichen Street.

As shown in Figure 4.7, there is one lane on the approach to the junction (with two lanes going in the other direction) and all turns are banned, with all traffic required to go straight ahead. The banned turns protect parallel pedestrian crossings. All traffic entering the junction from this arm will have just passed another set of traffic lights and turned left around 50m before the stopline.

Figure 4.7: Photo of Torphichen Street (Westbound at West Maitland Street / Atholl Place) (Image Source: Author)

Unusually, no cycle facilities are provided at all, not even an ASL (which appear to be almost universal in Edinburgh). The reason for this is unclear, though may be due to a relatively low number of cyclists using the junction (since cyclists can use alternate more direct routes not available to car drivers for many journeys that would pass through the junction).

4.1.2.5 Palmerston Place (Eastbound at West Maitland Street / Atholl Place)

This approach is similar to the one described above in Section 4.1.2.4, being the opposite approach to the same junction.

All traffic must proceed straight ahead to protect the parallel pedestrian crossings. However, unlike the opposite arm, there are two lanes on approach and cycle facilities are provided in the form of an ASL and early release signals, as can be seen in Figure 4.8.

During the period observed, Haymarket Terrace was closed eastbound for roadworks and this may have led to higher levels of traffic on Palmerston Place than normal.

Figure 4.8: Photo of Palmerston Place (Eastbound at West Maitland Street / Atholl Place) (Image Source: Author)

4.1.3 Times to Record

Ideally, recording would have taken place at a variety of times, chosen systematically and the same for each junction. One study by Clifford et al. (2018), mentioned in Section 2.5.2, sampled the first two signal cycles per hour of junctions studied for 14 hours per day over a one-week period. Unfortunately, resource constraints mean such an approach was not possible in this case.

Instead, approximately 2 hours were recorded at each junction during daytime hours (between

0830 and 1830). Recordings were taken during Monday to Friday only.

Due to the timing of the MSc Transport Planning and Engineering course being undertaken, all recordings took place in July and early August, during which time local schools are on holiday. This means traffic volumes were likely be lower than during term times. This may have affected the results.

4.2 Analysis

The footage from the two cameras was synchronised using DataVyu software. All road users with an opportunity to run the red light (i.e. those who could physically have passed the red light if they chose to) were recorded (initially in Excel, then exported to SPSS), categorised according to the classification in Table 3.1. Vehicles that passed through the junction on a green light or amber light (without the red being displayed at the same time) were not recorded.

A pilot was undertaken on Monday 10 July with a short amount of footage at one junction taken and analysed to determine likely time required for analysis and whether noting all issues in Table 3.1 was realistic. This also helped determine the optimal locations of the cameras (in terms of factors such as height, angle, distance from junction) and how to best synchronise the two cameras when doing analysis.

One issue noted in the pilot was defining exactly what certain terms meant, especially relating to 'the stopline'. A consistent approach was required, and the following examples help to show where the line was drawn.

For cars, bikes and other vehicles with small front overhang, a vehicle was recorded as having crossed a stopline if the front wheel had fully crossed the stopline. For example, if the vehicle shown in Figure 4.9 had stopped in this position, it would have been recorded as having stopped correctly, but had it stopped in the position shown in Figure 4.10 (having crossed on a red light), it would have been recorded as stopping after the relevant stopline.

Figure 4.9: Photo of a van which would be recorded as having stopped correctly (Image Source: Author)

Figure 4.10: Photo of a van which would be recorded as having stopped over the stopline) (Image Source: Author)

However, for lorries, buses and other vehicles with large front overhangs, the front of the vehicle rather than the wheel was used as the reference point. This was necessary to avoid situations like the bus in Figure 4.11 being recorded as stopping correctly even as it blocks a significant proportion of the ASL. Due to the camera angle, this sometimes required a certain amount of judgement; the benefit of the doubt was given where there was any ambiguity.

Figure 4.11: Photo of a bus which would be recorded as having stopped over the stopline (Image Source: Author)

Following the completion of data collection, data analysis was undertaken to determine basic statistics including the average number of drivers and cyclists breaking the law overall, then breaking the overall results down by junction, severity of offence, whether or not the driver/rider appears to be working in the gig economy and other recorded factors. Statistical tests were then carried out to determine if differences between types of road user (cyclist/driver, gig economy/other) and junction were statistically significant and the null hypothesis could be discounted.

4.2.1 Limitations

4.2.1.1 Identifying Gig Economy Workers

When identifying people driving and cycling as part of the 'gig economy', it is impossible to all those drivers/cyclists or to be sure not to count people who are not. For example, it is easy to identify taxis and private hires since they must have signage on the vehicle. For cyclists, those delivering for food delivery companies tend to have a distinctive large branded backpack.

However, it is effectively impossible to know if a driver is delivering for a food delivery company. Similarly, we cannot know if a car marked as a private hire is being used as a private hire or if it is being used for non-work purposes.

4.2.1.2 Law-Breaking Behaviour Not Recorded

During the observations, it became clear that some behaviour was illegal and/or dangerous but not captured on camera. For example, blocking box junctions (those with a box of criss-cross yellow lines painted on the road that drivers must not enter unless they can exit it, unless turning right).

A decision was made only to focus on law-breaking while the lights were at red. Law-breaking while the lights were green was not analysed (for example, turning left where that turn is banned).

Chapter 5

Results and Discussion

5.1 Descriptive Analysis

The five junctions described in Section 4.1.1 were surveyed during weekdays between 11 July and 4 August 2023. A total of 429 vehicles with an opportunity to run a red light were observed, of which 95 (22%) were pedal cycles, 14 (3%) powered two wheelers (mopeds and motorbikes) and the remaining 320 (78%) motor vehicles.

Of the 320 motor vehicles, 193 were cars (of which 66 were SUVs), 62 vans, 13 taxis, 19 private hires, 9 lorries, 21 buses/coaches and 3 other motor vehicles (two ambulances and one campervan), as shown in Figure 5.1.

