Ministry of Transport
TE MANATŪ WAKA

Evaluation of the Graduated Driver Licensing System

Prepared by Aaron Schiff of Schiff Consulting

July 2019

Transport Evidence Base report 19/1 A

New Zealand Government

Ministry of Transport
TE MANATŪ WAKA

Disclaimer

All reasonable endeavours are made to ensure the accuracy of the information in this document. However, the information is provided without warranties of any kind including accuracy, completeness, timeliness or fitness for any particular purpose.

The Ministry of Transport excludes liability for any loss, damage or expense, direct or indirect, and however caused, whether through negligence or otherwise, resulting from any person's or organisation's use of, or reliance on, the information provided in this document.

Copyright

Citation

Schiff Consulting. [2019]. Evaluation of the graduated driver licensing system – Transport Evidence Base report 19/1 A. Wellington: Ministry of Transport.

Published in July 2019 by the Ministry of Transport, PO Box 3175, Wellington 6140, New Zealand.

ISBN 978-0-478-07283-9

For more information

For more information about this project and associated report, please contact evaluation@transport.govt.nz

Domain Strategy, Economics and Evaluation

The Domain Strategy, Economics and Evaluation team operates within the Regulatory and Data Group of the Ministry of Transport. The team supports the Ministry's policy teams by providing the evidence base at each stage of the policy development.

The team is responsible for:

- Developing the Transport Evidence Base (see below) and the Transport Knowledge Hub which connects people from across the wider transport sector and promotes the sharing of transport data, evidence, knowledge, research, information, capabilities, and ideas.
- Providing economic input on business cases, funding requests, competition issues and specific projects such as value capture, natural disasters, and the social impacts on environment and health.
- Providing the evaluation function for the Ministry, including designing evaluation frameworks, developing performance metrics and indicators, and designing, conducting and procuring evaluations.

The Transport Evidence Base

The Transport Evidence Base Strategy creates an environment to ensure data, information, research and evaluation play a key role in shaping the policy landscape. Good, evidence-based decisions also enhance the delivery of services provided by both the public and private sectors to support the delivery of transport outcomes and improve wellbeing and liveability in New Zealand.

The evaluation of the Graduated Driver Licensing System is listed on the 2018/19 Evaluation Programme, which forms part of the Transport Evidence Base implementation plan.

Acknowledgements

We would like to thank the following people for their input and assistance to this project and the preparation of this report:

- NZ Transport Agency for providing access to the relevant datasets
- The cross-agency Driver Licensing Senior Officials group for providing feedback and comment on the project scope and earlier drafts of this report
- Dr Lyndel Bates and Margo van Felius from Griffith University who conducted the peer review

Contents

List of tables

List of figures

Glossary of terms

Advanced certificate: A certificate issued to a holder of a car (Class 1) licence who has successfully completed an approved advanced driver training course.

At-fault crash involvement: For the purpose of analysis in this report, at-fault crash involvements are defined as crashes where the driver or rider involved was determined to be partly or primarily at-fault in a multi-party crash, or at-fault in a single-party crash.

CBTA 6F certificate: A certificate issued to a holder of a motorcycle (Class 6) licence who has successfully completed the Competency Based Training and Assessment requirements for obtaining a full licence.

CBTA 6R certificate: A certificate issued to a holder of a motorcycle (Class 6) licence who has successfully completed the Competency Based Training and Assessment requirements for obtaining a restricted licence.

Characteristics (of drivers or riders): Observed demographic attributes of licence holders recorded in the licensing data used for this analysis. Observed characteristics of licence holders include the date of birth (or age calculated at any given date), gender, region of residence at the time a licence was issued, and the amount of time that the person has held a licence.

Class 1 licence: A licence required to legally drive a car on public roads in New Zealand[1].

Class 6 licence: A licence required to legally ride a motorcycle on public roads in New Zealand[2].

Competency Based Training and Assessment (CBTA): An alternative to the standard practical tests for progressing to a restricted and/or full motorcycle (Class 6) licence. CBTA involves an assessment of riding skills by an approved CBTA assessor, plus optional rider training. CBTA can be chosen at either or both the restricted and full licence stages.

Crash involvement: An event where a driver or rider was involved in a crash. A single crash could involve multiple drivers and/or riders. The analysis in this report is limited to involvements in fatal and serious crashes where the driver or rider was at-fault.

Crash rate: The number of crashes in a given period of time (typically one year) divided by a measure of licence-holder exposure to crash risk during that period. For the purpose of analysis in this report, in per-driver crash rates, exposure is measured by the total driver-years of licence holding during the relevant period.

Experience (driving or riding): Due to data limitations, in this report we measure driving or riding experience as the amount of time since the licence holder obtained the relevant licence.

Exposure (to crash risk): A measure of the extent to which a group of people face the risk of being involved in a crash in a given period of time. Due to data limitations, in this report we measure exposure of drivers and riders based on the amount of time that people in the relevant group held a licence, measured in driver-years or rider-years. For example, if a

[1] For the exact definition of a Class 1 licence, see https://www.nzta.govt.nz/driver-licences/getting-a-licence/licences-by-vehicle-type/what-you-can-drive/.
[2] For the exact definition of a Class 6 licence, see https://www.nzta.govt.nz/driver-licences/getting-a-licence/licences-by-vehicle-type/what-you-can-drive/.

group of 1 million drivers held licences for a given three-year period, we would calculate exposure to crash risk in that period as 3 million driver-years.

Fatal crash: A crash where at least one person died within 30 days of when the crash happened due to an injury or multiple injuries sustained in the crash.

Four-year progression status: An indicator of a licence holder's progression through the licence stages on the fourth anniversary of obtaining their learner licence, that is, whether they remained on a learner licence, had progressed to a restricted licence but not yet obtained a full licence, or had progressed to a full licence by that date.

Light motor vehicle crash: A crash involving a vehicle that could be legally driven on a Class 1 licence, that is, a car, van, ute, or SUV. For the purpose of analysis in this report, moped crashes where the rider did not have a Class 6 licence at the time of the crash were defined as light motor vehicle crashes and included in the Class 1 analysis.

Motorcycle crash: A crash involving a vehicle that could be legally ridden on a Class 6 licence, that is, a motorcycle. For the purpose of analysis in this report, moped crashes where the rider had a Class 6 licence at the time of the crash were defined as motorcycle crashes and included in the Class 6 analysis.

Odds: The probability of an event occurring divided by the probability of it not occurring. For example, an event that occurs with probability 0.25 has odds of 0.25 / 0.75 = 0.33.

Region of residence: The geographic region of New Zealand in which a licence holder lived at the time of receiving their relevant licence.

Serious crash: A crash where at least one person was seriously injured. Serious injuries include fractures, concussions, internal injuries, crushings, severe cuts, lacerations, severe general shock necessitating medical treatment, and any other injury requiring admittance or detention in hospital.

Statistically significant: A finding that is unlikely to have occurred by random chance. In this report, results that we expect to observe less than 5% of the time by chance are deemed to be statistically significant.

Time discount: Drivers who hold an advanced certificate and who progressed from a restricted to a full licence in less than the standard minimum time are said to have obtained a time discount at the restricted stage. The standard minimum time at the restricted stage is 18 months for drivers aged under 25 at the time of applying for their full licence, and 6 months for drivers aged 25 and over. For holders of advanced certificates, these minimums reduce to 12 months and 3 months respectively.

Abbreviations

CAS	Crash Analysis System
CBTA	Competency Based Training and Assessment
CC	Cubic Centimetres
DLR	Driver Licence Register
GDLS	Graduated Driver Licensing System
NZTA	New Zealand Transport Agency
VKT	Vehicle-Kilometres Travelled

1. Summary of main findings

In 2018/19, the New Zealand Ministry of Transport commissioned an evaluation to:

- Examine the safety outcomes of the current Graduated Driver Licensing System (GDLS) for both Class 1 motor vehicle and Class 6 motorcycle licences.
- Estimate the safety-related effects of selected changes to the GDLS between 2009 and 2012:
    - Changes to penalties for driver licensing breaches (2009).
    - Changes to the minimum ages for obtaining learner and restricted licences (2011).
    - Strengthened practical driving tests (2012).
    - Introduction of the Competency Based Training and Assessment (CBTA) system for obtaining restricted and full motorcycle licences (2012).

This report presents the main findings from the study. Additional findings are reported in the associated *Technical Report*.

The data used for this analysis included records of all Class 1 and Class 6 licences of all stages (learner, restricted, and full) issued in New Zealand between 2003 and 2017 (inclusive),[3] and subsequent involvements of these drivers and riders in fatal and serious at-fault crashes between 2003 and 2017 (inclusive), based on data from the Crash Analysis System (CAS) supplied by the New Zealand Transport Agency (NZTA).[4]

Analysis of safety outcomes in this report is limited to analysis of crash rates and crash involvements of drivers and riders, as other aspects of road safety such as behaviour are more difficult to measure. Crash rates were calculated on a per-driver or per-rider basis due lack of data on driving or riding activity by individual licence holders. That is, we use the number of people that hold licences when calculating exposure to crash risk and driving or riding experience. Per-driver and per-rider crash rates are useful for identifying groups of licence holders with higher or lower crash rates, but any such differences may need further investigation to determine if these are due to differences in driving or riding activity, or other factors related to the characteristics of the licence holders.

[3] New Zealand's Driver Licence Register (DLR) moved to electronic form in May 1999. Based on advice from NZTA, 2003 was chosen as the starting point for analysis due to data consistency and reliability issues in the DLR prior to this date, particularly for licence status data.

[4] All analysis in this report is based on driver involvements in fatal and serious at-fault light motor vehicle crashes (for Class 1) and fatal and rider involvements in serious at-fault motorcycle crashes (for Class 6). Light motor vehicle (Class 1) crashes were defined as those involving cars, vans, utes, SUVs, and mopeds where the rider did not have a Class 6 licence at the time of the crash. Motorcycle crashes were defined as those involving motorcycles and mopeds where the rider had a Class 6 licence at the time of the crash. Due to resourcing limitations, it was not possible to analyse moped crashes separately. In this report, at-fault crashes are defined as those where the driver or rider was recorded as primarily or partly at fault (for multi-vehicle crashes) or at fault (for single-vehicle crashes) in the CAS data. CAS defines road deaths as those where an injury or multiple injuries resulted in death within 30 days of when the crash happened. Serious injuries include fractures, concussions, internal injuries, crushings, severe cuts, lacerations, severe general shock necessitating medical treatment, and any other injury requiring admittance or detention in hospital.

1.1. Main findings for drivers (Class 1)

The following findings are based on analysis of crashes involving drivers of light motor vehicles with Class 1 licences, and crashes involving riders of mopeds where the rider did not have a Class 6 licence at the time of the crash.

1.1.1. Overall patterns and trends in crash rates

Per-driver crash rates for learners are not significantly different from those for fully licensed drivers

- Our analysis found no statistically significant difference (p-value 0.35) between the overall crash rate for drivers aged 16 to 27 years old with learner licences between 2015 and 2017 (6.8 crashes per 10,000 licensed drivers per year) versus that for drivers of the same age range with full licences (6.4 crashes per 10,000 licensed drivers per year).
- This study found no evidence that supervision requirements for learner drivers or the learner theory test are inadequate to prepare learner drivers for the risks that they face while driving, relative to fully licensed drivers.
- However, the dataset used for this analysis does not measure driving activity directly (e.g. kilometres driven per driver per year). It is possible that more people with learner licences are less active drivers compared to those with full licences (e.g. because they obtained a licence as a form of identification, rather than to drive). Further research would be needed to determine whether crash rates for active learner licensed drivers are similar to those for active fully licensed drivers.

Crash rates are high for 17- and 18-year-old drivers with restricted licences

- Current crash rates for 17- and 18-year-old drivers with restricted licences are around 1.5 times higher than for drivers aged 16 to 27 with restricted licences, and two to three times higher than for fully licensed drivers aged 16 to 27. In our analysis, these differences are statistically significant (p-values < 0.01).
- This raises questions about whether the changes to the Class 1 GDLS could better protect young drivers with restricted licences from crash risks. For example, other studies have found some evidence that longer minimum learner licence durations and stricter requirements for progressing from a learner to a restricted licence are associated with lower crash rates at the restricted stage (Scully et al, 2014; Senserrick et al, 2016; VicRoads, 2017; Williams, 2017).

Per-driver crash rates for drivers aged under 25 have stopped falling

- Between around 2008 and 2013, per-driver crash rates for drivers at all licence stages aged under 25 years old were generally declining, but since 2013 per-driver crash rates have mostly remained the same or increased slightly in some cases (e.g. drivers aged 22 years old on learner and restricted licences; see section 3.1.3 of the Technical Report for details).
- These trends likely reflect a number of factors unrelated to driver licensing such as changes in population demographics and participation in driving, investments in road safety improvements, changes to the vehicle fleet, etc. However, this raises a question of whether further adjustments to licensing could help to offset other factors that may have contributed to increasing per-driver crash rates for those aged under 25 since 2013.

1.1.2. Estimated safety impacts of the 2009 to 2012 changes to the Class 1 GDLS

Increasing the minimum learner age from 15 to 16 years old in 2011 led to a reduction in crashes

- Increasing the minimum age for obtaining a Class 1 learner licence from 15 to 16 years old is estimated to have caused an overall long-term reduction of around 23 crashes per year. Around three-quarters of the estimated reduction (around 17 crashes per year) was due to 15-year-olds no longer being able to legally drive. The remainder of the reduction (around 6 crashes per year) was the net effects of changes in the distribution of driver ages and the amount of time that drivers had held driver licences among drivers aged under 30 years old.
- In 2017 the overall crash rate for drivers aged under 30 years old was 7.84 crashes per 10,000 licensed drivers per year. It is estimated that this crash rate would have been 8.13 crashes per 10,000 licensed drivers per year if the minimum learner age had remained at 15 years old. As above, most of this difference is due to 15-year-olds no longer being able to drive.
- In 2017 there would have been around 18,300 licensed 15-year-old drivers if the minimum age had not changed, and these people would have obtained some value from being able to drive. While we have not estimated this value in this report, it is a social cost of increasing the minimum driver licensing age.

We did not find evidence that strengthening the restricted licence test in 2012 had a statistically significant effect on crash rates

- Drivers under 30 years who obtained their restricted licence after the test was strengthened were estimated to be between 22% less likely to 6% more likely (with 95% confidence) to be involved in a crash while on their restricted licence, compared to drivers of the same age who obtained their restricted licence under the previous test.

Rebalancing the penalties for licensing breaches in 2009 had no measurable effect on crash rates

- The rebalancing of penalties for driver licensing breaches included changes to the fines and demerit points for breaching licence conditions. Under the changes, the infringement fee was decreased from $400 to $100 and the demerit points (except for failing to display an L plate) increased from 25 to 35 points. Licences are suspended for three months if drivers receive 100 or more demerit points within any two-year period.
- Learner and restricted crash rates for drivers aged 20 and under did change around the time that penalties were rebalanced, but these changes in crash rates are more likely to be explained by general road safety trends and changes in driver demographics. Any impact of the rebalanced penalties on crash rates appear to be too small to distinguish from other factors that affected crash rates at the same time.

1.1.3. Comparison of crash rates for restricted and fully licensed drivers

Obtaining a full licence is associated with lower crash rates after controlling for differences in driver characteristics

- Fully licensed drivers are around 23% less likely to crash than drivers with restricted licences after controlling for driver age, gender, region of residence, and amount of

time since obtaining a licence, and this difference is statistically significant (p-value < 0.01). This suggests that the restricted and full licence stages make distinct contributions to drivers' progression from novice to experienced drivers beyond any effects of simply getting older and gaining more driving experience.

- A plausible reason for this is that the full licence practical test encourages drivers to improve their driving skills to pass the test and/or inhibits less competent drivers from progressing through the GDLS. Further analysis of crash rates for drivers who pass this test on their first attempt versus those who do not would be useful to better understand the impact of the full licence practical test on road safety outcomes.

1.1.4. Effectiveness of the night-time driving restriction

Restricted drivers crash more often at night than fully licensed drivers of the same age, despite the supervision requirement

- Drivers aged 16 to 27 with restricted licences are involved in around 1.8 times as many crashes as fully licensed drivers of the same age between the hours of 10pm and 5am, despite being required to have a fully licensed supervisor when driving during these times, and this difference is statistically significant in our analysis (p-value < 0.01).5
- Other studies have found good evidence that restrictions on night-time driving and carrying passengers reduce crashes among drivers with restricted licences, but compliance with, and enforcement of, these restrictions is difficult (Begg et al, 2001; Curry et al, 2017; Fell, Todd & Voas, 2011; Karaca-Mandic & Ridgeway, 2010; McKnight & Peck, 2002; Williams, 2007).
- While the difference in crash rates may partly reflect factors unrelated to driver licensing, if the night-time crash rate for restricted drivers aged 16 to 27 could be reduced to that of fully licensed drivers of the same age, around 16 crashes per year could be prevented.
- A possible next step is to investigate whether changes to the night driving restriction could reduce the crash rate for restricted drivers to be closer to that of fully licensed drivers.