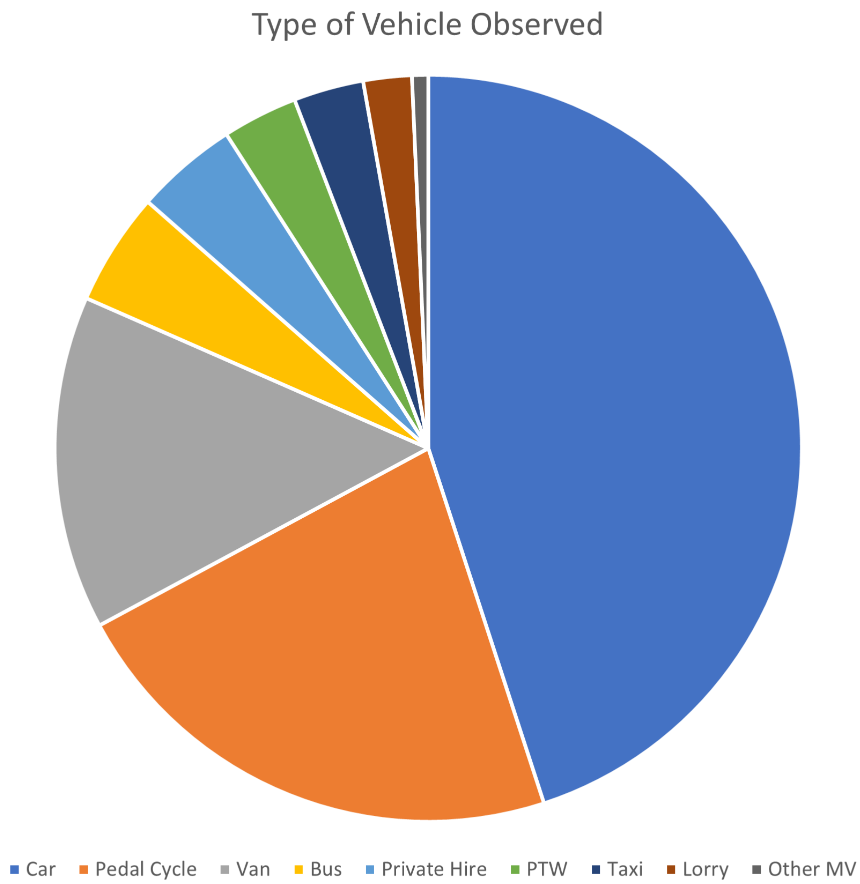

Figure 5.1: Graphical representation of type of vehicle observed

Of the 95 cyclists observed, 65 appeared to be male and 30 female, 59 were wearing a helmet, 12 appeared to be delivering food and 11 appeared to be riding e-bikes. These are shown in Figure 5.2. Except for helmet wearing, the above statistics required an element of judgement and may not be completely accurate. A man with long hair riding a bike with a step-through frame could easily be misidentified as female, for example, or an e-bike without an obvious battery or motor may have been recorded as an acoustic (i.e. non-electric) bike).

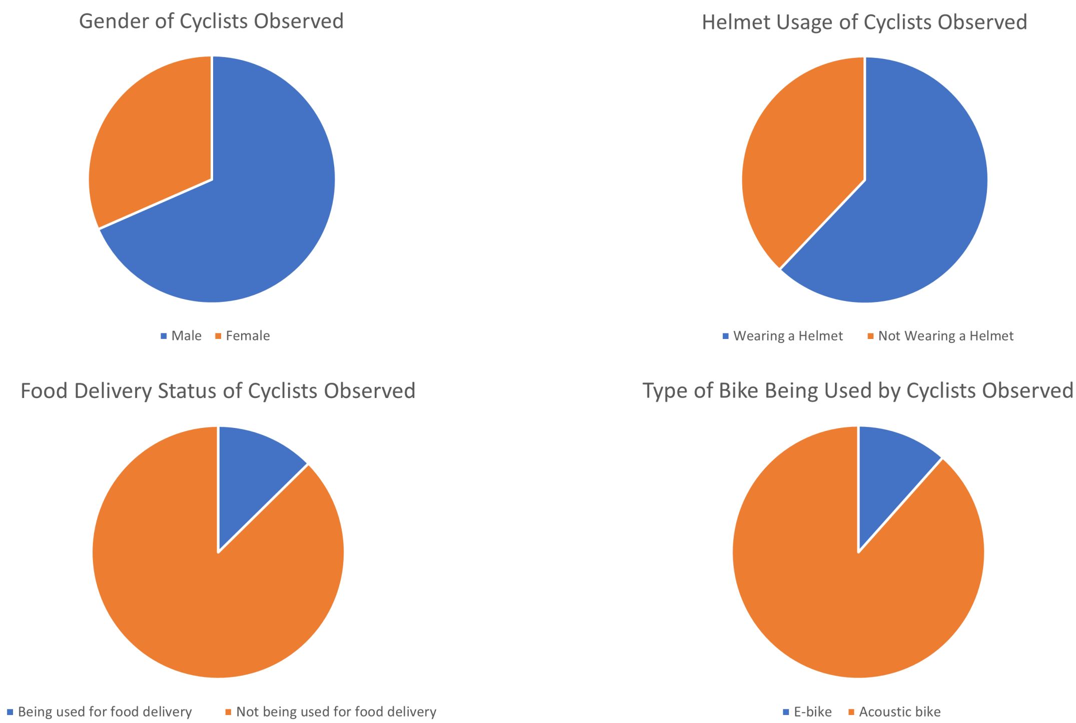

Figure 5.2: Graphical representation of properties of cyclists observed

The results, shown in Table 5.1 show that the proportion of motor vehicles and pedal cyclists completely obeying the law (e.g. severity 'legal' in Table 3.1) was very similar, at just over half for both groups, while just under half broke the law, including in relatively minor ways. For powered two wheelers, the vast majority (93%) broke the law.

Table 5.1: Overall Summary of Results

	Law Abiding	Not Law Abiding	Total
Motor Vehicles	170 (53%)	150 (47%)	320
Powered Two Wheelers	1 (7%)	13 (93%)	14
Pedal Cycles	51 (54%)	44 (46%)	95
Total	222	207	429

However, this highest-level summary has significant limitations, since the sample was not necessarily representative of the larger population as the research was not based on a representative sample of junctions.

Detailed analysis does, however, produce data that is more meaningful.

5.1.1 Summary by Cycle Facilities

Firstly, offending rates can be looked at by junction type, as shown in Table 5.2 and visually in bar charts in Figure 5.3.

Table 5.2: Behaviour by Motor Vehicle (MV) drivers, Powered Two Wheeler (PTW) riders and Pedal Cycle (PC) riders at different junction types

	Law Abiding			Not Law Abiding			Total		
	MV	PTW	PC	MV	PTW	PC	MV	PTW	PC
Junction with Early Release and ASL	41%	0%	72%	59%	100%	28%	195	11	58
Junction with ASL only	68%	33%	22%	32%	67%	78%	78	3	32
Junction with no Cycle Facilities	79%	-	40%	21%	-	60%	47	0	5
All Junctions (Total)	53%	7%	57%	47%	93%	43%	320	14	95

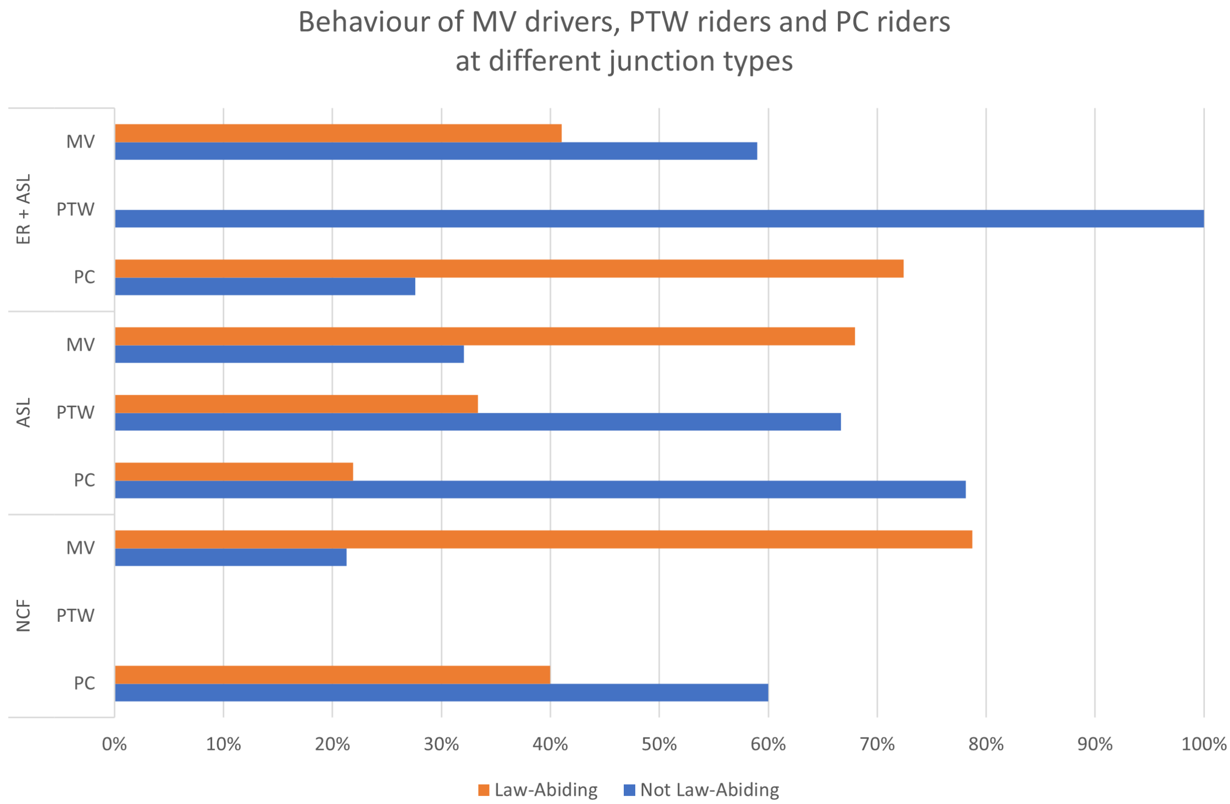

Figure 5.3: Graphical representation of behaviour of pedal cycle riders, powered two wheeler riders and motor vehicle drivers at junctions with Early Release (ER) and ASL, ASL only and No Cycle Facilities (NCF)

It is notable that people driving motor vehicles tended not to break the law where cycle facilities did not exist (79% law-abiding) or where only an ASL was provided (68% law-abiding), yet most drivers broke the law where an early release signal and ASL were provided (41% law-abiding). In other words, drivers observed were almost 3 times more likely to break the law at a junction with early release and ASL than one without any cycling facilities.

For cyclists, we see the opposite - where cyclists were provided with an early release and ASL, they tended to follow the law (72% law-abiding), yet were prone to breaking it where the early release was not provided (22%/40% law-abiding when an ASL was/was not provided). Statistical analysis of the effect of cycle infrastructure is provided in Section 5.2.1.

For motorists, the early release light gives extra notice that their lights are about to change - far more than needed to get into gear and release the handbrake. When drivers see the cycle light illuminated, there are still 5 seconds before they can legally go (3 seconds of cycle-only and 2 seconds of starting amber). While observing the junctions, it was noted that a number of car engines were started (after being stopped by the start-stop feature in modern cars) almost immediately after the cycle light illuminated, suggesting the driver had put the car into gear, ready to go - much sooner than is necessary.

At the same time, it is very difficult for cyclists to set off early at the junctions with early release studied since there is no starting amber phase for cyclists (so they do not get a warning that their green light is imminent).

It could be argued that where the early release is not provided, cyclists are often, in effect, creating their own early release by setting off during the starting amber phase (or even before it, where they know the sequence of the junction). Of course, this may not always be safe; where an early release is provided, the junction should be clear when the early release light begins, but the junction may not have cleared during starting amber at other junctions. However, it seems cyclists often use their judgement to determine if it is safe to proceed at that point. Similarly, where no ASL is provided or the ASL is occupied by a vehicle, cyclists often in effect make their own ASL - breaking the rules in the process, but often causing little in the way of harm.

5.1.2 Severity of Offences

As discussed in Section 2.4.1, rule-breaking comes in many forms, some much more severe than others. As expected, most rule-breaking observed is of the relatively minor type. Breaking the results down by severity, based on the categories established in Table 3.1 shows the different rates of offending at the different severities established.