1.1.5. Advanced driving certificates

Drivers who complete approved advanced driver training and obtain an advanced driving certificate are able to reduce the minimum time at the restricted licence stage from 18 months to 12 months for drivers aged under 25 and from 6 months to 3 months for drivers aged 25 and over.

Crash rates for fully licensed drivers with advanced certificates are similar to those without

- Our analysis found no statistically significant differences in crash rates for fully licensed drivers with advanced certificates and who received time discounts at the restricted stage, compared to drivers without advanced certificates, after controlling for differences in driver age, gender, region of residence, and length of time holding a licence (p-values between 0.31 and 0.91).

[5] Due to data limitations, we were not able to differentiate between crashes involving drivers with restricted licences who were driving with or without a supervisor. For the same reason, we were also not able to analyse the effectiveness of the restriction on unsupervised driving while carrying passengers.

- There is some evidence that crash rates for fully licensed drivers with advanced certificates who did not obtain a time discount at the restricted stage are lower than for drivers without advanced certificates.6 However, since drivers choose whether to obtain an advanced certificate and whether to get a time discount, it is not clear if this is caused by the advanced driver training itself or whether it reflects underlying characteristics of such drivers (or both).
- Another recent study (Begg & Brookland, 2015) found that advanced driver training combined with faster progression through the GDLS appears to be ineffective at reducing crashes. It is possible that time discounts offset any safety-related benefits of advanced driver training.

1.1.6. Progression through the licence stages

There appears to be no relationship between the length of time taken to progress to a full licence and crashes, for drivers who did progress by the end of 2017

- For drivers in the dataset who progressed to a full licence by the end of 2017, we found no evidence that the amount of time taken to progress (i.e. speed of progression) had an impact on crash rates.

Crash rates are high for drivers who do not progress within four years

- Across all drivers who obtained a learner licence between 2003 and 2013 (and controlling for differences in driver age, gender, region of residence, year of obtaining a learner licence, and amount of time since obtaining a licence), the odds of crash involvement7 while on a learner licence were 6.0 times higher for drivers who still remained on a learner licence after four years and 2.4 times higher for drivers who had progressed to a restricted licence but had not yet obtained a full licence after four years, compared to crashes at the learner stage for drivers who had progressed to a full licence within four years (p-values < 0.01).
- Similarly, the odds of crash involvement while on a restricted licence were 1.9 times higher for drivers who remained on a restricted licence after four years, compared to crashes while on a restricted licence for drivers who had progressed to a full licence within four years (p-value < 0.01).
- This suggests that there may be safety benefits of encouraging non-progressing drivers to gain driving skills and to progress through the licence stages, provided this is done in a way that raises the competence of these drivers rather than simply increasing progression per se.
- There is some international evidence that drivers who have difficulty progressing through the licence stages are more likely to be involved in crashes (Boufous et al, 2011).Further analysis of the reasons for non-progression and the relationship between those factors and crash rates would be useful to determine how road safety outcomes could be improved for this cohort of drivers.

[6] Specifically, we estimate that the odds of crash involvement in the combined period from 2015 to 2017 of fully licensed drivers who were aged under 30 years old at the end of 2017 were 45% lower for drivers with advanced certificates and no time discount compared to drivers without advanced certificates, after controlling for differences in driver age, gender, region of residence, and length of time holding a licence (*p*-value 0.04).

[7] Our analysis of individual drivers is based on predicting the odds that a driver will be involved in a crash in a given period of time. The odds of being involved in a crash is the probability of crashing divided by the probability of not crashing. For low-probability events such as crashes, the odds of crash involvement are similar to the probability of crash involvement, and the results can also be interpreted in terms of crash rates.

1.2. Main findings for motorcyclists (Class 6)

The following findings are based on analysis of crashes involving riders of motorcycles with Class 6 licences and crashes involving riders of mopeds who held a Class 6 licence at the time of the crash.

1.2.1. Overall patterns and trends in crash rates

Crash rates for fully licensed riders are relatively high

- Between 2015 and 2017 the crash rate for fully licensed riders aged 16 to 27 years old was 1.8 times higher than the crash rate for learner riders of the same age, and this difference is statistically significant (p-value 0.01).
- Controlling for differences in rider age, gender, region of residence, and amount of time since obtaining a Class 6 licence, riders with full licences are around 1.5 times more likely to crash than riders with restricted licences, and this difference is statistically significant (p-value < 0.01).
- It may be that riders with full licences are more active motorcyclists, that is, they ride more kilometres per year on average than riders with learner or restricted licences, and therefore have greater exposure to crash risk. However, kilometres ridden per year is not measured in the available data, so this hypothesis has not been tested directly in this analysis.
- These findings raise a question of whether the Class 6 GDLS adequately prepares riders for the increased exposure to crash risk that they are likely to face after obtaining a full licence.

Crash rates for young riders with learner licences are high and have increased substantially

- Comparing the combined period from 2015 to 2017 with the combined period from 2009 to 2011, the per-rider crash rate for all learner riders aged 16 to 20 years old more than doubled from 18 to 39 per 10,000 licensed riders per year and this difference is statistically significant (p-value 0.01).
- Crash rates between 2015 and 2017 were around three to six times higher for people aged 16 to 18 years old with Class 6 learner licences compared to the overall crash rate for people aged 16 to 27 years old with learner licences and these differences are statistically significant in our analysis (p-values < 0.05).
- This suggests that further consideration of the requirements to obtain a motorcycle learner licence and the effect on safety for young riders is needed.

1.2.2. Estimated safety impacts of the 2009 to 2012 changes to the Class 6 GDLS

Increasing the minimum age in 2011 had a minimal impact on crash rates

- Prior to the increase in the minimum age, only around 5% of motorcycle learner licences were issued to 15-year-olds (around 200 per year). Therefore, increasing the minimum learner licence age affected only a small proportion of learner riders.
- It is estimated that 15-year-old riders would have been involved in around 1.3 crashes per year on average if the minimum age remained at 15 years. However, most of this reduction in crashes for 15-year-olds was likely offset by an increase in crashes among 16-year-old riders.
- Overall, increasing the minimum learner age is estimated to have led to a reduction of less than one crash per year for motorcycle riders.

Rebalancing the penalties for licensing breaches in 2009 had no measurable effect on crash rates

- As with Class 1, the effect of this change on crashes is too small to detect given the variability in crash rates over time.

We found no effect on crash rates of strengthening the learner and restricted tests in 2012

- Controlling for differences in rider age, gender, region of residence, and time since obtaining a Class 6 licence, our analysis found no statistically significant difference in crash rates for riders who obtained licences after the tests were strengthened compared to those who obtained licences before the tests were strengthened (p-value 0.57 for the strengthened learner test and 0.92 for the strengthened restricted test).
- It is plausible that the strengthened tests reduced crash rates, but this is difficult to measure due to the relatively small number of riders and crashes. This was compounded by the introduction of CBTA at the same time as the tests were strengthened, which substantially reduced the number of riders choosing the practical test to obtain their restricted licence.

1.2.3. Effectiveness of the night-time riding restriction

The night-time restriction for riders with restricted licences is generally effective

- Riders with Class 6 restricted licences are effectively prohibited from riding between 10pm and 5am. Despite this, a small number of night-time crashes involving riders with restricted licences occur, but the night-time crash rate for restricted riders aged 16 to 27 is almost the same as that for fully licensed riders (around one crash per 10,000 licensed riders per year).
- Given the small number of such crashes and the similarity of the crash rate for restricted and fully licensed riders, the restriction appears to be effective in practice and the safety-related benefits of trying to further reduce the night-time crash rate of restricted riders are limited.

1.2.4. CBTA

CBTA gives riders an alternative to the traditional practical tests to progress from learner to restricted, and/or from restricted to full licences. It requires riding skills to be assessed by an approved assessor, plus optional training. Riders who choose CBTA can reduce the minimum time required at the learner and restricted licence stages.

Given the relatively recent introduction of CBTA we do not yet have sufficient data to determine if there is a difference in crash rates between those who progress using CBTA versus those who progressed via the traditional tests

- In general, our analysis found no statistically significant difference in crash rates between riders who progressed via CBTA and riders who progressed via traditional practical tests, since CBTA was introduced in October 2012.

- Riders who progressed via the most common CBTA pathways8 have been involved in around 1.5 to 2.0 times as many crashes as riders who passed the traditional practical tests during the same period, but given the limited time since the introduction of CBTA, we cannot be sure that these differences are not due to random variation in crashes (relevant p-values range from 0.17 to 0.38).
- Given the relatively short time since CBTA was introduced, there is no clear evidence of a difference in crash rates for riders choosing CBTA versus those choosing practical tests. However, given the higher crash rates observed so far for those progressing via all CBTA pathways, it is recommended that crash rates for riders choosing CBTA are closely monitored in the coming years and further analysis undertaken to better understand the reasons for any differences.

[8] Most riders who progressed via CBTA have chosen to use CBTA at the restricted stage and at the full stage (if they have progressed that far). Very few riders who had progressed to a full licence by the end of 2017 used CBTA at only the restricted stage. See section 5.5.

2. Introduction

This report summarises analysis of driver licensing and road crash data undertaken for the New Zealand Ministry of Transport. The objectives of the analysis were to empirically evaluate the road safety-related effects of some of the recent changes to New Zealand's three-stage graduated driver licensing system (GDLS), and to study some other aspects of the relationships between driver licensing and road safety. The analysis was limited to drivers with Class 1 (light motor vehicle) licences and riders with Class 6 (motorcycle) licences.

2.1. Scope of the analysis

The following is a summary of topics that were determined to be in and out of the scope of this analysis. Section 1 of the *Technical Report* describes the scope of the analysis requested by the Ministry of Transport.

2.1.1. Driver licensing and road safety: Topics in scope

The general aspects of the relationships between driver licensing and road safety included in scope are:

- High-level analysis of patterns and trends in crash rates by licence stage and driver or rider gender, age, and region of residence.
- More detailed comparisons of crash rates for restricted versus full licence holders.
- Evaluation of the effectiveness of the night-time restriction for people holding restricted licences at preventing crashes.
- Analysis of the relationships between progression through the licence stages and crash rates. In particular, whether there are differences in crash rates for people who progress versus those who do not and/or people who progress relatively quickly versus those who progress more slowly.
- Comparison of crash rates for fully licensed drivers with advanced driving certificates compared to those without (for Class 1 only).

2.1.2. Driver licensing and road safety: Topics out of scope

Specific topics that are outside the scope of this analysis include:

- Heavy vehicle driver licensing (this was the subject of a separate review in 2014).9
- How the GDLS is operationalised by NZTA, including the testing processes, location and number of testing stations, the content of licence tests, costs of testing, etc.
- Implications of driver licensing for access to education and employment, and wider economic and equity implications of the driver licensing system. To manage its scale and complexity, this project focuses on road safety outcomes.
- Any relationship between driver ethnicity and licensing or road safety outcomes (age and gender were analysed since they are recorded in the licensing data used for this analysis; ethnicity is not).

[9] https://www.transport.govt.nz/assets/Uploads/Land/Documents/2ea8253819/Literature-review-of-heavy-vehicle-driver-licensing.pdf

- Separate analysis of crashes involving mopeds, which can be ridden on either a Class 1 or Class 6 licence. Crashes involving mopeds were included in the Class 6 analysis if the rider held any Class 6 licence at the time of the crash, otherwise these crashes were included in the Class 1 analysis. It was not feasible to analyse moped crashes separately due to the relatively small number of such crashes and the amount of extra analysis required.
- Whether licensing breaches lead to further interactions with the justice system.
- Analysis of crashes involving unlicensed drivers or riders (since by definition they are not included in the dataset used for the analysis).
- Geographic analysis of crash rates beyond the licence holder's region of residence (e.g. comparing crashes in urban versus rural areas).
- Analysis of other factors aside from basic demographics and licensing-related characteristics that could play a role in crashes, for example, weather conditions, traffic conditions, vehicle type, blood alcohol level, etc.10

2.1.3. GDLS changes in scope

The changes to the GDLS that were evaluated are:

- Changes to the penalties for breaching the conditions of learner and restricted licences (e.g. driving without a supervisor when required) introduced in December 2009.
- Raising the minimum age for obtaining a learner licence from 15 to 16 years old and raising the minimum age for obtaining a restricted licence from 15.5 to 16.5 years old introduced in August 2011.
- Strengthening the Class 1 restricted practical test in February 2012 and strengthening the Class 6 learner and restricted practical tests in October 2012.
- Introducing the CBTA options for Class 6 progression in October 2012.

Analysis of the impacts of these changes was limited to road safety outcomes measured by crash involvements of individual licence holders and crash rates of groups of licence holders. Other potential impacts of the changes, for example on uptake of licences or progression through licence stages, were deemed to be out of scope.

2.1.4. GDLS changes and other changes out of scope

Other changes to the GDLS and related road safety initiatives that occurred around the same time were excluded from the scope of this analysis:

- All changes to the GDLS prior to December 2009.
- Reducing the validity of learner and restricted licences from ten years to five years in 2014. The impacts of this will not be apparent until the first cohort of five-year licences expire in 2019 but the dataset used for this analysis only covers the period to the end of 2017.
- Introducing a zero blood-alcohol limit for drivers and motorcyclists under 20 years old. This change is related to age rather than licence type or stage and therefore determined to be outside of the GDLS.

[10] To control for such factors in the analysis in this report, we would need to know how these affected both licence holders who were involved in crashes and those who were not. While there is data on many of these factors for people who were involved in crashes, the corresponding data for people who were not involved in crashes is not available.

- Specific or local licensing initiatives and programmes, for example those offered by community-based organisations to support young people to get a licence. This evaluation was specifically focussed on the system level, rather than on specific initiatives and programmes.
- Initiatives related to international visitors to New Zealand since this is outside of the GDLS.
- The introduction of power-to-weight restrictions for Class 6 learner and restricted licence holders in 2012 due to data limitations.

2.2. Literature summary

There is very robust empirical evidence from New Zealand (Begg & Stephenson, 2003; Frith & Perkins, 1992; Langley *et al*, 1996; Reeder *et al*, 1999, and) and many international studies (e.g. Baker *et al*, 2007; Chen *et al*, 2006; Fell *et al*, 2011; Russell *et al*, 2001; Simpson, 2003; Shope, 2007; Williams *et al* 2012; Williams, 2017) that crashes are lower under a three-stage (learner/restricted/full) graduated system compared to a two-stage (learner/full) system.

Most of the reduction in crashes from a three-stage GDLS appears to come from a reduction in exposure to crash risk, that is, a reduction in the number of people who drive and/or a reduction in the amount and types of driving (e.g. at night or carrying passengers) by teenage drivers (e.g. Fohr *et al*, 2015; Poirier *et al*, 2018). There is limited evidence that introducing a GDLS changes driver behaviour directly.

In terms of specific features of a GDLS and impacts on road safety:

- There is good evidence that restrictions on night-time driving and carrying passengers reduce crashes among drivers with restricted licences, although compliance with, and enforcement of, these restrictions is generally imperfect (Begg et al, 2001; Curry et al, 2017; Fell, Todd & Voas, 2011; Karaca-Mandic & Ridgeway, 2010; McKnight & Peck, 2002; Williams, 2007).
- Advanced driver training combined with time-discounts offered at the restricted licence stage (in New Zealand) appear to be ineffective at reducing crash rates, and there is some evidence that time discounts work to offset safety-related benefits of driver training (Begg & Brookland, 2015).
- There is some evidence that longer minimum learner licence durations (e.g. 12 months compared to 6 months or 3 months) and stricter requirements for progressing from a learner to a restricted licence (e.g. minimum supervised driving hours) are associated with lower crash rates at the restricted stage (Scully et al, 2014; VicRoads, 2017; Williams, 2017).

A brief review of the literature on the overall relationship between driver licensing and road safety (both in New Zealand and internationally) is provided in the Appendix.

2.3. Structure of this report

The remainder of this report is structured as follows:

- Section 3 gives a brief overview of the data, methodology, and limitations of the analysis.

- Section 4 summarises the findings regarding driver licensing and crash rates, including demographics, trends, progression, advanced driving certificates, and evaluation of the 2009-2012 changes.
- Section 5 summarises the findings regarding motorcycle licensing and crash rates, including demographics, trends, progression, CBTA, and evaluation of the 2009-2012 changes.
- A brief literature review is provided in the Appendix.

The accompanying *Technical Report* gives more information about the analysis and findings.

3. Data sources, methodology, and limitations

3.1. Data sources

3.1.1. Licensing data

The licensing data provided by NZTA contained records of 2,628,084 Class 1 and 169,823 Class 6 licences issued from 1 January 2003 to 31 December 2017. For each licence, the dataset included:

- Unique identifiers for the licence holder.
- The licence holder's date of birth.
- The licence class and stage.
- The start date of the licence (at each licence stage).
- Whether or not an advanced driving certificate was held by the driver (for Class 1 licences).