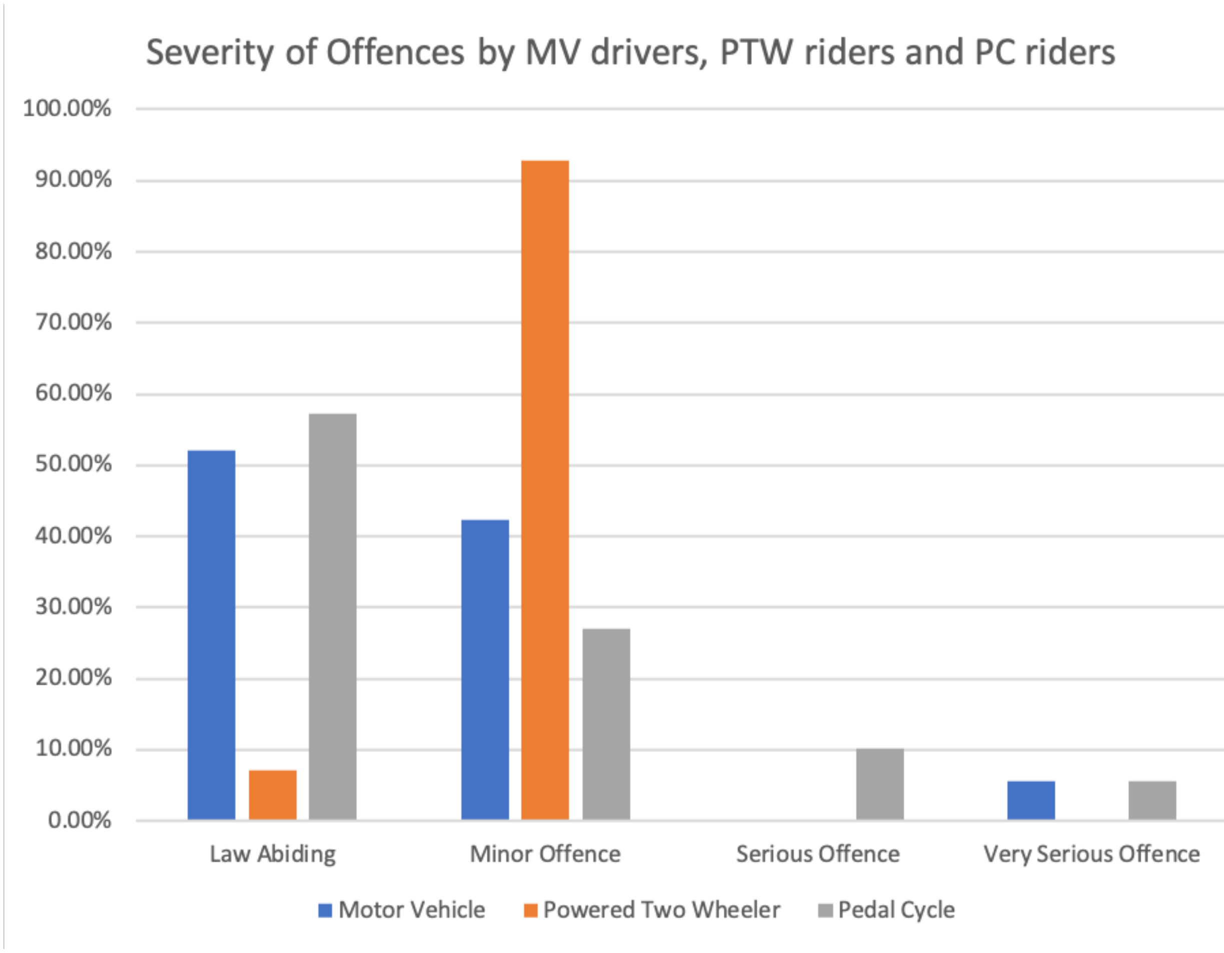

Figure 5.4: Graphical representation of offence type by vehicle type

As seen in Figure 5.4, minor offences (stopping over the line and/or setting off early) were by far the most common type of law-breaking behaviour seen among all groups; 42% of drivers and just over a quarter of cyclists (27%) were seen committing this offence. For powered two wheelers, the vast majority (93%) committed a minor offence, with the remaining 7% law-abiding; keep in mind, however, the small sample size for this vehicle type.

Serious and very serious offences were only seen in relatively small numbers; going through a red light after slowing down and giving way was, perhaps unsurprisingly, only observed among cyclists - 1 in 10 cyclists engaged in this behaviour. Going through a red light without slowing down and giving way, considered a very serious offence, was seen by approximately 6% of drivers and the same proportion of cyclists.

The nature of those offences was rather different - all the motor vehicles that committed this offence went through the lights just after they turned red - perhaps thinking they could 'beat the light' or simply assuming that breaking the light by a second or two was unlikely to result in a collision. This behaviour was seen among some cyclists, but others went through significantly after the lights had changed. Since no collisions were observed, perhaps they would have given way had it been required, though this is impossible to know. Of the 18 motor vehicles that went through on red, the time they crossed the first stopline they passed after the onset red ranged from 63 to 1596 milliseconds (mean 502ms, median 357ms).

Breaking this down by junction type, we can see the contingency table in Table 5.3.

Table 5.3: Specific Behaviour by Junction Type

	Law Abiding			Minor Offence			Serious Offence			Very Serious Offence			Total		
	MV	PTW	PC	MV	PTW	PC	MV	PTW	PC	MV	PTW	PC	MV	PTW	PC
Junction with Early Release and ASL	41%	0%	79%	52%	100%	19%	0%	0%	6%	7%	0%	6%	195	11	53
Junction with ASL only	68%	33%	22%	31%	67%	53%	0%	0%	19%	1%	0%	6%	78	3	32
Junction with No Cycle Facilities	79%	-	40%	13%	-	60%	0%	-	0%	9%	-	0%	47	0	5
All Junctions (Total)	53%	7%	57%	41%	93%	32%	0%	0%	9%	6%	0%	5%	320	14	90

5.1.3 Work vs Non-Work

Behaviour of motor vehicles has been broken down by whether the vehicle is one visibly used for work or not. The aim is to separate out drivers for whom 'time is money'. This includes taxis and private hires, vans and lorries. It does not include buses, since the driver should follow a timetable, so they may have quite different characteristics. The non-work vehicles are only cars; of course, some may be being driven for work, but this is impossible to know. The results can be seen in Table 5.4 and Figure 5.5.

Table 5.4: Comparison of Vehicles Being Driven for Work / Not Being Driven for Work

	Law Abiding	Minor Offence	Serious Offence	Very Serious Offence	Total
Taxi	31%	62%	0%	8%	13
Private Hire	32%	68%	0%	0%	19
Van	44%	48%	0%	8%	62
Lorry	44%	44%	0%	11%	9
Total Work MV	40%	53%	0%	7%	103
Non-Work MV (Car)	61%	34%	0%	6%	193
Work Pedal Cycle	33%	42%	17%	8%	12
Non-Work Pedal Cycle	57%	30%	8%	5%	83

The data shows that car drivers observed were around 50% more likely to fully comply with the law (61%) compared to motor vehicles being driven for work (40%). The difference is even starker when looking at taxi and private hire drivers, less than a third of whom (31%) drove legally at the junctions observed.

The vast majority of the difference can be accounted for by committing a minor offence (53% vs 44%), while only a small difference is seen for the very serious offence of going through a red light without stopping or giving way (7% vs 6%).

For cyclists, the sample of people visibly cycling for work is rather low (12). In hindsight, more filming during peak delivery hours would have been helpful in gathering more samples of this group. Nevertheless, the samples captured show people cycling for work approximately 40% less likely to fully comply with the law compared to other cyclists. Their rate of careful red light jumping (after slowing down and giving way) was just over double that of other cyclists, perhaps showing them balancing the temptation to get ahead and earn more money against not wanting to be involved in a collision.