Additional datasets were provided by NZTA and linked to the licensing dataset using the unique identifiers. These included the holder's gender, CBTA 6R and 6F certificates[11] issued (i.e. whether or not they had used CBTA to progress to their restricted or full Class 6 licence), and the holder's region of residence recorded by NZTA at the time the licence was issued.[12]

3.1.2. Crash data

NZTA provided data on all crashes recorded in CAS between 2003 and 2017 that involved people in the licensing dataset. For each crash involvement, information was provided about the date and time of the crash, an identifier to enable matching with the licensing dataset, the driver's or rider's age, the class and stage of licence held by the driver or rider at the time of the crash, vehicle characteristics including type, CC rating (i.e. engine size), and year of manufacture, the severity of the crash, and an indicator of whether the driver or rider was determined to be primarily, partly, or not at fault in the crash.

Given the focus on licensing, the analysis was limited to fatal and serious crashes where the driver or rider was recorded as being partly or primarily at fault. After these exclusions, the analysis of Class 1 crash rates was based on 9,341 involvements in fatal and serious at-fault light motor vehicle crashes (including moped crashes where the rider did not have a Class 6 licence at the time of the crash), and the analysis of Class 6 crash rates was based on 1,238 involvements in fatal and serious at-fault motorcycle crashes (including moped crashes where the rider did have a Class 6 licence at the time of the crash).[13]

[11] Holding a CBTA 6R certificate allows a rider to progress to a Class 6 restricted licence and holding a CBTA 6F certificate allows a rider to progress to a Class 6 full licence. See section 5.5.

[12] NZTA geo-coded the address that it had on file for the driver at the time each licence was issued and allocated the addresses to Regional Council areas (using 2013 boundaries). Just over 90% of the addresses could be successfully allocated to a Regional Council area. NZTA does not regularly update licence holders' addresses outside of these instances. The analysis therefore assumes that the driver's region of residence at the time they received their licence did not change while they held that stage of licence.

[13] A moped is permitted to be ridden in New Zealand on either a Class 1 or a Class 6 licence. When a person held both a Class 1 and Class 6 licence and was involved in a moped crash, this was included in the Class 6 analysis since the skills required to

3.2. Empirical methods used

The actual number of crashes observed for any given group of licence holders in any given period of time is subject to random variation as any individual licence holder's involvement in a crash is an unpredictable event with relatively low probability. The empirical methods used in this report are designed to account for this variation when comparing crash involvements or crash rates across groups of licence holders and across time. The following is a brief summary of these methods (see section 2.4 of the *Technical Report* for more detail).

3.2.1. Analysis of aggregated crash rates

We calculated and compared crash rates for various groups of licence holders and time periods by dividing the relevant number of crashes by the relevant number of licensed driver-years or rider-years (i.e. using the number of licensed driver-years or rider-years as the measure of exposure to crash risk). Since the number of licence holders varies continuously over time, we measured this at a representative point in time, for example on June 30 each year for annual crash rates. In most cases, we report 95% confidence intervals around calculated crash rates as a measure of the uncertainty associated with the crash rate.

As discussed in section 2.4.1 of the *Technical Report*, in many cases we aggregate crash rates across three-year periods (e.g. 2015 to 2017) to increase the number of licence holders and crashes included in the calculation of crash rates. This allows crash rates to be estimated more accurately (i.e. associated confidence intervals are narrower). However, aggregating across years means that we may miss changes in crash rates over time, and the limitations of the licensing dataset means that the age range of licence holders that can be included in the crash rate calculation reduces as we go further back in time (see section 3.3.1 below). Balancing these trade-offs, we chose three-year periods for the calculation of crash rates.

3.2.2. Analysis of outcomes for individual licence holders

We also used the unit record data for individual licence holders to model their involvement in crashes as a function of observed characteristics such as age and gender. The analysis of individual driver or rider crash involvements uses logistic regression models which predict the binary outcome of whether or not a licence holder was involved in crash during a given time period as a function of factors including their age, gender, region of residence, and other licensing-related characteristics of interest in our analysis.

A logistic regression model predicts the *odds* that a licence holder was involved in a crash in a given time period. The odds of being involved in a crash is the probability of being involved in a crash divided by the probability of not being involved in a crash. For low-probability events, such as crashes, the odds of the event are very similar to the probability of the event.[14] Thus, while the discussion of these models refers to the odds of crash involvement to be consistent with how the logistic regression models are formulated, the results can also be interpreted in terms of the probability of crash involvement, and hence in terms of crash rates. This issue is discussed further in section 2.4.1 of the *Technical Report*.

ride a moped were deemed to be more similar to the skills required to ride a motorcycle, compared to the skills required to drive a light motor vehicle.

[14] For example, if the probability that a driver is involved in a crash in a year is 1/1000, the odds of crash involvement is (1/1000)/(999/1000) = 1/999, which is very similar to the probability.

3.3. Limitations of the data

3.3.1. Limitations due to construction of the licensing dataset

The licensing dataset did not contain any information about licences issued before 2003 but which were still valid after 2003. Thus, while the dataset contains records of all licences *issued* between 2003 and 2017, it does not include information about all licences *held* during that time. Since experience (measured by the length of time a person has held a licence) is likely to be related to the probability that they are involved in a crash, the construction of the licensing dataset potentially introduces bias into the analysis of crash rates, unless this is accounted for in the analysis. For licence holders who first obtained a licence before 2003, we do not know the total amount of time that they have held a licence and thus including such people in the analysis has the potential to introduce biases. Table 1 shows the combinations of ages of licence holders for which we can assume the licensing dataset contains a complete record of all people who held licenses in that year given that the minimum age for obtaining a learner licence was 15 years old up to August 2011 and 16 years old thereafter.

The licensing dataset also does not contain any information about expiry and renewal of licences, or disqualification of licence holders. Since licences are typically valid for 10 years, some licences issued between 2003 and 2007 will have expired before the end of 2017 and not been renewed. Our analysis effectively assumes that all licences issued from 2003 onwards remained valid until the end of 2017. This will over-estimate the number of licence holders between 2013 and 2017 and will cause calculated crash rates for licence holders aged between 25 to 29 years old to be underestimated by an unknown amount in those years.

Table 1 Combinations of years and licence holder ages for which the licensing dataset can be assumed to contain records of all licence holders.

	Age														
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2003	✓														
2004	✓	✓													
2005	✓	✓	✓												
2006	✓	✓	✓	✓											
2007	✓	✓	✓	✓	✓										
2008	✓	✓	✓	✓	✓	✓									
2009	✓	✓	✓	✓	✓	✓	✓								
2010	✓	✓	✓	✓	✓	✓	✓	✓							
2011	✓	✓	✓	✓	✓	✓	✓	✓	✓						
2012	n/a	✓	✓	✓	✓	✓	✓	✓	✓	✓					
2013	n/a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
2014	n/a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2015	n/a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
2016	n/a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
2017	n/a	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

3.3.2. Limitations for Class 6 due to the small number of licensed riders

For Class 6, the number of licensed riders and their crashes in any given year are relatively low. This means that crash rates for Class 6 are subject to relatively high levels of uncertainty, particularly when calculated for individual years or for subsets of riders. This makes it more difficult to determine whether observed differences in Class 6 crash rates are due to underlying differences in safety or are due to random variation. To partially overcome this, we have used crash rates calculated for combined three-year time period, as described above. However, for Class 6 it is still difficult to reach strong conclusions about differences in crash rates in many cases.

3.3.3. Limitations due to inability to accurately measure exposure to crash risks

We cannot observe the actual amount and type of driving or riding done by each licence holder, for example vehicle-kilometres travelled (VKT), for any given licence holder in any given period of time. Therefore, the analysis of per-driver and per-rider crash rates implicitly assumes that each licence holder has the same exposure to crash risk per period of time. That is, in all cases in this report we use the amount of time that people have held licences in the calculation of exposure to crash risk and as a measure of driving or riding experience.

In reality, the amount of time that a person has held a licence may not be perfectly correlated with actual experience or exposure to crash risk. For example, some people may obtain a learner licence as a form of identification but not actually drive, and thus the amount of time they have held a licence does not accurately reflect their exposure to crash risk or actual driving experience. Thus, the calculated crash rates for learners may appear relatively low compared to people with restricted and full licences, but some of this difference is

possibly due to lower levels of exposure by learners relative to people with restricted or full licences.

3.4. Other limitations of this study

In analysing changes in crash rates over time, external factors may also have affected crash rates. Where possible, we control for external factors by comparing the impacts of GDLS changes between groups of licence holders who were affected by the changes versus groups not affected by those changes. We also include time trends or year-specific dummy variables in most models to try to capture external factors. However, these methods will not control for all factors that may have affected crash rates at the same time as the changes to the GDLS. For example:

- Safety campaigns or investments could reduce crashes and the impacts of these interventions could be confounded with the impacts of changes to the GDLS.
- Changes in vehicle safety ratings over time, and relationships between safety ratings and licence holder age and/or licence stages may affect crash rates in ways that appear to be linked to licensing but are unrelated (e.g. younger licence holders may tend to drive cheaper second-hand vehicles which tend to be older and less safe).
- The legal maximum blood alcohol level for drivers and riders under 20 years old was reduced to zero in August 2011. As this change occurred around the same time as the changes evaluated in this report, and because it applied to all licence holders under 20 years old regardless of licence stage, it is not possible to clearly separate the effects of that change from the other changes evaluated in this report.

4. Evaluation results for the driver licensing system (Class 1)

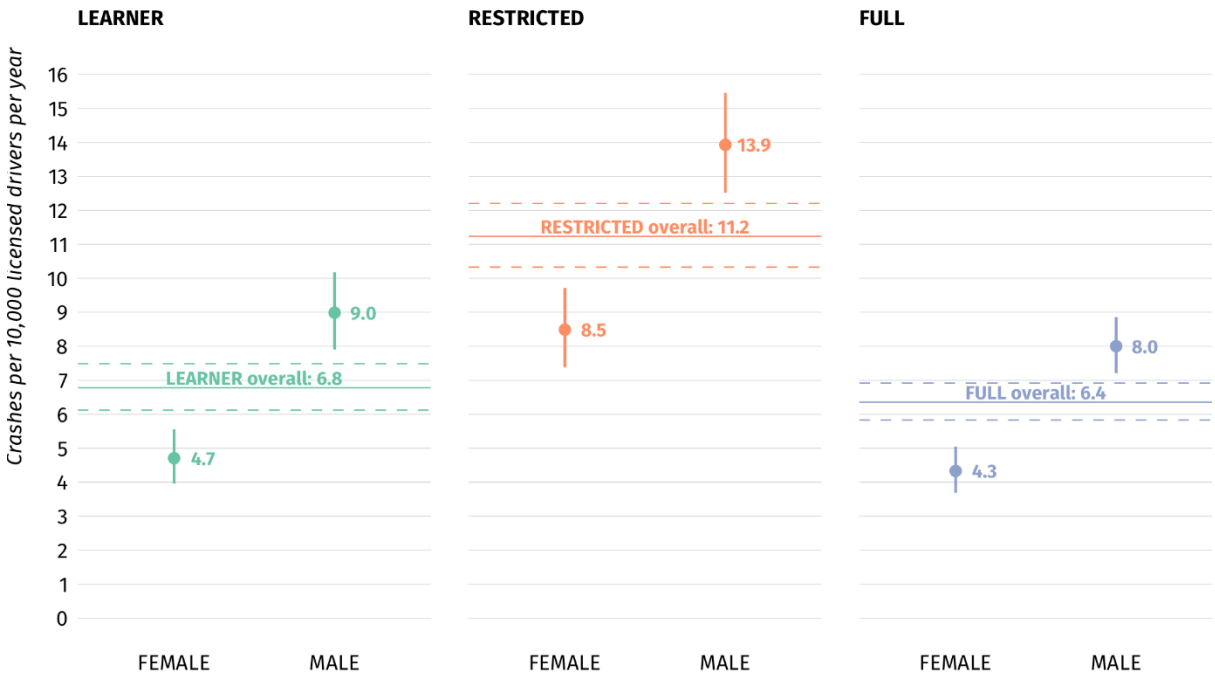
4.1. Context: Overall patterns and trends in crash rates

As described in more detail in section 3.1 of the *Technical Report*, we undertook detailed analysis of crash rates for drivers by licence stage, driver age, gender, and region of residence, and analysed trends in these crash rates over time. These crash rates reflect various factors and trends, many of which are not directly related to driver licensing (e.g. changes in population demographics, investments in road safety improvements, road safety campaigns, changes in the vehicle fleet, etc.), but this analysis provides useful context for what follows.

4.1.1. Crash rates by licence stage and driver gender

Figure 1 shows how crash rates vary by licence stage and gender among drivers aged 16 to 27 years old for the combined period from 2015 to 2017 (the horizontal lines show the overall crash involvement rate across all drivers aged 16 to 27 years old for each licence stage and associated 95% confidence interval).[15] Overall, crash rates among these drivers at the learner and full licence stages are similar, at just under 7 crashes per 10,000 licensed drivers per year. Crash rates at the restricted stage are higher, with an overall rate of just over 11 crashes per 10,000 drivers per year. At each licence stage, the crash rate for male drivers is approximately double the rate for female drivers, and in our analysis these gender differences are statistically significant (*p*-values < 0.005 for all gender comparisons).

Figure 1 Fatal and serious at-fault light motor vehicle crash involvements per 10,000 licensed drivers aged 16 to 27 per year for 2015 to 2017 combined by driver's gender and licence stage with 95% confidence intervals.

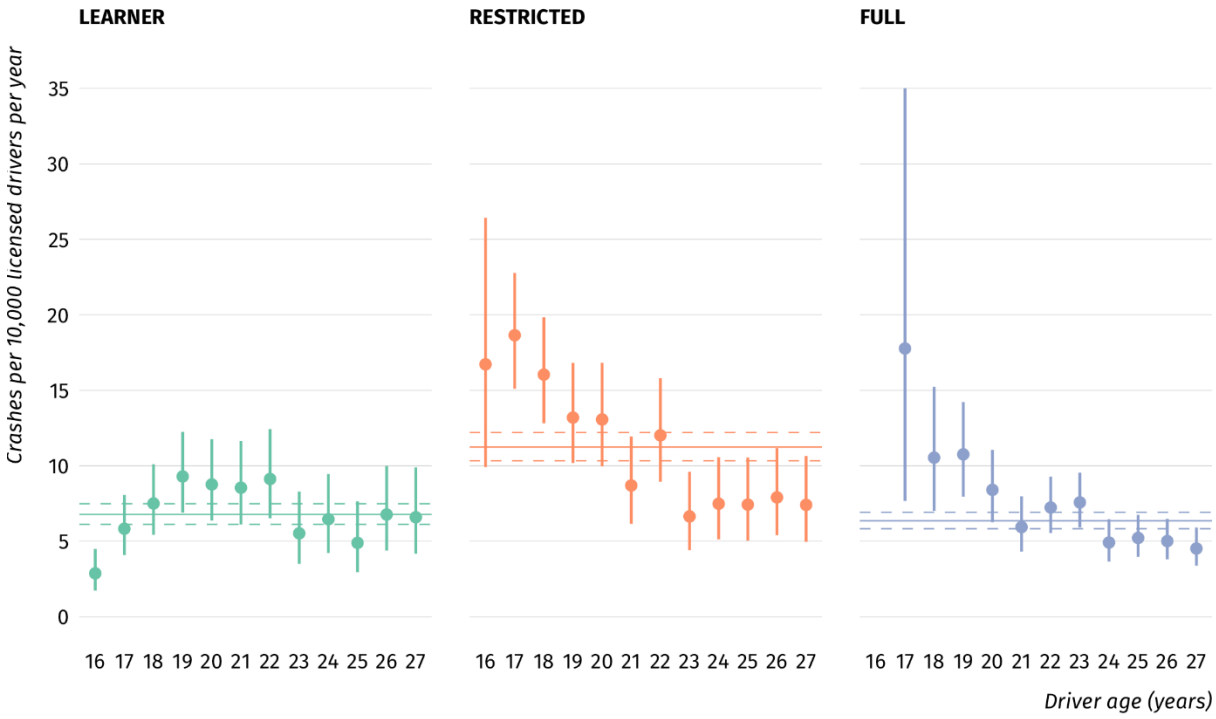


[15] Crash rates were calculated for this combined period to increase accuracy of the estimated rates. See section 3.2.1.

4.1.2. Crash rates by licence stage and driver age

Figure 2 shows how crash rates at each licence stage vary with the driver's age, for the combined period from 2015 to 2017 (horizontal lines show the overall crash rate for each licence stage across all drivers aged 16 to 27 and associated 95% confidence intervals). At the restricted and full licence stages, crash rates generally decline with age, and drivers aged 20 and under have relatively high crash rates compared to drivers aged 21 to 27. Drivers aged 17 and 18 years old with restricted licences are particularly high risk, with crash rates more than 1.5 times higher than the overall rate for restricted drivers aged 16 to 27. For fully licensed drivers, crash rates for drivers aged under 20 years old in our analysis are statistically significantly higher than the overall rate (around 1.7 to 2.8 times higher, *p*-values < 0.02 in all cases). At the learner stage, 16-year-olds appear to be relatively safe with a crash rate of 2.9 crashes per 10,000 licensed drivers per year (*p*-value < 0.005).

Figure 2 Fatal and serious at-fault light motor vehicle crash involvements per 10,000 licensed drivers per year for 2015 to 2017 combined by licence stage and driver's age with 95% confidence intervals.



4.1.3. Crash rates by licence stage and driver region of residence

Across regions of residence (see section 3.1.7 of the *Technical Report*), crash rates for drivers aged 16 to 27 years old for the combined period from 2015 to 2017 at all licence stages are relatively low in Auckland and Wellington compared to many other regions, suggesting that drivers in predominantly urban areas have fewer crashes and/or that crashes in rural areas are more likely to be serious or fatal due to higher speeds and other factors (e.g. remoteness and subsequent delay in medical treatment). Crash rates tend to be higher in southern and western regions of the South Island, that is, the West Coast, Southland, and Otago. Relatively high crash rates are also observed in Northland and Manawatu-Wanganui.

4.1.4. Crash rates by licence stage and two-way combinations of driver age, gender, and region

We also analysed crash rates by licence stage and two-way combinations of driver age by gender and region of residence, for the combined period from 2015 to 2017. These crash rates are subject to greater uncertainty due to the smaller number of drivers in each category. Table 2 shows the ratios of crash rates for licence stage, driver gender, and age combinations versus the overall crash rate for each licence stage and age combination, for the combined period from 2015 to 2017. In Table 2, statistically significant (at the 5% level, two-tailed tests) high and low crash rate ratios are highlighted. This shows similar patterns to those described above, that is, in most cases relatively high crash rates for drivers aged under 21 years old and relatively low crash rates for drivers aged 21 to 27 years old. In general, female drivers aged 16 to 27 have somewhat lower crash rates and male drivers have somewhat higher crash rates.[16]

Table 2 Ratios of crash rates by licence stage, driver gender, and age, to overall crash rates for each licence stage, for the combined period from 2015 to 2017.

Comparison	Licence stage	Driver age											
		16	17	18	19	20	21	22	23	24	25	26	27
Drivers by age vs all drivers aged 16 to 27	L	0.4	0.9	1.1	1.4	1.3	1.3	1.3	0.8	1.0	0.7	1.0	1.0
	R	1.5	1.7	1.4	1.2	1.2	0.8	1.1	0.6	0.7	0.7	0.7	0.7
	F	n/a	2.8	1.7	1.7	1.3	0.9	1.1	1.2	0.8	0.8	0.8	0.7
Female drivers by age vs all drivers aged 16 to 27	L	0.2	0.6	1.1	0.9	0.6	0.6	1.0	0.7	0.8	0.5	0.9	0.5
	R	1.9	1.4	1.1	0.9	0.6	0.7	0.8	0.5	0.6	0.5	0.7	0.3
	F	n/a	3.0	1.2	1.1	1.2	0.6	0.6	0.7	0.5	0.5	0.6	0.6
Male drivers by age vs all drivers aged 16 to 27	L	0.6	1.1	1.1	1.8	2.0	2.0	1.7	1.0	1.1	1.0	1.1	1.6
	R	1.2	1.9	1.7	1.5	1.7	0.9	1.3	0.6	0.8	0.8	0.7	1.1
	F	n/a	2.6	2.1	2.2	1.5	1.2	1.6	1.6	1.0	1.1	1.0	0.8

4.1.5. Trends in crash rates over time

Analysis of trends in crash rates is constrained by the limitations of the licensing dataset (see section 3.3). In general, crash rates for drivers aged 16 to 19 years old have been trending down over time. However, in most cases the reductions occurred before around 2013, and per-driver crash rates after that time have been constant or increased slightly. For drivers aged 20 and older, crash rates have remained relatively constant, or increased slightly. Our analysis found only one case of a statistically significant increasing trend (22-year-old learners). Section 3.1.9 of the *Technical Report* has more detail on these trends.

[16] One possible exception is 17-year-old fully licensed females, with a crash rate 3.0 times higher than the overall rate for 16- to 27-year-old fully licensed drivers. This difference is not statistically significant at the threshold used in this report (*p*-value 0.09) but if this difference persists in future years it may deserve further investigation.

4.1.6. Implications for driver licensing

Our analysis found relatively large variations in crash rates across drivers of different genders, ages, and regions of residence, and at different licence stages. In general, the GDLS can seek to influence road safety by encouraging or inhibiting groups of people from driving (e.g. people below the minimum driving age cannot legally drive), or by giving people incentives and ability to become more competent drivers (e.g. via testing required to progress through the licence stages), and by protecting less experienced drivers from some risks (e.g. the conditions imposed on learner and restricted drivers).[17] However, there are practical constraints on how finely the GDLS rules can be adjusted to compensate for differences in crash risk and exposure across groups of drivers. For example, there would be practical and ethical implications of having different licensing rules for males versus females, or for drivers in Southland versus Auckland. Thus, the GDLS should focus on population-level factors rather than narrowing on particular sub-groups identified within the analysis in a way that could be considered discriminatory.

Overall crash rates at the learner licence stage are not significantly different from crash rates at the full licence stage, for drivers aged 16 to 27 years old. This suggests that the supervision requirements and learner theory test may be adequate to prepare learner drivers for risks that they face while driving, at least relative to fully licensed drivers. However, as noted above, crash rates for active learner drivers may be higher than those calculated here, as it is possible that there is a higher proportion of people with learner licences who are not active drivers compared to full licence holders. Further research into rates of active driving for learners is needed to determine whether learner crash rates are in fact the same as those for fully licensed drivers.

The most obvious safety-related outcome for Class 1 that the GDLS could attempt to influence is the relatively high crash rate for drivers with restricted licences, particularly those aged 17 and 18 years old. Given that the transition from supervised to unsupervised driving must occur at some point, the question is whether the conditions under which this occurs are optimal, that is, whether the GDLS is adequately designed to cope with the change in crash rates that accompanies the transition from a learner to a restricted licence.

Possible changes include increasing the minimum age for obtaining a restricted licence (currently 16.5 years) or increasing the minimum learner licence duration (currently 6 months) so that drivers are older and/or have held a learner licence for longer and presumably have more driving experience on average when they obtain their restricted licence.[18] However, such changes would have a range of effects including delaying people's progression through the licensing stages, which may affect ability access employment or education.

Further strengthening the practical driving test for obtaining a restricted licence could also be considered, but in this study we found no clear evidence that an earlier strengthening of this test led to a reduction in crash rates (see section 4.2 below). In any case, any safety-related benefits of such changes would need to be balanced against other impacts in a broader analysis of their effects, which is beyond the scope of this report.

[17] More generally, a GDLS is a public health intervention that works by starting drivers in less risky situations and exposing them to more risk as they gain experience. Williams and Ferguson (2002) provide more information about the rationale for a graduated licensing system.

[18] Williams *et al* (2016) reviewed the evidence for changes to existing GDLS laws in the United States aimed at further reducing crashes among young drivers. They conclude that the evidence is mixed about the effectiveness of increasing the learner licence duration.

The trends in crash rates summarised above for drivers aged under 30 years old also raise a question of whether further changes to the GDLS could be used to partly compensate for the flat or increasing trends in per-driver crash rates that have been observed since around 2013, in contrast to falling crash rates observed between 2008 and 2013. It is not clear if these trends are directly related to driver licensing, and similar trends have occurred for the entire population of licensed drivers.[19] Regardless of the cause, it may be appropriate to investigate whether licensing rules can be adjusted to offset these trends in crash rates.

4.2. Estimated safety impacts of the 2009 to 2012 GDLS changes

4.2.1. Context for analysis of the changes

As discussed in section 3.6.1 of the *Technical Report*, changes in driver demographics occurred around the same time of the changes to the GDLS, some of which were likely caused by the changes to driver licensing, and some of which reflected longer term socio-economic trends:

- The median age of drivers receiving learner licences increased following the increase in the minimum age, from around 16 years old before 2011 to around 17 years old in 2017. Similarly, the median age of people obtaining a restricted licence increased from around 18 years old to around 19 years old. The median age of people obtaining full licences also increased from around 21 years old to around 22 years old, but some of this increase appears to reflect a trend that started before the minimum learner licence age was increased.
- The gender distribution of people receiving Class 1 learner and restricted licences remained roughly constant between 2003 and 2017, with an almost equal proportion of licences issued to males and females. The change to the minimum age appears to have caused a temporary reduction in the proportion of learner and restricted licences issued to males for about the first six months after the change. The proportion of full licences issued to males has also gradually declined over time, from around 57% in 2003 to around 50% in 2017, which appears to reflect a longer-term trend in driver licensing.20
- The change to the minimum age appears to have caused a temporary increase and then decrease in the amount of time people spend at the learner and restricted stages. Before the minimum age increased, drivers aged 20 and under took a median of around 30 months to obtain their full licence. In 2017 this had reduced to around 26 months, with all of the reduction occurring at the restricted stage. Some people therefore appear to have responded to the increased minimum ages by speeding up their progression through the licence stages. This may reflect, for example, people who are planning to enter the workforce at 18 years old and want to have a full licence by that time. Following the increase in the minimum learner age, such people needed to progress through the licence stages more quickly in order to have a full licence by the time they turned 18.

[19] See https://www.transport.govt.nz/mot-resources/transport-dashboard/2-road-transport/rd054-road-fatal-and-injury-crashes-per-100000-population/rd042-road-deaths-and-injuries-per-million-licence-holders/.

[20] This also suggests that the proportion of full licences issued to males has reduced to be closer to the overall proportion of males in the New Zealand population, which is currently around 49% (https://www.stats.govt.nz/topics/population).

4.2.2. Estimated effects on crash rates of increasing the minimum driving ages (August 2011)

As described above, increasing the minimum ages had both temporary and long-term effects on the characteristics of drivers obtaining Class 1 licences. The temporary impacts of the changes to the minimum ages on driver characteristics appear to have taken around 18 to 24 months to resolve, that is, for key metrics such as the median age of learner drivers to settle at a new long-term level. It is possible that these temporary effects on driver characteristics also had temporary effects on crash rates. However, these effects are difficult to measure due to the relatively high uncertainties associated with crash rates measured over short periods of time. Our analysis of the impacts of increases to the minimum ages on crash rates therefore focuses on the long-term effects after the characteristics of licensed drivers stabilised.

In terms of long-term safety outcomes, there are two potentially offsetting effects of increasing the minimum age for obtaining a learner licence from 15 to 16 years old:

1. The total population of licensed drivers is reduced, since 15-year-olds are no longer allowed to drive. Fewer drivers means fewer crashes, all else being equal, and all or almost all crashes involving 15-year-old drivers were prevented.[21]
2. The age and driving experience[22] profile of remaining drivers is altered. The typical driver is older, which likely makes them safer (see Figure 2 above, and similar evidence has been found in a range of international studies such as McCartt *et al*, 2009). However, the typical driver also has less driving experience, because increasing the minimum learner age took away up to one year of potential driving experience from all drivers who would have obtained their learner licence at 15 years old.

Increasing the minimum age for obtaining a restricted licence from 16 to 16.5 years is unlikely to have had a significant *additional* effect on safety outcomes, given that the minimum learner licence duration was unchanged at six months. The remainder of this analysis therefore focuses on the effects of increasing the minimum learner licence age from 15 to 16 years old.

Prior to the minimum learner age increasing, just under half of the Class 1 learner licences issued each year were to 15-year-olds. Figure 3 shows how the distribution of ages at which people obtained their learner licence changed between 2010 and 2017. In general, the shape of the distribution is similar, and most people who would have obtained a learner licence at 15 years old appear to have obtained their licence around one year later. However, it appears that some people responded by bringing forward the date at which they obtained a learner licence. For example, in 2010, 17% of learner licences were issued to people within a month of their 15th birthday, while in 2017, just under 20% of licences were issued to people within a month of their 16th birthday.

[21] It is possible that some 15-year-olds continue to drive illegally and there may still be some crashes involving this age group. We do not have information that allows us to estimate the number of 15-year-olds who drive illegally. However, there is no evidence that increasing the minimum learner duration in Queensland led to an increase in unsupervised driving by learners (Scott-Parker *et al*, 2011).

[22] As with other analysis in this report, driving experience is measured by the amount of time since each driver obtained their learner licence.

Figure 3 Learner licences issued versus the driver's age at the time of obtaining their learner licence, for 2010 and 2017.

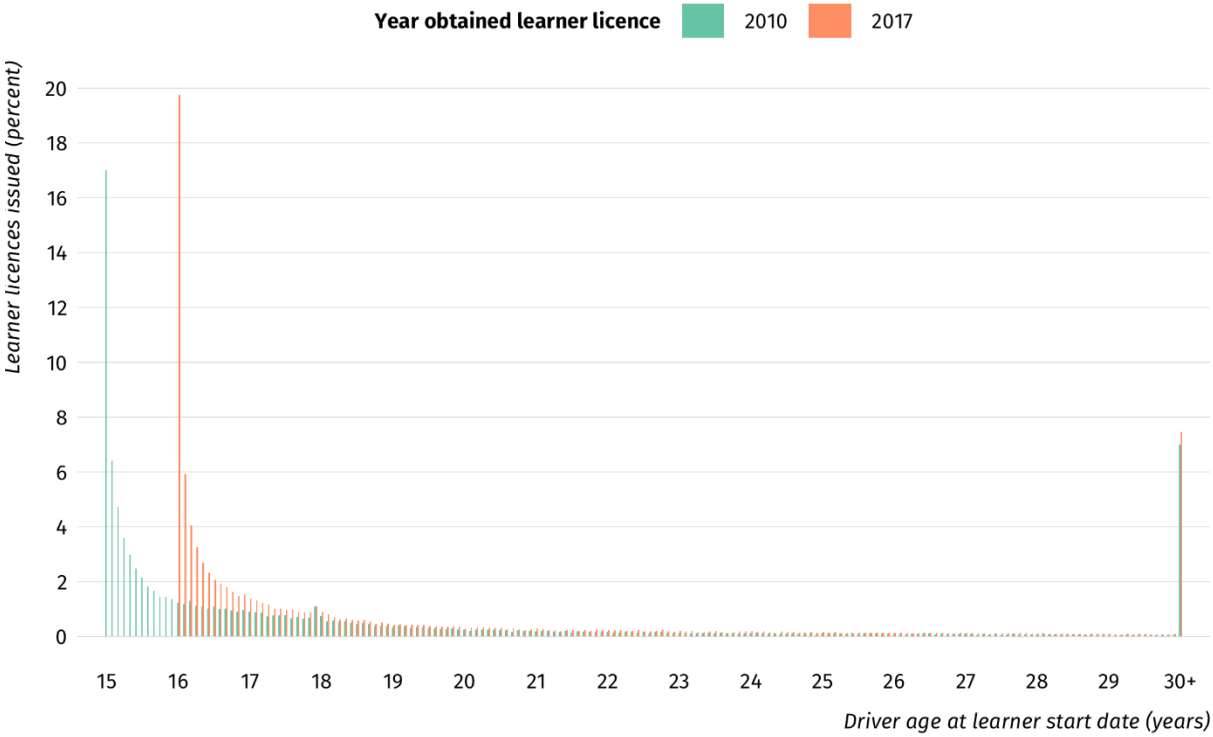
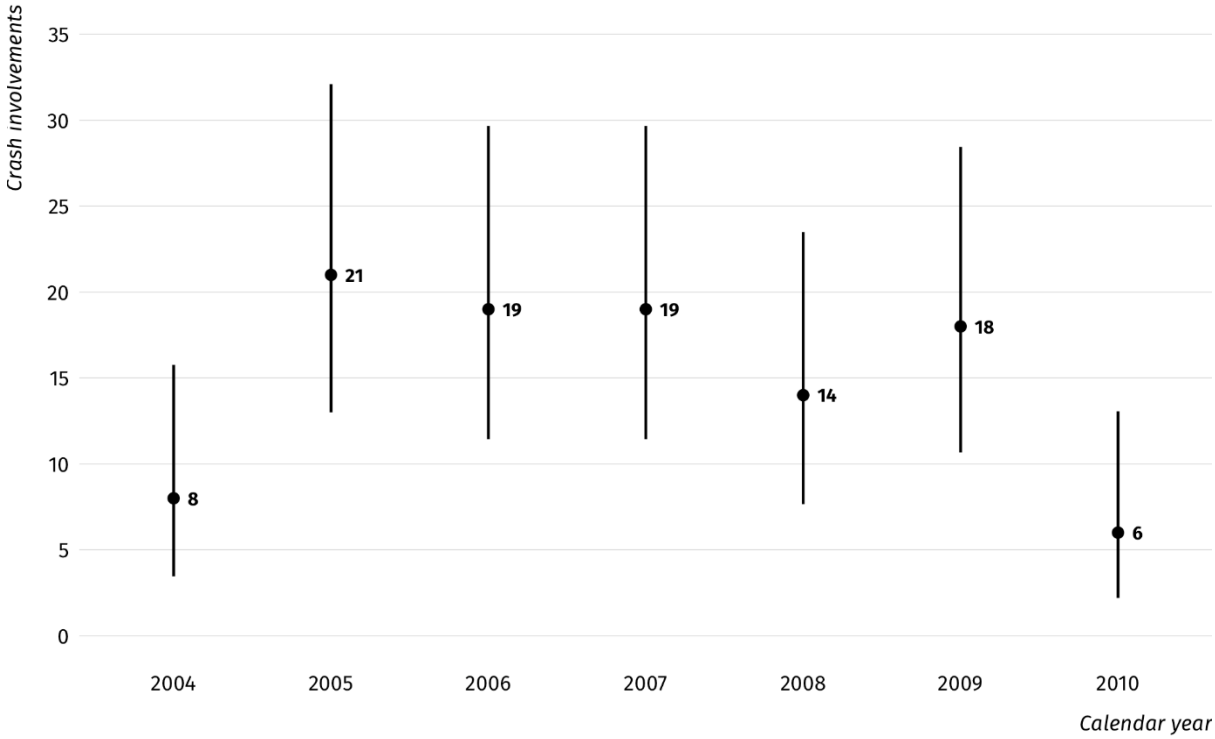


Figure 4 shows the annual number of annual crashes involving 15-year-old drivers in years prior to the increase of the minimum learner age. On average across all years shown (2004 to 2010), 15-year-olds were involved in 15 crashes per year. Based on trends in the proportion of the 15-year-old population with a driver licence and the total population of 15-year-olds in 2017, we estimate there would have been around 18,300 15-year-old licensed drivers in 2017. Using a model of crash involvements (described in section 3.6.2 in the *Technical Report*), we estimate that these 15-year-old drivers would have been involved in 17.4 crashes in 2017 if the minimum learner age had remained at 15 years old (with a 95% confidence range from 15.2 to 19.8 crashes).