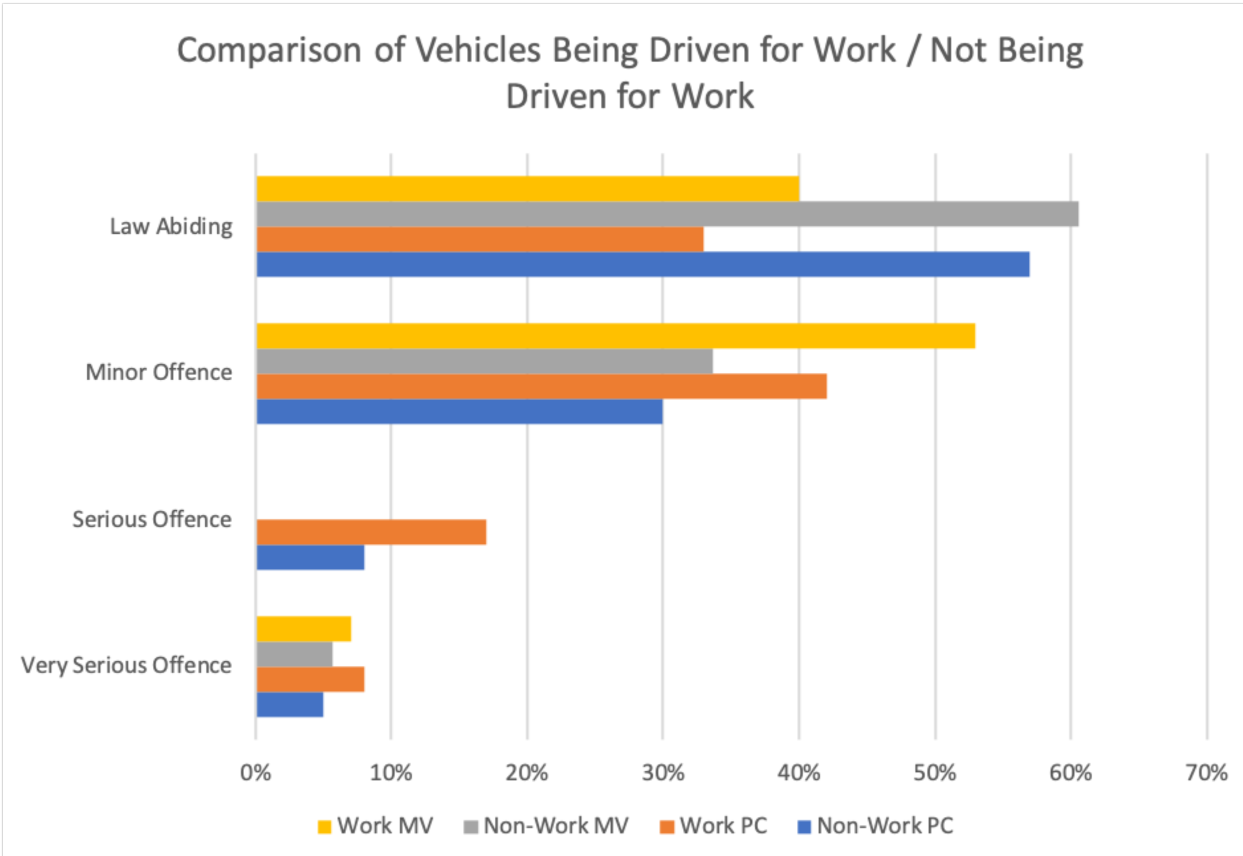

Figure 5.5: Graphical representation comparing offences committed by vehicles being driven for work with those not being driven for work

5.2 Statistical Analysis

While the previous section identified increased probabilities of seeing certain behaviour from certain road users, it merely reflects what was observed in the sample. To determine whether this difference is likely to be true of the wider population of road users, statistical analysis is required. Since the output being analysed is generally binary (e.g. lawbreaking or not, minor offence or not), binary logistic regression was used to test for statistical significance (within 95% confidence intervals) using IBM SPSS software.

5.2.1 Cycles and Junction Type

Firstly, a simple model has been created to consider whether, as a whole, cyclists are more likely than other road users to behave illegally at junctions and whether cycling facilities at junctions affect tendency to break the law.

For this model, we consider just two behaviours, law-abiding and law-breaking (covering all types of law-breaking) and two vehicle types, cyclist and other.

The binary logistic model was statistically significant, $\chi^2(2) = 14.15$, p=0.001. The model, shown in Table 5.5, shows that an increase in the provision of cycle facilities (coded as 0 = no facilities, 1 = ASL only, 2 = early release and ASL) corresponds with a higher likelihood of illegal behaviour.

Whether or not the road user was a cyclist was not statistically significant ($p = 0.546$) meaning we cannot reject the null hypothesis and do not find a statistically significant relationship between being a cyclist and breaking the law.

Table 5.5: Logistic Regression Predicting the Likelihood of Any Offence

							95% CI[1] OR	
	B	SE[2]	Wald	*df*[3]	*p*	OR[4]	LL[5]	UL[6]
Cycle Facilities	0.53	0.15	13.30	1	0.000	1.70	1.28	2.26
Cyclist	-0.14	0.24	0.36	1	0.546	0.87	0.55	1.38
Constant	-0.84	0.25	11.57	1	0.001	0.43		

If we consider only serious and very serious offences and two vehicle types, cyclist and other, we can create a binary logistic model to check how the cycle facilities at the junction and whether the road user was a cyclist has a statistically significant influence on this behaviour.

This binary logistic model was statistically significant, $\chi^2(2) = 8.22$, p=0.016. The model,

[1]Confidence Interval
[2]Standard Error
[3]degrees of freedom
[4]Odds Ratio
[5]Lower Limit
[6]Upper Limit

shown in Table 5.6, does not find evidence that the extent of cycle facilities at the junction affected rates of serious red-light jumping, but being a cyclist increased the chance by a factor of 3.06 (though with relatively high range within 95% confidence intervals - from 1.46 to 6.43).

Table 5.6: Logistic Regression Predicting the Likelihood of Serious/Very Serious Offences

							95% CI OR	
	B	SE	Wald	*df*	*p*	OR	LL	UL
Cycle Facilities	-0.10	0.27	0.14	1	0.705	0.90	0.54	1.53
Cyclist	1.12	0.38	8.74	1	0.003	3.06	1.46	6.43
Constant	-2.72	0.45	36.18	1	0.000	0.07		

Finally, when making a similar binary logistic model, but only considering very serious offences (i.e. going through a red light without slowing down or giving way) as the dependant variable, a statistically significant model is not found ($\chi^2(2) = 0.41$, p=0.980), meaning we cannot reject the null hypothesis and do not find a relationship between jumping a red light without slowing down and/or giving way and whether or not the road user is on a pedal bike when controlling for cycle facilities at the junction.

5.2.2 Work

When checking if those driving for work had a higher rate of law-breaking, the same definitions have been used as in Section 5.1.3.

If we consider all illegal behaviour, then a binary logistic model finds people driving/cycling for work 2.26 times more likely to break the law when controlling for the cycle facilities at the junction and whether we are considering a cyclist or motor vehicle driver. The model is statistically significant ($\chi^2(3) = 23.21$, $p<0.0005$) and shown in Table 5.7.

Table 5.7: Logistic Regression Predicting the Likelihood of Any Offence

							95% CI OR	
	B	SE	Wald	*df*	*p*	OR	LL	UL
Work	0.82	0.24	12.06	1	0.001	2.26	1.43	3.58
Cycle Facilities	0.45	0.15	8.80	1	0.003	1.57	1.17	2.12
Cyclist	0.13	0.25	0.28	1	0.586	1.44	0.71	1.86
Constant	-1.09	0.27	16.29	1	0.000	0.36		

Interestingly, when considering only serious or very serious offences (as defined in Table 3.1), the models were not statistically significant at 95% confidence; for the former, $\chi^2(3) = 7.218$, $p = 0.065$, with the p value for 'work' within the model 0.382, for the latter $\chi^2(3) = 0.402$, $p = 0.940$. This could simply be due to insufficient samples and a relationship may well exist; however, with the data gathered we cannot reject the null hypothesis.

5.3 Relationship to Previous Studies

As noted in other studies (e.g. Richardson and Caulfield, 2015), cultural differences make comparing behaviour across countries, or even cities, challenging. Nevertheless, it is interesting to compare results to this study to that examined in the literature review.

For most studies, red-light jumping refers to what this study calls serious or very serious offences, with minor offences not recorded. Overall levels of red-light jumping vary considerably across studies. The headline figure here is that 86% of observations of pedal cycles were compliant (e.g. not a serious or very serious offence). This is slightly lower than the 89% to 97% seen in Melbourne (M. Johnson, Charlton, and Oxley, 2008) and marginally higher than the 84% observed in London (Transport for London, 2007). It is also similar to the figure of 81% of junctions with a cycle lane in Dublin (Richardson and Caulfield, 2015. These studies were also looking at on-road cycling in major cities, so broadly similar results are not surprising.

On the other hand, compliance is much higher than what has been observed in Bologna; just 37% fully complied there. While cultural differences may play a role, half of the observations in their study were at red lights which are more akin to toucan crossings in a UK context; these are parallel to pedestrian crossings and cyclists may view them more like pedestrian crossings and not junctions per se. The finding that the vast majority (99%) of cyclists broke the cycle light at a junction with a bidirectional cycle track and dedicated cycle lights in Dublin emphasises the role of infrastructure in compliance - all of the junctions surveyed in this research had signficantly higher compliance.