Figure 4 Crashes involving 15-year-old drivers, by year, with 95% confidence bands showing the plausible range of the number of crashes in each year given random variation in crash rates.

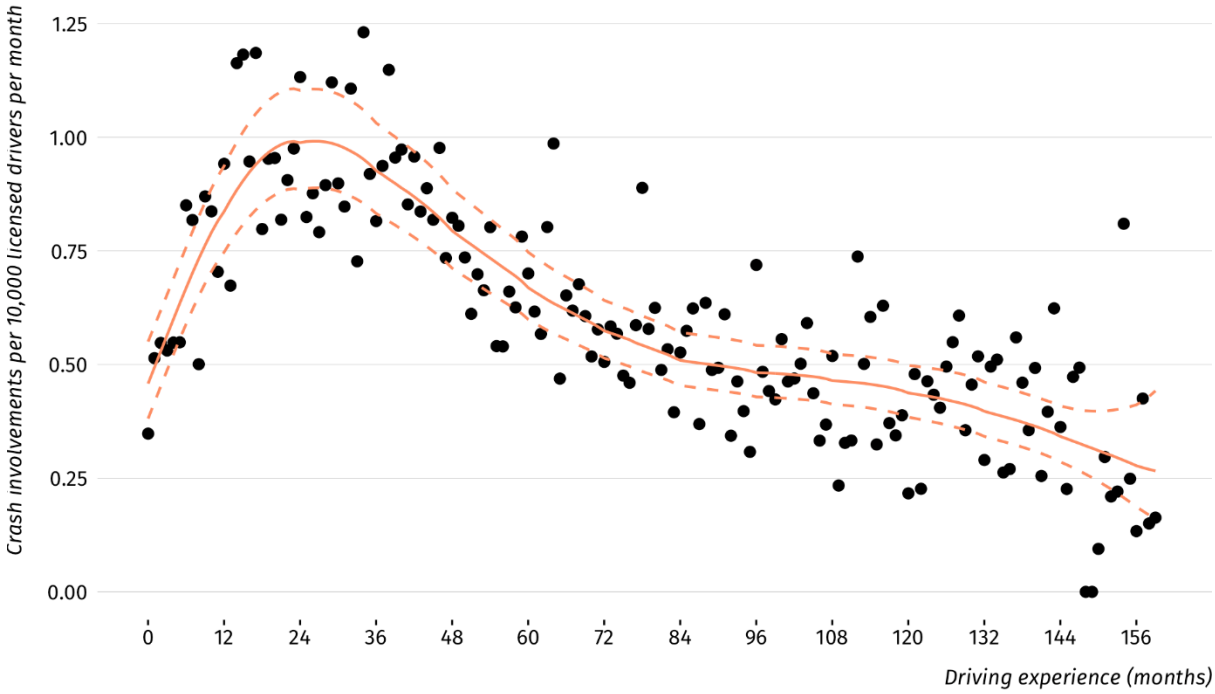


Among drivers aged 16 and older, the effects of increasing the minimum learner age depend on how this affected the age and driving experience profile of such drivers, and the relationships between age, experience, and crash rates. We estimated these effects using a model that predicted crash involvements as a function of driver age, experience, gender, and year (using the amount of time since obtaining a learner licence as a proxy for driving experience).

The actual rate of monthly crash involvements for Class 1 licensed drivers (overall, including progression through the licence stages) as a function of the amount of time since obtaining a learner licence and the predictions from this model are shown in Figure 5. In general, the rate of crash involvements starts out relatively low for new learner drivers and reaches a peak while most drivers are in the early stages of their restricted licence, before gradually declining as with time.[23] In addition, older drivers tend to crash less often (all else being equal), and the model used for this analysis predicts that each year of age (up to 30 years old) translates to about a 5% reduction in the odds of crash involvement (see section 3.6.2 of the *Technical Report* for details of the estimated relationships between crash involvement and driver age).

[23] Over time, drivers get older and have held a licence for longer, both of which affect the probability that a driver is involved in a crash. The curve shown in Figure 5 reflects both of these effects.

Figure 5 Actual (black dots) and modelled (red line, with 95% confidence bands) monthly crash rates for drivers aged under 30 versus driving experience measured as the amount of time since obtaining a learner licence, from 2008 to 2017 combined.

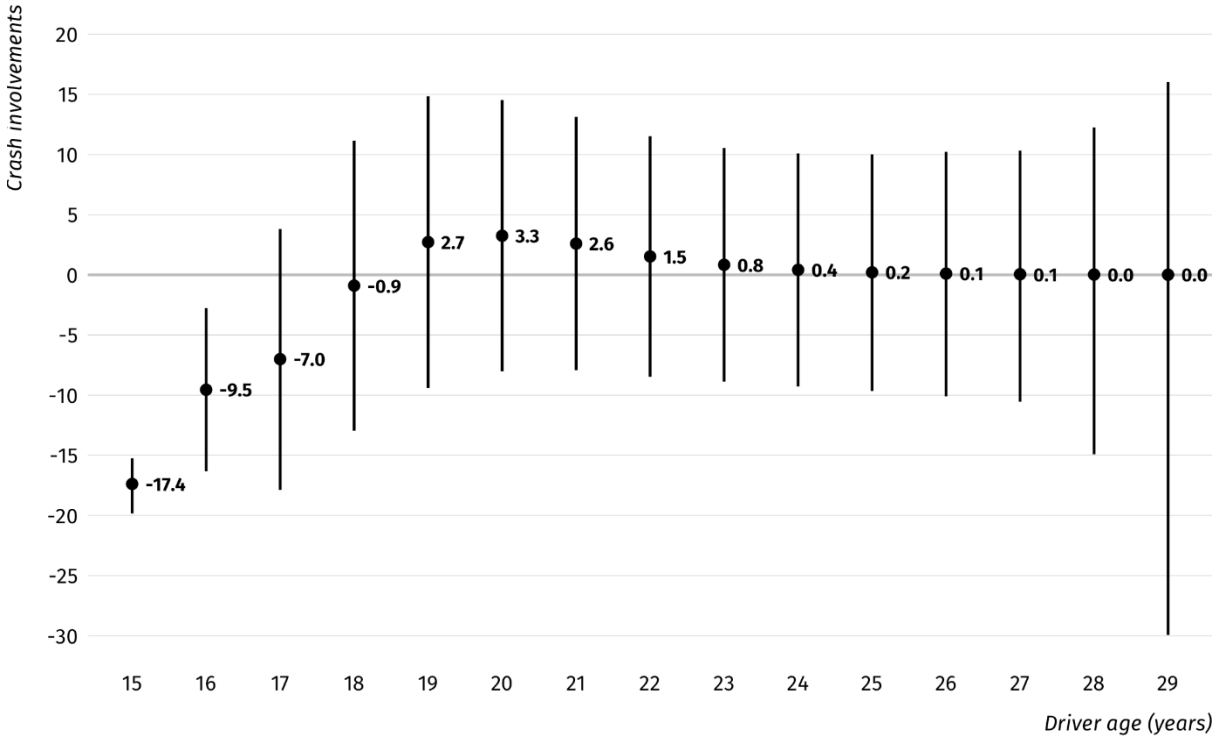


Changes to the age and experience profiles as a result of changing the minimum age therefore have relatively complex effects on crashes among drivers aged 16 and older. We used the model of crash involvements to predict crashes among drivers aged 16 to 29 years old in 2017 if the minimum driving age had remained at 15 years old, that is, if the age and experience profile of these drivers was what we estimate it would have been if the minimum age had remained at 15 years old (see section 3.6.2 of the *Technical Report*).

The results of this analysis are shown in Figure 6. As well as the reduction in crashes for 15-year-olds, we estimate that increasing the minimum ages reduced crashes among 16-, 17-, and 18-year-olds, due to a greater proportion of drivers in these age groups holding learner licences where they are relatively less likely to be involved in a crash. Among 19- to 24-year-olds we estimate small increases in crashes, due to reduced driving experience that is not fully offset by drivers being older. Among drivers aged 25 to 29 years old, we estimate negligible impacts on crashes, as once drivers have held a licence for a relatively long time, small changes to the amount of time that they have held a licence are estimated to make little difference to the likelihood that they are involved in a crash.

Overall, we estimate that increasing the Class 1 minimum ages resulted in around 23 fewer crashes in 2017, all else being equal, and this is a reasonable estimate of the annual long-term effects of this policy change given that the characteristics of drivers receiving Class 1 licences have been relatively stable in recent years (see section 3.6.1. of the *Technical Report*). This is comprised of a reduction of around 35 crashes among drivers aged 15 to 18 years old, offset by an increase of around 12 crashes among drivers aged 19 to 29 years old. As noted above, around three-quarters of this effect corresponds to the reduction in crashes due to 15-year-olds no longer being able to legally drive. A much smaller effect is estimated to be due to changes in the age and experience profile of drivers aged 16 to 29 years old.

Figure 6 Estimated change in the annual number of crash involvements due to changing the minimum driving age (with 95% confidence bands).



4.2.3. Estimated effects on crash rates of strengthening the restricted test (February 2012)

We used data on the crash involvements of around 550,000 drivers who received restricted licences between 2003 and 2017 and who were aged under 30 years old at the time to estimate whether the odds of crash involvement while on a restricted licence were different for drivers who obtained their restricted licence after the test was strengthened compared to drivers who received their restricted licence earlier.

The model is described in section 3.6.3 of the *Technical Report*. We estimate that, after controlling for driver age, gender, region of residence, amount of time spent on a learner licence, length of time holding a restricted licence, and year effects, the odds of crash involvement while on a restricted licence were not statistically significantly different for drivers who obtained their restricted licence after the test was strengthened compared to those who obtained their restricted licence before the test was strengthened (*p*-value 0.23).

4.2.4. Estimated effects on crash rates of rebalancing penalties for driver licensing breaches (December 2009)

This change affected all drivers from 1 December 2009 onwards with a learner or restricted licence. The changes to the penalties were designed to discourage people with learner and restricted licences from driving in breach of the conditions of their licence, that is, driving without a supervisor while on a learner licence, or carrying passengers or driving at night without a supervisor while on a restricted licence. In theory this change could have led to a reduction in crashes, assuming that people driving in breach of their licence conditions are at higher risk of crashing than they otherwise would be. In practice, such an effect is likely to be difficult to measure, unless people driving in breach of their licence conditions were involved in a relatively large proportion of crashes.

Given that this change affected all drivers with learner and restricted licences, we compared crash rates for drivers with learner and restricted licences in the immediate period before and after the penalties were rebalanced. Given that changes to the minimum ages had significant effects on safety outcomes (see section 4.2.2), we performed the analysis on the period from 1 January 2008 to 30 July 2011, that is, 23 months before the changes to penalties and 20 months after.[24]

During this time, crash rates for learner and restricted drivers were also affected by changes in the characteristics of such drivers (e.g. the age and gender profile) and by general safety trends that affected all drivers (e.g. investments in road infrastructure). To account for this, we estimated a model of monthly crash involvements for drivers aged 20 and under[25] with learner and restricted licences that controlled for observed characteristics of such drivers and used fully licensed drivers as a control group who were affected by general safety trends but who were not directly affected by the rebalanced penalties. As shown in more detail in section 3.6.4 of the *Technical Report*, the results of this "difference-in-differences" model show that there was no measurable change in crash rates for learner and restricted drivers after the rebalanced penalties compared to before that cannot be explained by changes in driver characteristics and by general safety trends.

4.3. Comparison of crash rates for restricted and fully licensed drivers

We analysed crash rates for fully licensed drivers relative to restricted drivers, controlling for the amount of time since obtaining a learner licence (as a proxy for driving experience) and other characteristics (driver age, gender, and region of residence), to see whether progression to a full licence is predictive of any change in the odds of crash involvement over and above that caused by factors such as increasing age and driving experience. If so, it can be argued that the full licence practical test is effective at promoting road safety, for example by:

- preventing less competent drivers from progressing to a full licence and requiring them to continue driving under restricted licence conditions which may reduce their exposure to some risks (e.g. when carrying passengers), and/or
- giving less competent drivers an incentive to improve their driving ability to pass the practical test and to be able to drive without restrictions under a full licence.

We estimated a logistic regression model of crashes for drivers in the licensing dataset who were aged under 30 when they obtained a learner licence, who had progressed to at least a restricted licence by the end of 2017, and who did not have an advanced driving certificate.[26] The model predicts crash involvement of individual fully licensed and restricted drivers as a function of the amount of time since they obtained a restricted or full licence, their age, gender, region, amount of time since they obtained a learner licence (as a proxy for total

[24] This specific period was chosen to allow the analysis to include all drivers aged 20 and under (due to dataset restrictions; see Table 1), and to end before the minimum driving age was increased in 2011, to avoid conflating the effects of that change with the changes to penalties.

[25] Given the time period for this analysis (2008 to 2011), limitations of the licensing dataset mean that the analysis could only include drivers up to 20 years old.

[26] We excluded fully licensed drivers with advanced certificates as having an advanced certificate is likely to have additional effects on safety outcomes that may be difficult to separate from the effects of passing the full licence test and progressing from a restricted to a full licence. Safety impacts of advanced certificates are analysed in section 4.5 below.

driving experience), and year indicators (see section 3.3 of the *Technical Report* for more details).

The key result from the model is that the overall odds of crash involvement for drivers aged under 30 with full licences is around 23% lower than for drivers with restricted licences, and in our analysis this difference is statistically significant (*p*-value < 0.01). While not all of this difference may be due to the full licence test on its own, this supports the hypothesis that drivers with full licences are safer drivers than those with restricted licences, after accounting for differences in the driver characteristics listed above. That is, it appears that drivers who progress to a full licence are less likely to be involved in crashes than drivers with restricted licences even after accounting for the fact that fully licensed drivers tend to be older and have held a driver licence for longer than drivers with restricted licences.[27]

The main implications of this are:

- The difference in crash rates for fully licensed drivers suggests that there is value in maintaining the distinction between the restricted and full licence stages for driver licences. The available evidence supports the hypothesis that the full licence test promotes road safety via the mechanisms outlined above. However, it is not clear whether the full licence test promotes safety by causing drivers to become safer, or by preventing less competent drivers from progressing (or both).
- As long as the restricted licence conditions protect less competent drivers who do not progress to a full licence from some crash risks, preventing these drivers from progressing to a full licence is beneficial for road safety. To investigate this further, it would be useful to compare safety outcomes for drivers with restricted licences who failed the full licence test with the general population of restricted drivers. It could also be useful to compare safety outcomes for fully licensed drivers who passed the full licence test on the first attempt versus those who passed after more than one attempt.28

4.4. Is the night-time driving restriction for restricted drivers effective?

Drivers with restricted licences are prohibited from driving between the hours of 10pm and 5am unless a fully licenced supervisor[29] is in the front passenger seat. If the night driving restriction is fully effective, all else being equal we should expect to see a similar rate of crashes for restricted drivers between 10pm and 5am as for fully licensed drivers, assuming that supervisors are able to prevent any crashes that a competent fully licensed driver would not have been involved in.

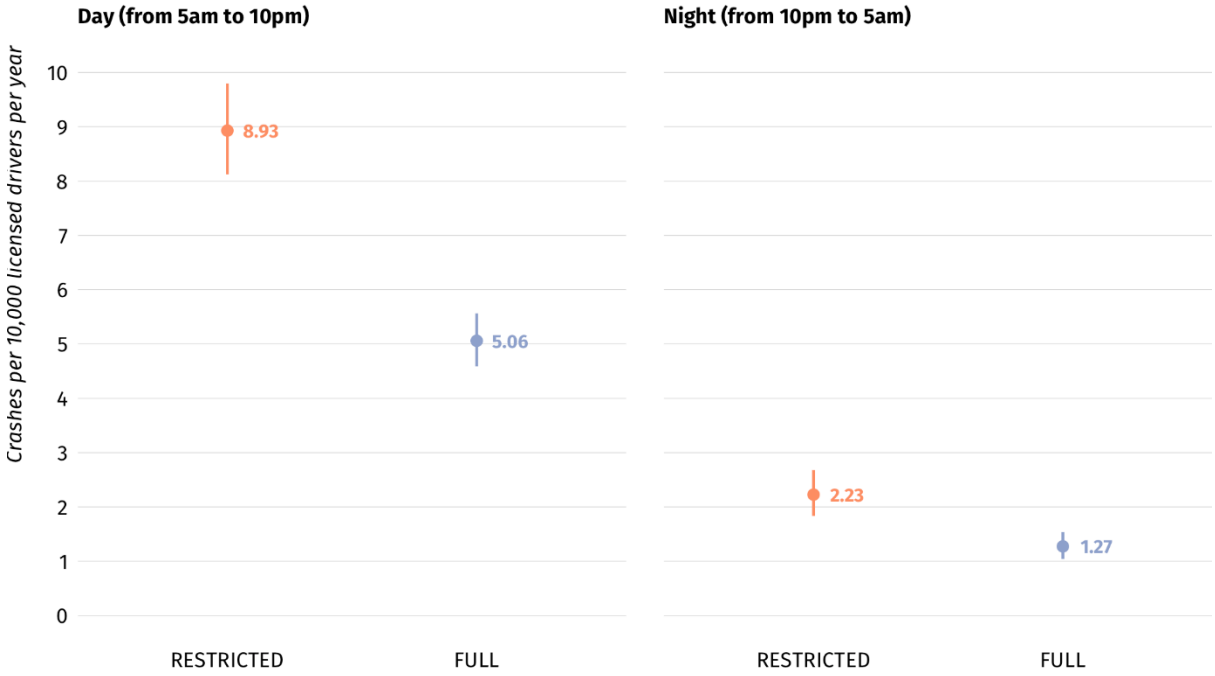
We compared the crash rate during the day (5am to 10pm) and night (10pm to 5am) for restricted versus fully licensed drivers aged 16 to 27 years old for the combined period from 2015 to 2017 (see section 3.2 of the *Technical Report*). The results shown in Figure 7 suggest that the night-time crash rate for restricted drivers is around 1.75 times greater than that for fully licensed drivers of the same age and in our analysis this difference is statistically significant (*p*-value < 0.01).

[27] The fact that crash rates tend to fall with driver age (particularly among drivers in their teens and 20s) is reflected in other results in this study (e.g. Figure 2 above), and other studies (e.g. Williams, 2003 and McCartt *et al*, 2009).

[28] Boufous *et al* (2011) examined this issue for drivers aged 17 to 24 years old in New South Wales, Australia. They found that drivers who failed the practical driving test to obtain an intermediate (i.e. restricted) licence at least four times were around 1.8 times more likely to be involved in a crash compared to drivers who passed the test on their first attempt.

[29] Class 1 supervisors must have had a full New Zealand Class 1 driver licence for at least two years and not have a supervisor condition on their own licence.

Figure 7 Fatal and serious at-fault light motor vehicle crash involvements per 10,000 licensed drivers aged 16 to 27 per year by licence stage and crash time periods, with 95% confidence intervals (2015 to 2017 combined).



We also analysed changes over time in night-time crash rates by comparing crashes in the combined period from 2015 to 2017 with the combined period from 2008 to 2010 (due to data limitations this was only possible for drivers aged 16 to 20 years old). At night, the crash rate for fully licensed drivers declined by 57% between these two periods, while the crash rate for restricted drivers only declined by 29%. This provides further evidence that other factors affect the night-time crash rate of restricted drivers compared to fully licensed drivers.

Overall, this analysis suggests that the requirement to have a fully licensed supervisor does not lead to restricted drivers crashing at the same rate as fully licensed drivers of the same age at night. This could be due to some degree of non-compliance with the supervision requirement,[30] and/or that in practice supervisors are not able to prevent all crashes at night that occur due to the restricted driver's relative inexperience.[31] Other factors could also be responsible for this difference, for example, restricted drivers may tend to drive vehicles with lower safety ratings than fully licensed drivers, or restricted drivers who choose to contravene the night-time driving restriction may also be more likely to engage in other risky behaviour such as drinking and driving, or dangerous driving.[32]

This analysis does not suggest that the night-time driving restriction should be removed – given that restricted drivers crash significantly more often than fully licensed drivers in during both the day (when they are mostly unsupervised) and the night, it is possible that there

[30] Carpenter and Pressley (2013) show that drivers aged 15 to 17 years old in the United States were not compliant with night-time driving restrictions in around 15% of fatal crashes between 2006 and 2009.

[31] The practical ability of supervisors to prevent crashes could not be analysed using the data available for this study.

[32] Carpenter and Pressley (2013) found that drivers aged 15 to 17 years old in the United States who were non-compliant with night-time driving restrictions and who were involved in crashes were around five times more likely to be drinking and 1.6 times more likely to be not wearing a seatbelt than similar drivers who were involved in crashes but who were compliant with night-time driving restrictions.

would be more crashes by restricted drivers at night if the night driving restriction did not apply.

Instead, there may be an opportunity for improved safety outcomes if the night-time crash rate for restricted drivers can be reduced to be closer to that for fully licensed drivers of the same age. If the night-time crash rate of restricted drivers aged 16 to 27 years old could be reduced from the current rate (2.2 crashes per 10,000 licensed drivers per year) to the equivalent rate for fully licensed drivers (1.3 crashes), around 16 crashes per year could be prevented. Further analysis including studying the factors involved in night-time crashes by restricted drivers is needed to determine if some or all of this potential reduction can be achieved.

4.5. Demographics of advanced certificate uptake and comparison of crash rates for drivers with and without advanced certificates

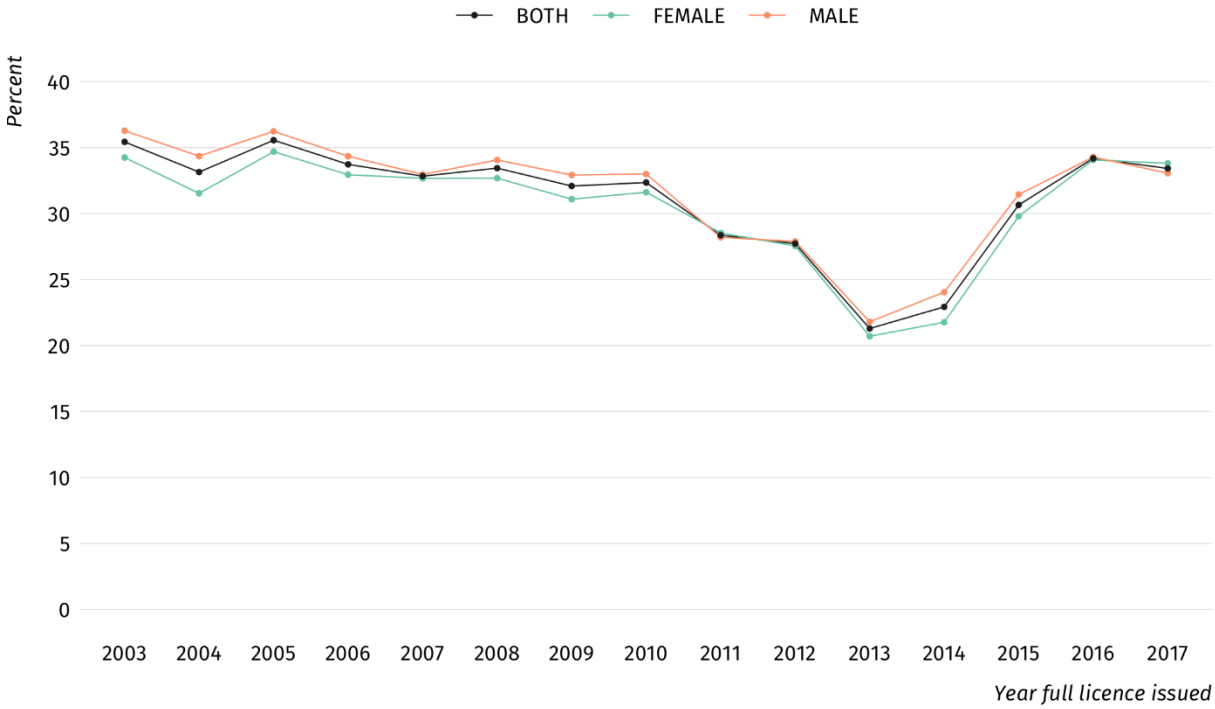
Drivers who complete an approved advanced driving course and obtain an advanced driving certificate can reduce the minimum time they must drive on their restricted licence from 18 months to 12 months for drivers aged under 25 and from 6 months to 3 months for drivers aged 25 and older. We analysed and compared demographic characteristics and crash rates of fully licensed drivers with and without advanced driving certificates (see section 3.5 of the *Technical Report* for more detail). For drivers with advanced certificates we also distinguished between those who obtained a time discount at the restricted stage and those who did not. However, since almost all drivers with an advanced certificate used it to get a time discount, crash rates for drivers with advanced certificates but without time discounts have wider confidence intervals (i.e. are estimated less accurately).

Our analysis in this section is based on full licences issued between 2003 and 2017 to drivers aged under 30 years old at the time. There are around 588,000 such drivers in the licensing dataset, of which 31% are recorded as having an advanced driving certificate at the time of obtaining their full licence. For drivers with an advanced certificate whose restricted licence is also recorded in the licensing dataset, 89% obtained a time discount.

4.5.1. Demographics of advanced certificate uptake and time discounts

The proportion of full licences issued to drivers aged under 30 where the driver held an advanced certificate has been relatively stable over time at around one-third, aside from a temporary reduction between 2011 and 2014 that was likely caused by changes to the minimum driving ages in 2011 (Figure 8). Historically, males were slightly more likely than females to obtain advanced certificates, but in most years since 2011 uptake has been almost equal across genders (Figure 8).

Figure 8 Proportion of full licences issued to drivers aged under 30 where the driver held an advanced certificate by driver's gender and year (percent).



Uptake of advanced certificates declines substantially with the driver's age at the time of obtaining their full licence (Figure 9). Given that most drivers with advanced certificates obtain a time discount, this suggests that people who obtain their full licence at a younger age were motivated to progress to a full licence relatively quickly.

Most drivers who obtain advanced certificates and get time discounts tend to take close to the maximum discount available. The median time discount for drivers aged 17 to 24 years old at the time of obtaining their full licence in 2017 was between 4 to 5 months, while for drivers aged 25 to 29 it was around 2.5 months (Figure 10). In Figure 10, labelled values are the upper quartile, median, and lower quartile time discount for each driver age. Some drivers appear to have obtained discounts greater than the permitted maximums of six months or three months. The reasons for this are not clear.

Figure 9 Proportion of full licences issued in 2017 where the driver held an advanced certificate by the driver's age at the time of obtaining their full licence (percent).

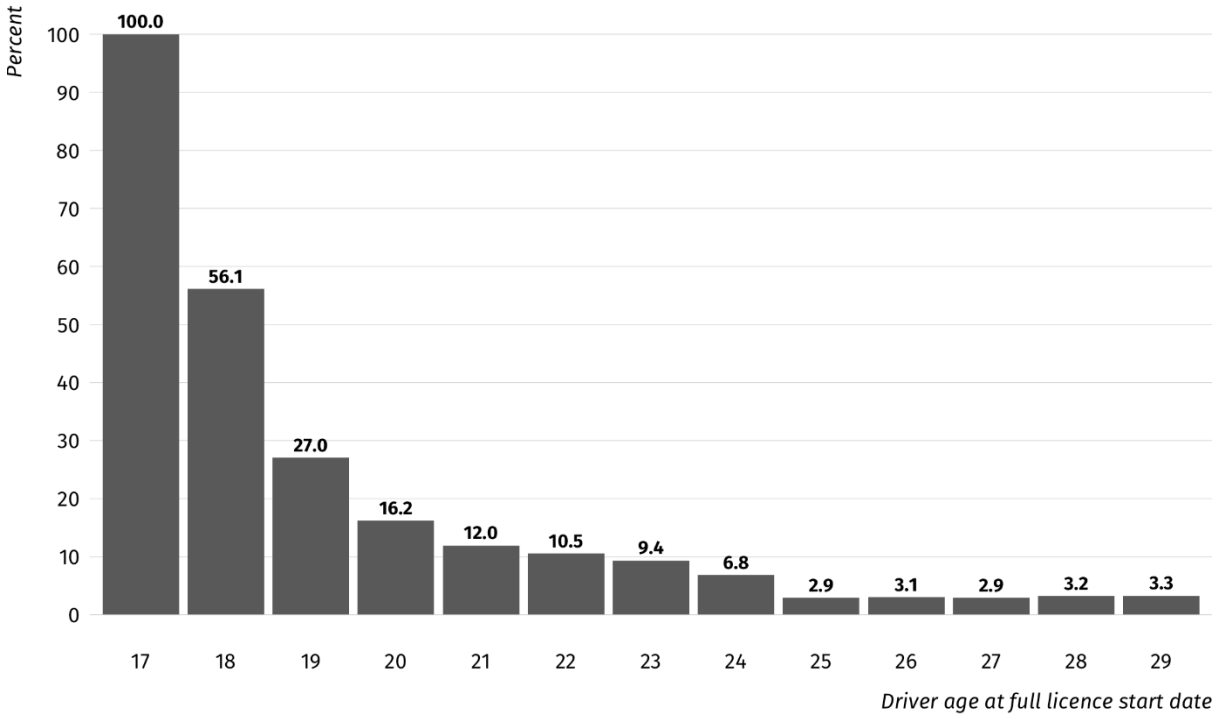
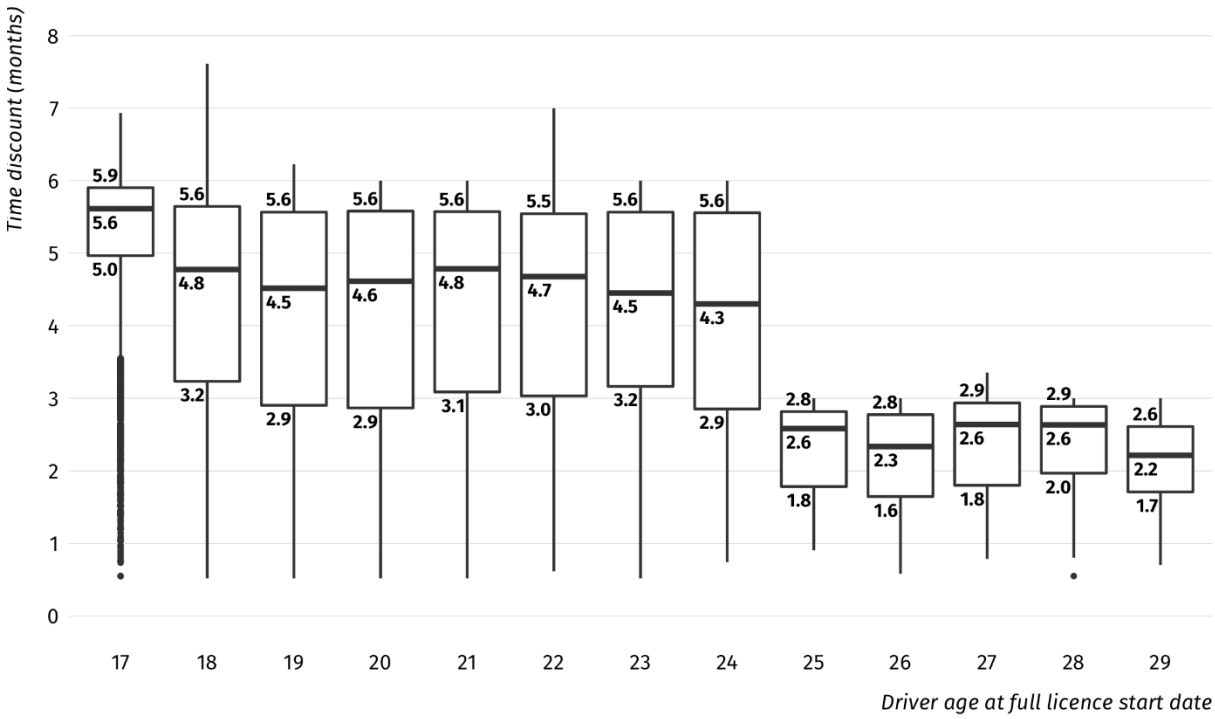


Figure 10 Distribution of time discounts obtained by drivers who received full licences with advanced certificates in 2017 by the driver's age the time of obtaining their full licence.