In terms of the effect of ASLs on drivers, it is unfortunately hard to make a comparison with the observational study in London, since the present study has grouped stopping beyond the stopline with setting off early, whereas the study by Transport for London (2006) has recorded only ASL offences. Comparisons involving the behaviour of cyclists at junctions with ASLs is also not possible since the sample of cyclists at a junction without an ASL was very low in the present study.

When considering the effect of early release signals, again the grouping of stopping over the stopline with setting off early in the present study makes a comparison difficult. However, the higher rate of minor offending seen by people driving motor vehicles in the present study (52%) does seem to correspond to the relatively high proportion of motor vehicles setting off before the green general traffic signal at Webber Street, London, in an observational study (35% to 42%) (Clifford et al., 2018); the additional proportion in the present study may be partially or fully explained by the wider definition of 'minor offence'.

Finally, the higher rates of offending by people driving for work are consistent with the findings of the self-reported study by Christie and Ward (2019).

Chapter 6

Conclusion

6.1 Overall Conclusion

The title of the dissertation, *Driver and Cyclist Behaviour at Junctions: Who is Really Running Red Lights?*, does not have a simple answer, but rather *it depends*. What junction? How exactly do you define 'running a red light'?

When strictly counting all law-breaking behaviour, the answer is that both groups do so in significant numbers when presented with the opportunity to do so and no statistically significant difference was found between people cycling and other road users.

Is this something to be concerned about? It is hard to say for sure. A driver crossing their stopline to block a cyclists' ASL is not an ideal situation, but neither is it a particularly serious issue; some junctions do not have them at all and, even at the ones that do, they can legally be blocked when drivers get stuck there as the lights change. Similarly, people who set off a second (or a fraction of a second) before their lights turn green are undoubtedly breaking the law, but in a way that likely causes little danger. In terms of blocking ASLs, Transport for London have lobbied the DfT to decriminalise the offence in order for highway authorities to enforce the offence (London Assembly, 2017); effectively putting it in the same category as parking offences. When considering the latter scenario, Maxwell (2006) noted that while there was concern around the behaviour, there was no safety case to address it.

However, when we consider only serious and very serious offences (where the road user enters the junction on a full red light), then we do see a difference and it is people cycling who have a higher tendency to go through a red light - around 3.1 times more likely when controlling for the type of cycling infrastructure present. If we only consider very serious cases, where the road user does not slow down or give way first, then no statically significant difference is found between people cycling and other road user; whether this is due to no relationship existing or insufficient sample size is not known.

This largely ties in with the research mentioned in Section 2.4.4, which stated the many cyclists do break the law, but rarely in reckless ways (Marshall, Piatkowski, and A. Johnson, 2017). The fact that they are more likely to carefully go through a junction perhaps should not be a surprise and parallels could be made with pedestrians waiting to cross at the red man, who will only wait for green if there is traffic, but cross on red when there is a gap. The difference, in a UK context at least, is that the behaviour is legal for pedestrians but illegal for cyclists. In hindsight, perhaps labelling this as a 'serious offence' is a misnomer and it really is only serious when compared to the minor offences also recorded.

The impact of junction design is interesting and does not appear to have been significantly researched previously. The behaviour of motor vehicle drivers seems influenced by the type of junction, with the simplest signalised junction (without ASL or early release) resulting in few minor offences, but the junctions with ASLs or ASL and early release signals seeing significantly higher rates of minor offences. It seems that these cycle facilities give extra possibilities of minor offences for drivers who enter the ASL illegally or set off when only cycles are permitted to do so. For cyclists, it is exactly at those junctions with ASL and early release that they tend to abide fully with the law. Perhaps this should be little surprise; when the junctions are designed with their needs more in mind, they have less desire (or need) to behave illegally. After all, signalised junctions are only needed because of the presence of motor vehicles.

6.2 Main Limitations

Inevitably with the resources available, especially in terms of time, the research has significant limitations. The biggest one is the range of junctions studied, number of observations at each junction and range of times observed. Doing the research during the school summer holidays is also likely to have impacted traffic volumes and perhaps affected results.

Ultimately, serious and very serious offences are quite rare events, so a large overall sample is necessary to capture significant numbers of them; this is especially true when trying to capture these offences for uncommon road users (such as gig economy cyclists, lorries etc).

The only genuinely dangerous incidents observed during while filming did not fit any of the categories since they happened during a green light. These were blocking a box junction and ignoring a banned turn. Both of these led to vehicles being driven through the green man phase, but since the cameras did not capture this well enough and the parts of the video where they happened (the green phase) were not analysed, these do not form part of the results. Nevertheless, I do consider this a kind of limitation and it would have been interesting to capture this.

The lack of statistically significant results around serious offences for vehicles being driven for work may well reflect an insufficient sample size. Filming at peak delivery hours (i.e. Friday and Saturday evenings) could have helped overcome this.

6.3 Possible Future Work

There are many possible ways to build upon this research. Further research on early release signals would be welcome, given these are relatively novel and extensive research has not been conducted; in particular, their effect on driver behaviour. Comparisons could be made between junctions with early release in Edinburgh and junctions in London where the early release signal is only displayed low-level cycle lights and not the main signal head (e.g. Burdett Road/Mile End Road, as shown in Figure 2.6). If drivers are not looking at that signal, perhaps they will not notice it changing, avoiding or reducing the issue of them setting off early.

Looking at other emerging types of cycle infrastructure and road design would also be an avenue worth investigating - CYCLOPS junctions and hold-the-left junctions are quite new in the UK and may impact compliance by people cycling and/or other road users.

Another possible avenue for future research could be physiological measures of drivers during the early release and starting amber phases at signals with early release lights; for example, does their heart rate rise on anticipation of their own green signal upon seeing the green cycle light? The observations of drivers starting their engine when the cycle lights go green suggests there might be worthwhile research around this.

Beyond that it would be interesting to investigate attitudes towards an Idaho Stop-style rule at some junctions and even test its effect in trials in the UK.

Finally, it may be worth considering if all the minor infractions of drivers, including those identified in this study, add up to something more - perhaps an attitude that other rules of the road are open to interpretation too. The broken window model of policing - the theory that enforcing low-level offences can prevent serious crime - is considered controversial (Roberts, 2014), but perhaps it has something to offer roads policing as cities strive for vision zero. A transport psychology approach to this question may be an interesting avenue for future research.

Chapter 7

Bibliography

13 Comme Une, 2018. *Un nouveau panneau pour les vélos* [Online]. Available from: https://13commeune.fr/actualite/un-nouveau-panneau-pour-les-velos/ [Accessed June 17, 2023].

acb, 2007. *Every time a cyclist jumps a red light God kills a kitten* [Online]. Available from: https://www.flickr.com/photos/acb/1441893194/ [Accessed August 11, 2023].

Allan, C., 2023. *Cycling and pedestrians* [Online]. Available from: https://www.cyclinguk.org/briefing/cycling-and-pedestrians [Accessed June 12, 2023].

Ball, S.D., Hopkin, J., Chesterton, V., Gardner, R., Smith, R., Kandasamy, G., Knight, P., and York, I., 2015. *Low Level Cycle Signals with an early release: Track trial report* [Online]. Available from: https://trl.co.uk/Uploads/TRL/Documents/TfL%20Cycling%20trials/PPR733%20-%20Low%20Level%20Cycle%20Signals%20with%20an%20early%20release.pdf [Accessed July 23, 2023].