We also found (see section 3.5.3 of the *Technical Report*):

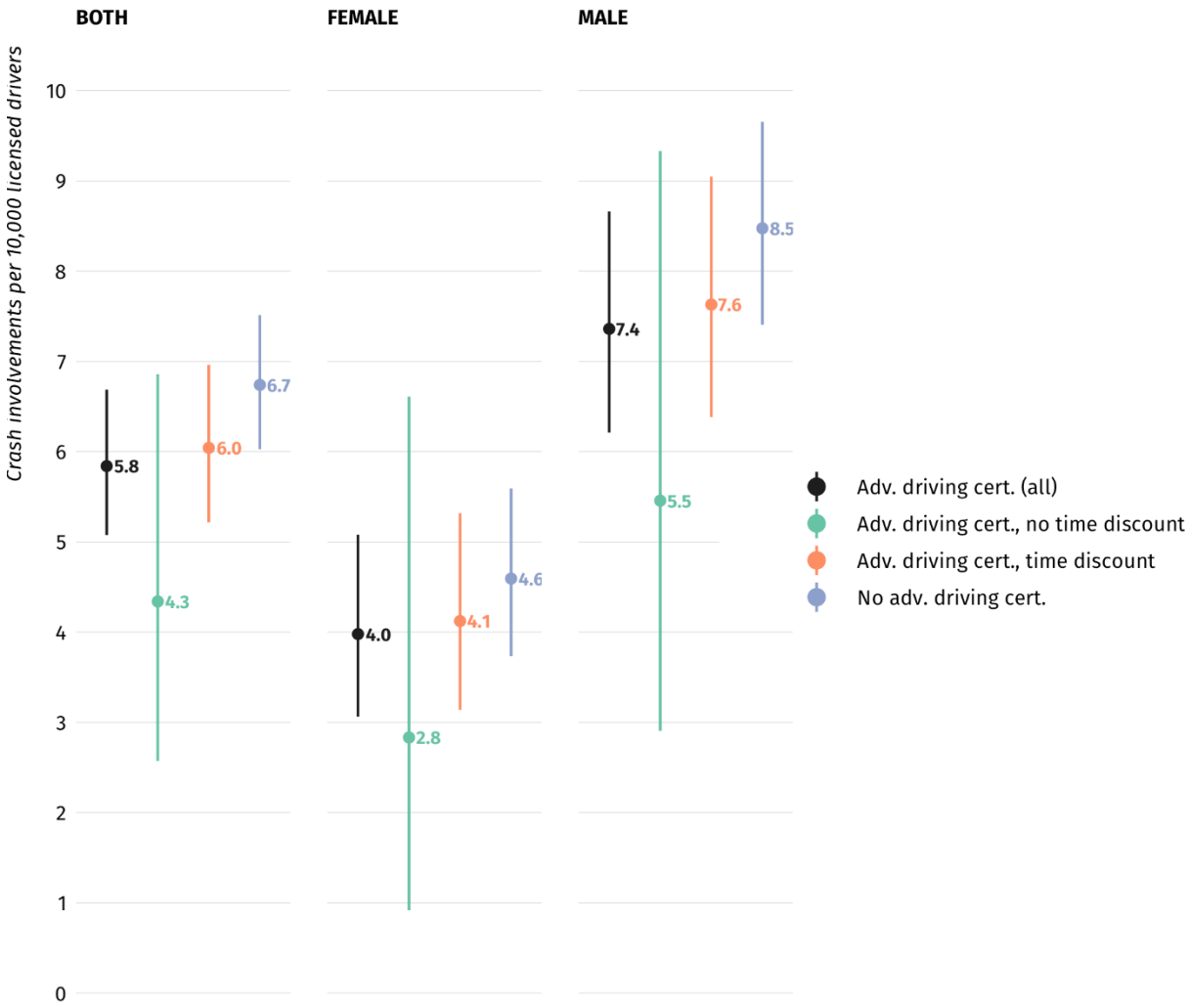
- Advanced certificate uptake is relatively low among drivers aged under 30 living in Auckland and Wellington compared to most other regions. Uptake is relatively high among drivers living in Marlborough, Nelson, Tasman, and Southland regions.
- Fully licensed drivers aged under 30 years old at the end of 2017 who had an advanced driving certificate tended to obtain their learner licences at younger ages compared to people who did not have an advanced driving certificate. This suggests that people who obtain advanced driving certificates are also those who tend to start learning to drive at a younger age.
- Drivers with advanced certificates also tended to spend less time at the learner stage compared to people without an advanced certificate. Among drivers aged under 30 years old who were fully licensed at the end of 2017:
    - Those with advanced certificates spent a median of 8.7 months on their learner licence if they subsequently obtained a time discount at the restricted stage, or 9.8 months if they did not obtain a time discount.
    - The median learner duration was 13.9 months for drivers who did not subsequently complete advanced driver training and get an advanced certificate.

Overall this analysis suggests a relationship between the choice to obtain an advanced certificate and a person's motivation to drive, either due to desire or necessity. For example, people who start learning to drive at a younger age or who live in a less urbanised region are more likely to obtain an advanced certificate. The high uptake of time discounts suggests that their availability appears to be a strong motivation for obtaining an advanced certificate.

4.5.2. Comparison of crash rates for drivers with and without advanced certificates

Figure 11 shows a simple comparison of the crash rate for fully licensed drivers aged 17 to 27 years old for the combined period from 2015 to 2017 by advanced certificate and time discount status. Our analysis found that crash rates for drivers with advanced certificates are not statistically significantly different from those for drivers without advanced certificates (*p*-values range from 0.07 to 0.57). We also performed similar comparisons of crash rates for drivers with and without advanced certificates broken down by the driver's age and region of residence (see section 3.5.4 of the *Technical Report*). Again, the differences in crash rates were not statistically significant in our analysis (all *p*-values > 0.05).

Figure 11 Fatal and serious at-fault light motor vehicle crash involvements per 10,000 fully licensed drivers per year for drivers aged 17 to 27 years old in 2015 to 2017 by gender, advanced certificate status, and time discount status, with 95% confidence intervals.



Comparisons of changes over time in crash rates for drivers with and without advanced certificates, and analysis of time trends estimated from Poisson regression models of crash rates for drivers of different ages with and without advanced certificates found no statistically significant differences in the estimated crash rate trends (all *p*-values > 0.05; see section 3.5.4 of the *Technical Report*). Overall, our analysis found no evidence that crash rates for drivers with advanced certificates have differed over time relative to drivers without advanced certificates.

We also used logistic regression models that predict crash involvements for individual fully licensed drivers to test the relationship between having an advanced certificate and the odds of being involved in a crash, while controlling for differences in driver age, gender, and region of residence. We tested three different models:

1. We analysed the current relationship between advanced certificates and crashes by predicting crashes between 2015 and 2017 for all fully licensed drivers aged 17 to 27 years versus advanced certificate and time discount status. The odds of crash involvement were 45% lower for drivers with an advanced certificate and no time discount compared to drivers without an advanced certificate, and this difference was

statistically significant in our analysis (*p*-value 0.04). The odds of crash involvement for drivers with an advanced certificate and a time discount were not statistically significantly different from the odds for drivers without an advanced certificate (*p*-value 0.64).

2. We found no evidence that having an advanced driving certificate (with or without a time discount) was predictive of the driver's odds of being involved in a crash during the first 12 months of having a full licence (*p*-value 0.91 for drivers with an advanced certificate and a time discount, and 0.82 for drivers with an advanced certificate and no time discount).
3. We analysed the long-term relationship between advanced certificates and crash involvements by predicting crashes while on a full licence for all drivers who obtained a full licence between 2004 and 2017 and who were aged under 30 years old at the time. This model estimated that the odds of crash involvement for drivers with an advanced certificate (with or without a time discount) were not statistically significantly different from the odds of crash involvement for drivers without advanced certificates (*p*-value 0.31 for drivers with an advanced certificate and a time discount, and 0.37 for drivers with an advanced certificate and no time discount).

Overall, these results indicate no clear relationship between advanced certificate status and crash rates among drivers aged under 30 years old, and suggest that at least some of the differences in crash rates between drivers with and without advanced certificates can be accounted for by differences in characteristics of drivers in these two groups. There is evidence that drivers with advanced certificates and no time discount were involved in fewer crashes in the period from 2015 to 2017, but it is not clear whether this is caused by advanced driver training, or is due to characteristics of drivers who chose to do advanced training but choose not to take a time discount at the restricted stage (or some combination of these effects).

Given this, it would be useful to further investigate the link between advanced driver training and crash rates. If clear evidence of a link can be established, it may be useful to examine whether alternative incentives for uptake of advanced certificates aside from time discounts at the restricted stage could lead to better safety outcomes.

4.6. Relationships between progression through the driver licensing stages, driver demographics, and crash rates

We analysed how progression through the driver licensing stages depends on observed driver characteristics (gender, age, and region of residence), and relationships between progression and crash rates. Progression was defined in terms of whether or not drivers had progressed from a learner to a restricted or a full licence in a given period of time. Since the definition of progressing vs non-processing drivers at any point in time is arbitrary, for the purpose of analysis we defined a driver's *four-year progression status* as whether they remained on a learner licence, progressed to a restricted licence but had not yet received a full licence, or progressed to a full licence on the fourth anniversary of obtaining their learner licence.[33]

For any given cohort of learner drivers, progression occurs gradually over time. Given this, and since the licensing dataset stops at the end of 2017, we can only analyse progression for cohorts of drivers who received their licence in earlier years. Figure 12 shows a snapshot

[33] Four years was chosen as it is double the standard minimum time for progression from a learner to a full licence for drivers aged under 25 without an advanced certificate.

of the progression pathways taken by drivers who obtained a learner licence in 2013 and were aged under 30 years old at the time, as at the end of 2017.

Figure 12 Snapshot of progression at the learner and restricted stages and achievement of full licences by the end of 2017 for drivers who obtained a learner licence in 2013 aged under 30.

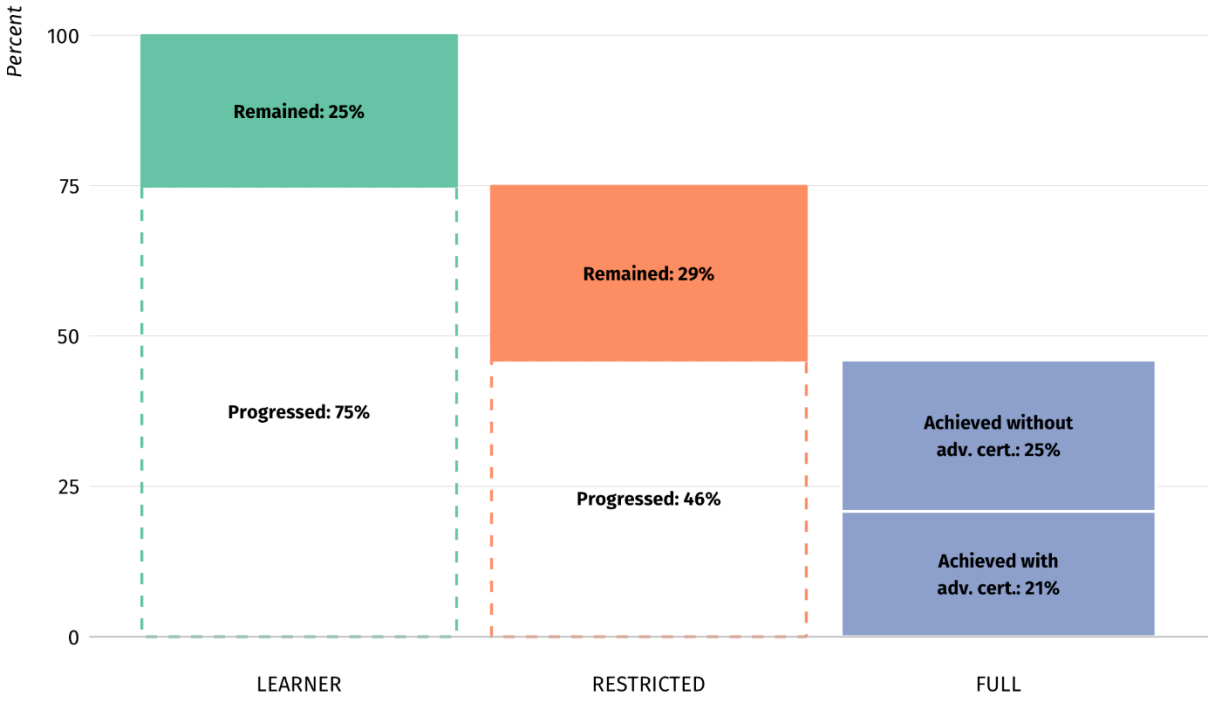
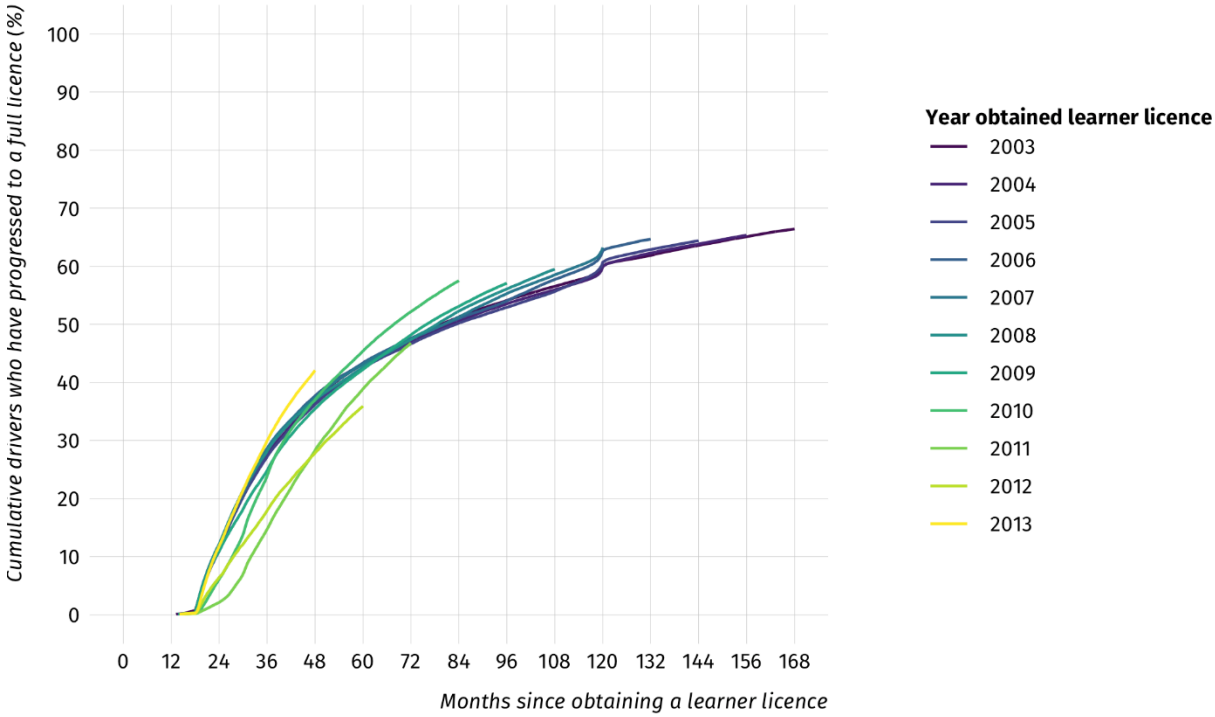


Figure 13 illustrates progression more generally by showing cumulative progression of cohorts of learners aged under 30 to a full licence. Historically, it has taken around 72 months (6 years) for half of each cohort of learners to progress to a full licence. Furthermore, the progression curve for the 2003 cohort is still increasing after 168 months (14 years), thus some drivers in that cohort are expected to continue to progress after 2017. For each cohort, progression is measured up to the end of 2017, so later cohorts have shorter curves. The figure also shows:

- There was a disruption to progression caused by the changes to the minimum ages in 2011, for cohorts of drivers who obtained their learner licence in 2011 and 2012.
- There appears to be a small jump in progression at around 120 months (10 years) after obtaining a learner licence. The expiry of learner licences after 10 years appears to have spurred some people to progress to subsequent licence stages.

We also analysed the time taken to progress for drivers who had progressed to a full licence by the end of 2017 and analysed whether there are differences in driver characteristics and crash rates for drivers who progress in the minimum time (or close to it) versus those who progress more slowly. To simplify the analysis of progression duration and crash rates, we focussed on drivers without advanced certificates (relationships between advanced certificates and crash rates are analysed separately in section 4.5).