Bernardi, R., 2009. *Origins of Idaho's "stop as yield" law* [Online]. Available from: https://www.bicyclelaw.com/origins-of-idahos-stop-as-yield-law/ [Accessed June 7, 2023].

Bridge, A., 2010. *Traffic signals ahead sign, Belfast* [Online]. Available from: https://www.geograph.org.uk/photo/1699223 [Accessed June 26, 2023].

Christie, N. and Ward, H., 2019. The health and safety risks for people who drive for work in the gig economy. *Journal of Transport & Health* [Online], 13, pp.115–127. Available from: https://doi.org/10.1016/j.jth.2019.02.007.

Clifford, S., Millard, K., Greenshields, S., and Wells, A., 2018. *Low-level cycle signals: On-street observations of early release and hold the left* [Online]. Available from: https://trl.co.uk/uploads/trl/documents/PPR856%20-%20Low-Level%20Cycle%20Signals%20-%20On-Street%20Observations%20of%20Early%20Release%20and%20Hold%20the%20Left.pdf [Accessed July 23, 2023].

Department for Transport, 2016. *Cycle-only green lights installed in York* [Online]. Available from: https://www.gov.uk/government/case-studies/early-release-for-cyclists-at-traffic-signals-micklegate-york [Accessed July 23, 2023].

Department for Transport, 2019. *Traffic Signs Manual Chapter 6* [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/851465/dft-traffic-signs-manual-chapter-6.pdf [Accessed June 26, 2023].

Department for Transport, 2020. *Cycle infrastructure design (LTN 1/20)* [Online]. Available from: https://www.gov.uk/government/publications/cycle-infrastructure-design-ltn-120 [Accessed August 22, 2023].

Department for Transport, 2022. *Guide to contributory factors for reported road casualties Great Britain)* [Online]. Available from: https://www.gov.uk/government/publications/guide-to-contributory-factors-for-reported-road-casualty-statistics/guide-to-contributory-factors-for-reported-road-casualties-great-britain [Accessed July 5, 2023].

Fraboni, F., Marín Puchades, V., De Angelis, M., Pietrantoni, L., and Prati, G., 2018. Red-light running behavior of cyclists in Italy: An observational study. *Accident Analysis & Prevention* [Online], 120, pp.219–232. Available from: https://doi.org/10.1016/j.aap.2018.08.013.

Gao, Y., Schwebel, D., Zhang, L., Xiao, W., and Hu, G., 2020. Unsafe bicycling behavior in Changsha, China: A video-based observational study. *International Journal of Environmental Research and Public Health* [Online], 17, p.3256. Available from: `https://doi.org/10.3390/ijerph17093256`.

Gazis, D., Herman, R., and Maradudin, A., 1960. The problem of amber signal light in traffic flow. *Operations Research* [Online], 8, pp.112–132. Available from: `https://doi.org/10.1287/opre.8.1.112`.

Glass, A., 2015. *'let cyclists run red lights,' says pressure group* [Online]. Available from: `https://www.bikeradar.com/news/let-cyclists-run-red-lights-says-pressure-group/` [Accessed June 12, 2023].

Hansard, 2022. *Highway code (Rule 149) (Volume 820)* [Online]. Available from: `https://hansard.parliament.uk/Lords/2022-04-06/debates/38BEE29B-4518-4288-9B1E-F70C04A85D29/HighwayCode(Rule149)#contribution-25BE9415-91EB-4E57-BA7C-B5E29B7C6B36` [Accessed August 11, 2023].

Hinchcliffe, S., 2022. *Three weeks – and ten years!* [Online]. Available from: `https://pedalonparliament.org/three-weeks-and-ten-years/` [Accessed June 16, 2023].

Jahangiri, A., Rakha, H., and Dingus, T.A., 2016. Red-light running violation prediction using observational and simulator data. *Accident Analysis & Prevention* [Online], 96, pp.316–328. Available from: `https://doi.org/10.1016/j.aap.2016.06.009`.

Jenne, E., 2022. *Londoners rage against cyclists as they accuse them of constantly breaking the law in a very dangerous way* [Online]. Available from: `https://www.mylondon.news/whats-on/cyclists-london-red-lights-stop-24517615` [Accessed June 12, 2023].

Johnson, M., Charlton, J., and Oxley, J., 2008. Cyclists and red lights — a study of the behaviour of commuter cyclists in Melbourne. *Australasian Road Safety Research, Policing and Education Conference, Adelaide, Australia.*

Johnson, M., Charlton, J., Oxley, J., and Newstead, S., 2013. Why do cyclists infringe at red lights? An investigation of Australian cyclists' reasons for red light infringement. *Accident Analysis & Prevention* [Online], 50, pp.840–847. Available from: https://doi.org/10.1016/j.aap.2012.07.008.

Johnson, M., Newstead, S., Charlton, J., and Oxley, J., 2011. Riding through red lights: The rate, characteristics and risk factors of non-compliant urban commuter cyclists. *Accident Analysis & Prevention* [Online], 43(1), pp.323–328. Available from: https://doi.org/10.1016/j.aap.2010.08.030.

Kinsman-Chauvet, G., 2023. *Cyclists should be allowed to ride through red lights, declares leading Scottish cycling figure* [Online]. Available from: https://www.scotsman.com/news/transport/cyclists-should-be-allowed-to-ride-through-red-lights-declares-leading-scottish-cycling-figure-3994030 [Accessed June 12, 2023].

Konečni, V., Ebbeson, E., and Konecni, D., 1976. Decision processes and risk taking in traffic: Driver response to the onset of yellow light. *Journal of Applied Psychology* [Online], 61, pp.359–367. Available from: https://doi.org/10.1037/0021-9010.61.3.359.

Kuntzman, G., 2022. *Fed safety administrator: Let's legalize the 'Idaho stop'* [Online]. Available from: https://usa.streetsblog.org/2022/10/20/fed-safety-administrator-lets-legalize-the-idaho-stop [Accessed June 17, 2023].

Leach, A., 2010. *Why are female cyclists so vulnerable to lorries?* [Online]. Available from: https://www.theguardian.com/environment/green-living-blog/2010/may/13/cycling-lorries-women-road-deaths [Accessed July 5, 2023].

London Assembly, 2017. *Questions to the Mayor: Advanced stop lines enforcement* [Online]. Available from: https://www.london.gov.uk/who-we-are/what-london-assembly-does/questions-mayor/find-an-answer/advanced-stop-lines-enforcement [Accessed August 22, 2023].

MacMichael, S., 2019. *Review: Channel 5's Cyclists: Scourge of the streets?* [Online]. Available from: https://road.cc/content/news/263602-review-channel-5s-cyclists-scourge-streets [Accessed June 12, 2023].

Marshall, W., Piatkowski, D., and Johnson, A., 2017. Scofflaw bicycling: Illegal but rational. *Journal of Transport and Land Use* [Online], 11, pp.1–31. Available from: https://doi.org/10.5198/jtlu.2017.871.

Maxwell, A., 2006. Starting amber - The first significant review since the 1960s. *Traffic Engineering & Control*, 17(7), pp.253–261.

Pai, C.-W. and Jou, R.-C., 2014. Cyclists' red-light running behaviours: An examination of risk-taking, opportunistic, and law-obeying behaviours. *Accident Analysis & Prevention* [Online], 62, pp.191–198. Available from: https://doi.org/10.1016/j.aap.2013.09.008.

Palat, B. and Delhomme, P., 2012. What factors can predict why drivers go through yellow traffic lights? An approach based on an extended theory of planned behavior. *Safety Science* [Online], 50(3), pp.408–417. Available from: https://doi.org/10.1016/j.ssci.2011.09.020.

Prinsen, L., Krol, L., and Dijck, G. van, 2016. *The length of amber signals* [Online]. Available from: http://www.jctconsultancy.co.uk/Symposium/Symposium2016/PapersForDownload/Effects%5C%20of%5C%20the%5C%20length%5C%20of%5C%20amber%5C%20times%5C%20at%5C%20signals.pdf [Accessed June 26, 2023].

Richardson, M. and Caulfield, B., 2015. Investigating traffic light violations by cyclists in Dublin city centre. *Accident Analysis & Prevention* [Online], 84, pp.65–73. Available from: https://doi.org/10.1016/j.aap.2015.08.011.

Roberts, S., 2014. *Author of 'broken windows' policing defends his theory* [Online]. Available from: https://www.nytimes.com/2014/08/11/nyregion/author-of-broken-windows-policing-defends-his-theory.html?unlocked_article_code=sVAOHSZ2ow7xBxtHIioSCD1331Rh5S6U1Ack_N0tSglWECZPsf_yZwLkThx48FaevYhhUVt_kjh15GeaWljCxA0FDE3HAcjXJbwg0nY1quillwvijpL7hzG0rsg8RI6aG0rahQuZ20lwUNxuckZMer_RFSCpFEQU8Cygyk-4D2-fFXVj9Op-XSVVXgbNpx7IXuU9exljIP7lWMSUVEpM6aw8iRffrWFfmsKpahvWUAzNVc3Q8nThMhaVqpahB63yIE2iBzev8COZkOeSwwRJmcKeGEzVbgcN18Yf3s4_m0zLCQm-CXwlQXlcLOwun-IIuVKymun9JLUWXULovtAzAJwMWRViC0atR1Wk_LxpZFTHQFCJfUQfRo-kqpb7vbI&smid=url-share [Accessed August 23, 2023].

Robinson, M., 2012. *No minister! Jeremy Hunt cycles into more trouble as he risks £3,000 fine by running a red light and ignoring TWO no entry signs as he bikes home (and he didn't even bother with a helmet)* [Online]. Available from: https://www.dailymail.co.uk/news/article-2152645/No-minister-Jeremy-Hunt-cycles-trouble-risks-3-000-fine-running-red-light-ignoring-TWO-entry-signs-bikes-home-didnt-bother-helmet.html [Accessed June 12, 2023].

Robson, A., 2013. *Untitled* [Online]. Available from: https://www.flickr.com/photos/blackpuddinonnabike/10991019106/ [Accessed August 2, 2023].

Sadik-Khan, J. and Solomonow, S., 2021. *The bikelash paradox: how cycle lanes enrage some but win votes* [Online]. Available from: https://www.theguardian.com/environment/bike-blog/2021/oct/29/the-bikelash-paradox-how-cycle-lanes-enrage-some-but-win-votes [Accessed June 17, 2023].

Safety Cameras Scotland, 2023a. *Safety camera locations - East - Edinburgh City* [Online]. Available from: https://www.safetycameras.gov.scot/cameras/safety-camera-locations/east/edinburgh-city/ [Accessed June 27, 2023].

Safety Cameras Scotland, 2023b. *Site selection process* [Online]. Available from: http://safetycameras.gov.scot/about/ [Accessed July 6, 2023].

Schleinitz, K., Petzoldt, T., Kröling, S., Gehlert, T., and Mach, S., 2019. (E-)Cyclists running the red light – The influence of bicycle type and infrastructure characteristics on red light violations. *Accident Analysis & Prevention* [Online], 122, pp.99–107. Available from: https://doi.org/10.1016/j.aap.2018.10.002.

Sutton, J., 2012. *Interview: Vulnerable road users* [Online]. Available from: https://www.bps.org.uk/psychologist/interview-vulnerable-road-users [Accessed August 11, 2023].

The Record-Courier, 2020. *State taking down some flashing warning lights* [Online]. Available from: https://www.recordcourier.com/news/2020/nov/24/state-taking-down-some-flashing-warning-lights/ [Accessed June 26, 2023].

Trades Union Congress, 2021. *Gig economy workforce in England and Wales has almost tripled in last five years – new TUC research* [Online]. Available from: https://www.tuc.org.uk/news/gig-economy-workforce-england-and-wales-has-almost-tripled-last-five-years-new-tuc-research [Accessed August 21, 2023].

Transport for London, 2006. *Research summary: Behaviour at cycle advanced stop lines* [Online]. Available from: https://content.tfl.gov.uk/behavour-at-advanced-stop-lines-summary.pdf [Accessed August 22, 2023].

Transport for London, 2007. *RNPR traffic note 8: Proportion of cyclists who violate red lights in London* [Online]. Available from: https://content.tfl.gov.uk/traffic-note-8-cycling-red-lights.pdf [Accessed June 1, 2023].

Transport Scotland, 2021. *Cycling by design* [Online]. Available from: https://www.transport.gov.scot/media/50323/cycling-by-design-update-2019-final-document-15-september-2021-1.pdf [Accessed August 22, 2023].

Transportation Research Board and National Academies of Sciences, Engineering, and Medicine, 2012. *Guidelines for timing yellow and all-red intervals at signalized intersections* [Online]. Ed. by S. Hugh McGee, K. Moriarty, K. Eccles, M. Liu, T. Gates, and R. Retting. Washington, DC: The National Academies Press. Available from: https://doi.org/10.17226/22700.

Treasure, M., 2013. *The psychology of riding on the pavement, and jumping red lights* [Online]. Available from: https://aseasyasridingabike.wordpress.com/2013/08/06/the-psychology-of-riding-on-the-pavement-and-jumping-red-lights/ [Accessed July 6, 2023].

Treasure, M., 2015. *Traffic lights have to make sense* [Online]. Available from: https://aseasyasridingabike.wordpress.com/2015/11/11/traffic-lights-have-to-make-sense/ [Accessed August 3, 2023].

TVArk, 2007. *Public information films A-F* [Online]. Available from: https://web.archive.org/web/20160304113631/http://www2.tv-ark.org.uk/pifs/pifs_a-f.html [Accessed June 8, 2023].

Walker, I., 2011. Chapter 26 - Bicyclists. In: B.E. Porter, ed. *Handbook of Traffic Psychology* [Online]. San Diego: Academic Press, pp.367–373. Available from: `https://doi.org/0.1016/B978-0-12-381984-0.10026-8`.

YouTube, 2011. *Amber gambler 1977 PIF Scottish version* [Online]. Available from: `https://www.youtube.com/watch?v=xQCcvZdMB8E` [Accessed June 8, 2023].