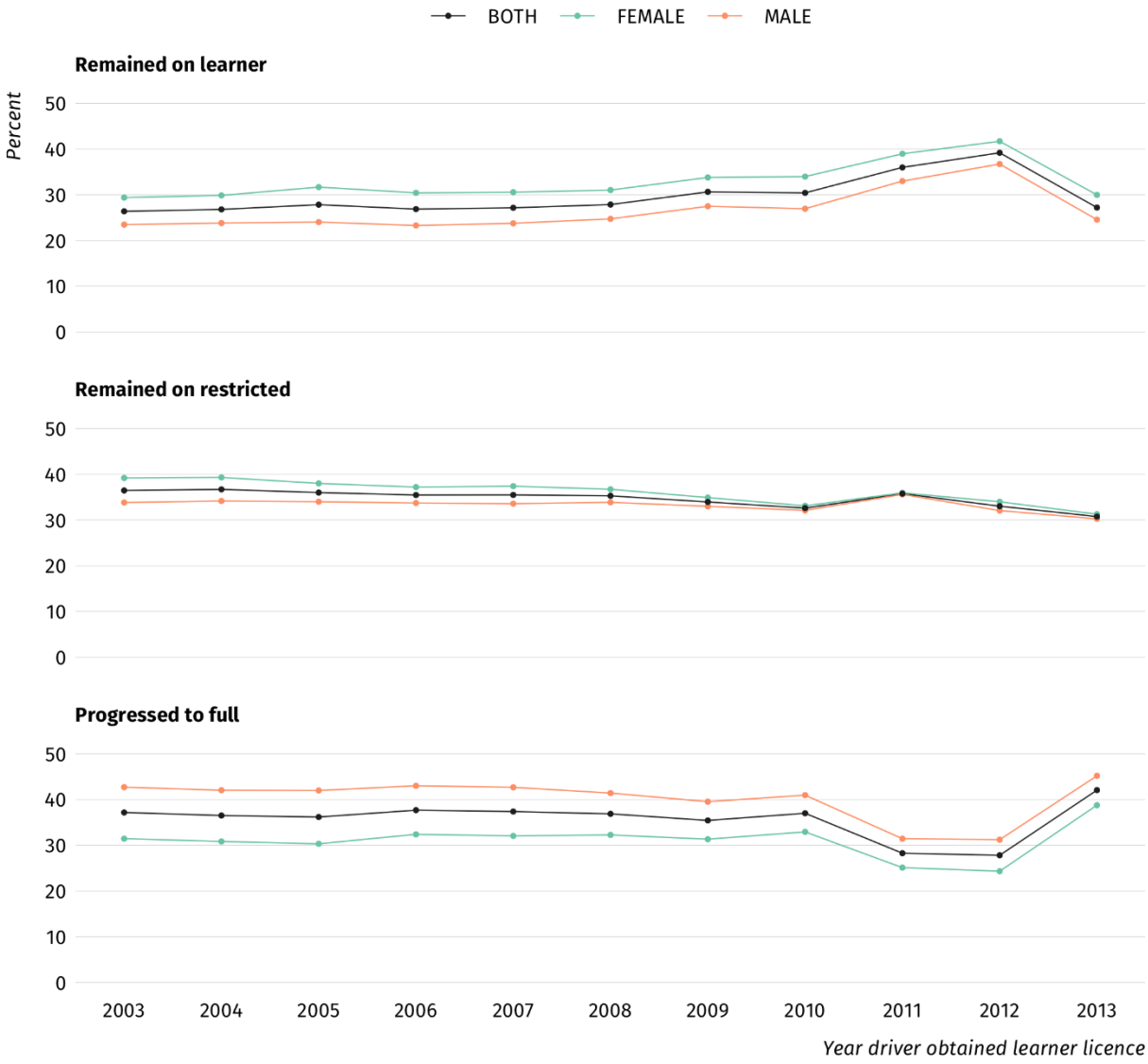
Figure 13 Cumulative proportion of drivers who received a Class 1 learner licence aged under 30 and who had progressed to a full licence in a given amount of time.



4.6.1. Four-year progression status: Relationships to driver characteristics

Figure 14 shows trends in four-year progression status for cohorts of drivers who obtained their learner licence in each year from 2003 to 2013 and who were aged under 30 years old at the time. In general, these outcomes have remained relatively stable over time, aside from the temporary disruption to progression caused by changes to the minimum ages in 2011.

Figure 14 Four-year progression status for drivers who were aged under 30 years old at the time of obtaining their learner licence, by gender and year of obtaining a learner licence (percent).



We also examined how driver characteristics relate to four-year progression status by analysing the 2013 cohort of learners aged under 30 (see section 3.4.3 of the *Technical Report*) and estimating logistic regression models to predict their progression as a function of driver age, gender, and region of residence.[34] We found:

- Rates of progression are very similar across genders, but statistically significantly different. The odds of a male driver progressing to a full licence within four years is around 4% greater than that for female drivers (p-value < 0.005). The difference in progression across genders has reduced slightly over time.

[34] These models predict indicators of whether the driver remained on a learner licence, remained on a restricted licence, or progressed to a full licence after four years. The coefficients of the estimated models correspond to multiplicative differences in the odds of the relevant four-year progression status occurring for an individual driver. Since the progression outcomes are not low-probability events, the odds ratios estimated by these models are not equivalent to differences in probabilities of progression status.

- Four-year progression status varies greatly depending on the driver's age at the time of obtaining their learner licence. For example, the odds of progressing to a full licence within four years for drivers who obtained their learner licence at 17 years old are 39% lower than for drivers who obtained their learner licence at 16 years old.
- Relationships between the driver's region of residence and four-year progression status are less clear but it appears that drivers located in less urbanised regions (e.g. Otago, Southland, Marlborough) are more likely to progress within four years compared to drivers located in more urbanised regions (e.g. Auckland, Wellington).

Overall, these findings suggest that progression is determined by the driver's motivation to drive, and to some extent this depends on and/or is reflected by the driver's characteristics such as their gender, age at the time of obtaining a learner licence, or the region in which they live.

4.6.2. Progression vs non-progression: Relationships to crash rates

We analysed whether progression status was predictive of crash involvement in two ways:

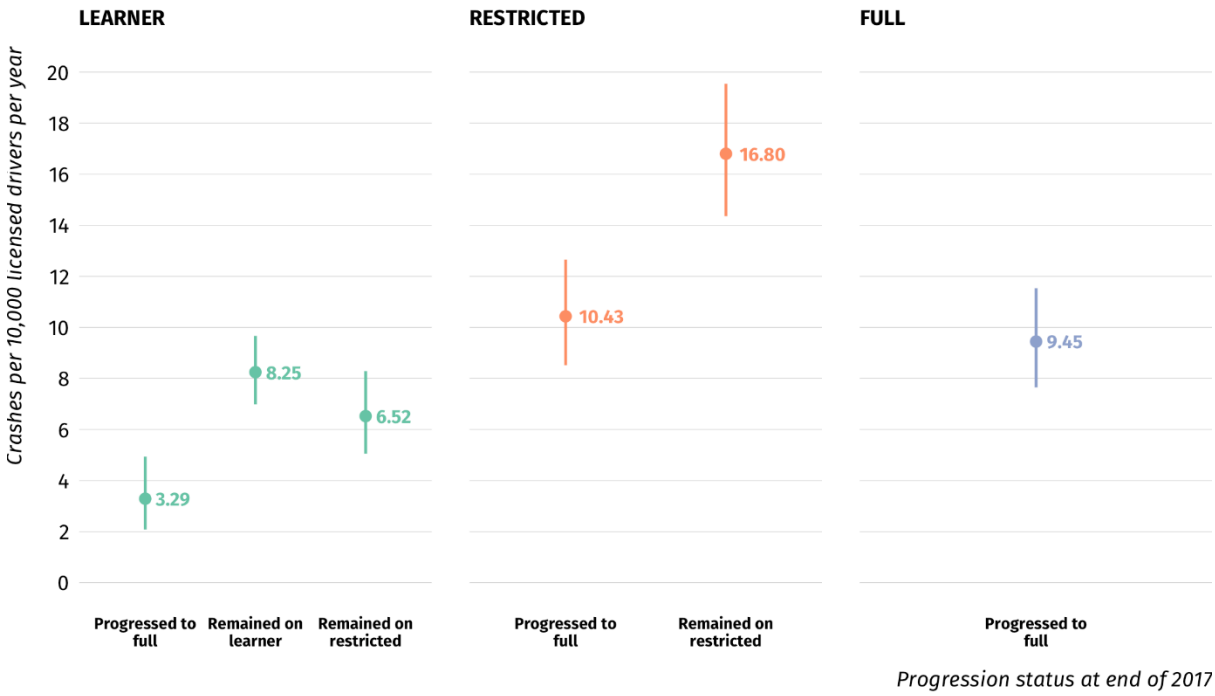
1. By analysing the relationship between crashes and progression at the end of 2017 for drivers who obtained a learner licence between 2012 and 2014 and were aged under 30 at the time.
2. Using data on all individual drivers who obtained a learner licence between 2003 and 2013 and were aged under 30 at the time, we estimated logistic regression models to test whether four-year progression status is predictive of crash involvement while on a learner or a restricted licence.

Figure 15 summarises the results of the first analysis. This shows that, at both the learner and restricted stages, drivers who had not progressed to a full licence by the end of 2017 were significantly more likely than drivers who had progressed to a full licence to be involved in a crash while they were on a learner or restricted licence. In particular:

- The crash rate while on a learner licence is 2.5 times greater for drivers who remained on a learner licence at the end of 2017 and 2.0 times greater for drivers who remained on a restricted licence at the end of 2017, compared to drivers who had progressed to a full licence by that time.
- The crash rate while on a restricted licence is 1.6 times greater for drivers who remained on a restricted licence at the end of 2017 compared to drivers who had progressed to a full licence by that time.

All of these differences are statistically significant in our analysis (p-value < 0.01 in each case) and the calculations of the crash rates account for differences in exposure to crash risk as measured by the amount of time holding a driver licence. For example, drivers who remained on a learner licence at the end of 2017 have held a learner licence for longer (on average) than drivers who had progressed to a full licence by that time.

Figure 15 Fatal and serious at-fault light motor vehicle crash involvements per 10,000 licensed drivers per year to the end of 2017 for drivers aged under 30 who obtained their learner licence between 2012 and 2014, by progression status as at the end of 2017 and licence stage, with 95% confidence intervals.



These results are robust to controlling for differences in driver gender, age, and region of residence that may affect both progression and crash involvement. Using logistic regression models of crash involvements (see section 3.4.4 of the *Technical Report*), we found:

- At the learner stage, the odds of crash involvement were:
  - 2.6 times higher for drivers who remained on a learner licence compared to drivers who progressed to a full licence by the end of 2017 (p-value 0.01)
  - 2.4 times higher for drivers who remained on a restricted licence compared to drivers who progressed to a full licence by the end of 2017 (p-value < 0.01).
- At the restricted stage, the odds of crash involvement for drivers who remained on a restricted licence were 2.0 times greater compared to drivers who progressed to a full licence by the end of 2017 (p-value < 0.01).

For all drivers who obtained a learner licence between 2003 and 2013 and were aged under 30 at the time, we found that their four-year progression status was highly predictive of their involvement in crashes while holding a learner or restricted licence, after controlling for driver age, gender, region, and year (see section 3.4.4 of the *Technical Report*). In particular:

- For crashes that occurred while the driver held a learner licence:
  - The odds of crash involvement for drivers who remained on a learner licence after four year were 6.0 times higher than for drivers who had progressed to a full licence within four years (p-value < 0.01).
  - The odds of crash involvement for drivers who remained on a restricted licence after four years were 2.4 times higher than for drivers who had progressed to a full licence within four years (p-value < 0.01).

- For crashes that occurred while the driver held a restricted licence:
    - The odds of crash involvement for drivers who remained on a learner licence after four years were 2.3 times higher than for drivers who had progressed to a full licence within four years (p-value < 0.01).
    - The odds of crash involvement for drivers who remained on a restricted licence after four years were 1.9 times higher than for drivers who had progressed to a full licence within four years (p-value < 0.01).

These results suggest that four-year progression status is predictive of crash involvement in a way that goes beyond what can be explained by the impact of driver gender, age, and region of residence on progression and crash involvement. There is strong evidence that drivers who have not progressed to a full licence within around four years of obtaining their learner licence are around twice as likely to be involved in a crash as drivers who have progressed to a full licence within four years, all else being equal.

These results raise a question of causality, that is, whether drivers who do not progress to a full licence within four years are involved in more crashes because they do not gain the additional driving skills and experience that come with progressing through the licence stages, or whether they do not progress because they are less competent drivers who are not able to pass the tests required to progress (or a combination of both). Any licensing policy changes intended to improve crash rates for non-progressing drivers therefore need to be based on a deeper understanding of the reasons for non-progression and any relationships between those factors and crash rates.

Nevertheless, there are potential safety benefits from encouraging drivers to progress to a full licence provided that such progression is associated with greater driver competency and consequently with improved crash rates. To illustrate the potential benefits, of the 55,599 drivers who obtained a learner licence in 2013 aged under 30 years old,[35] 25% remained on a learner licence and 46% had progressed to a full licence by the end of 2017. These drivers had crash rates while on a learner licence of 7.9 per 10,000 licensed drivers per year for those who remained on a learner licence, and 3.9 per 10,000 licensed drivers per year for those who had progressed to a full licence. If the crash rate of those who remained on a learner licence was reduced to that of those who progressed to a full licence, a total of around 25 crashes by learner drivers between 2013 and 2017 could have been prevented.

4.6.3. Progression duration for drivers who do progress: Relationships to driver characteristics

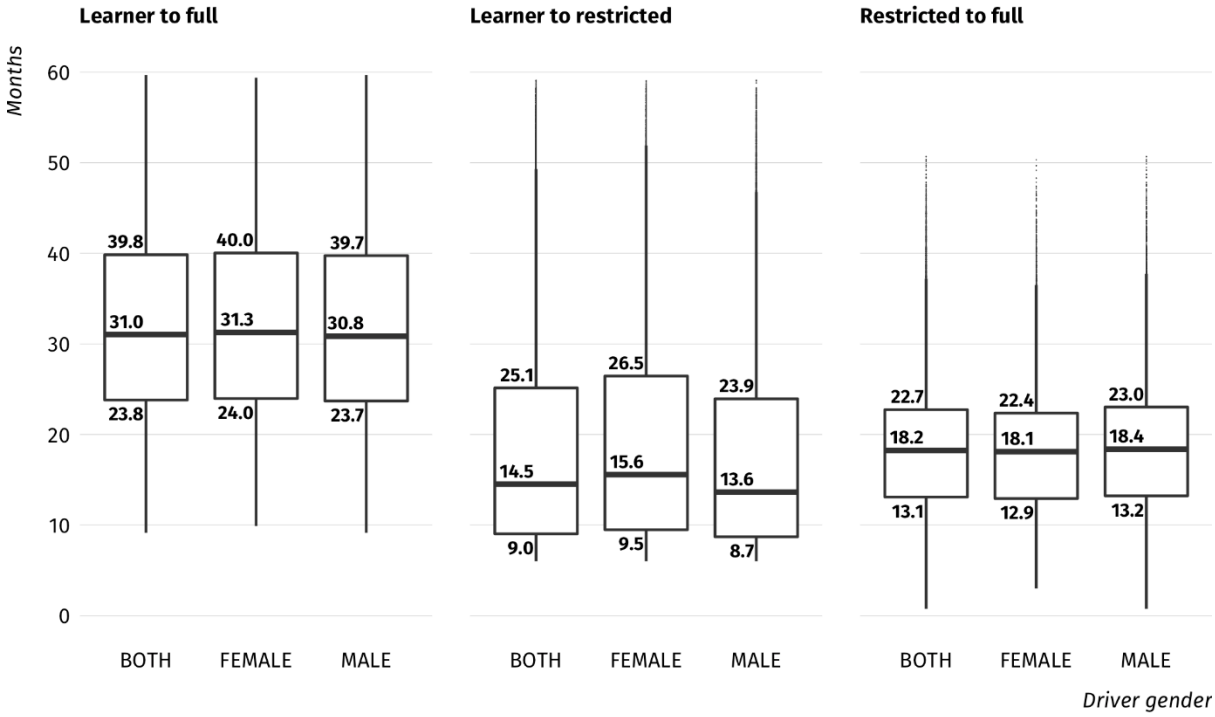
It is more difficult to compare progression durations for cohorts of drivers who obtained their learner licence at different points in time, as drivers who obtained their learner licence further in the past and who have progressed by the end of 2017 appear to have taken longer to progress on average simply because more time has passed. In addition, the changes to the minimum ages in 2011 and 2012 appear to have impacted the progression duration of many drivers who obtained their learner licence in those years (see Figure 13 above). To simplify the analysis of progression duration we therefore focussed on the cohort of drivers who obtained their Class 1 learner licence in 2013 and were aged under 30 years old at the time. For the drivers in this cohort who progressed to at least a restricted licence by the end of 2017, we measured how long it took them to progress at each step.

Figure 16 shows the distribution of progression durations for this cohort by gender (the labelled values are the lower quartile, median, and upper quartile of progression duration for

[35] This age range was chosen to reflect the typical age at which most people start learning to drive.

each progression step and gender). For drivers who did progress from a learner to a full licence, there is virtually no difference in duration or the variation of duration across genders. The median driver progressed from learner to full licence in around 31 months, with half of drivers progressing between around 24 months and 40 months.

Figure 16 Distribution of progression durations for drivers aged under 30 who obtained a learner licence in 2013 and progressed to subsequent stages by the end of 2017 by driver gender (months).



To analyse the combined effects of gender, age, and region of residence on progression duration, we estimated linear regression models of progression duration for the cohort of drivers aged under 30 who obtained a learner licence in 2013 and who had progressed to subsequent stages by the end of 2017 (see section 3.4.5 of the *Technical Report*). This shows that the baseline driver (a female living in Northland who obtained their learner licence at 16 years old) took an average of 31.4 months to progress from a learner to a full licence. Relative to that baseline:

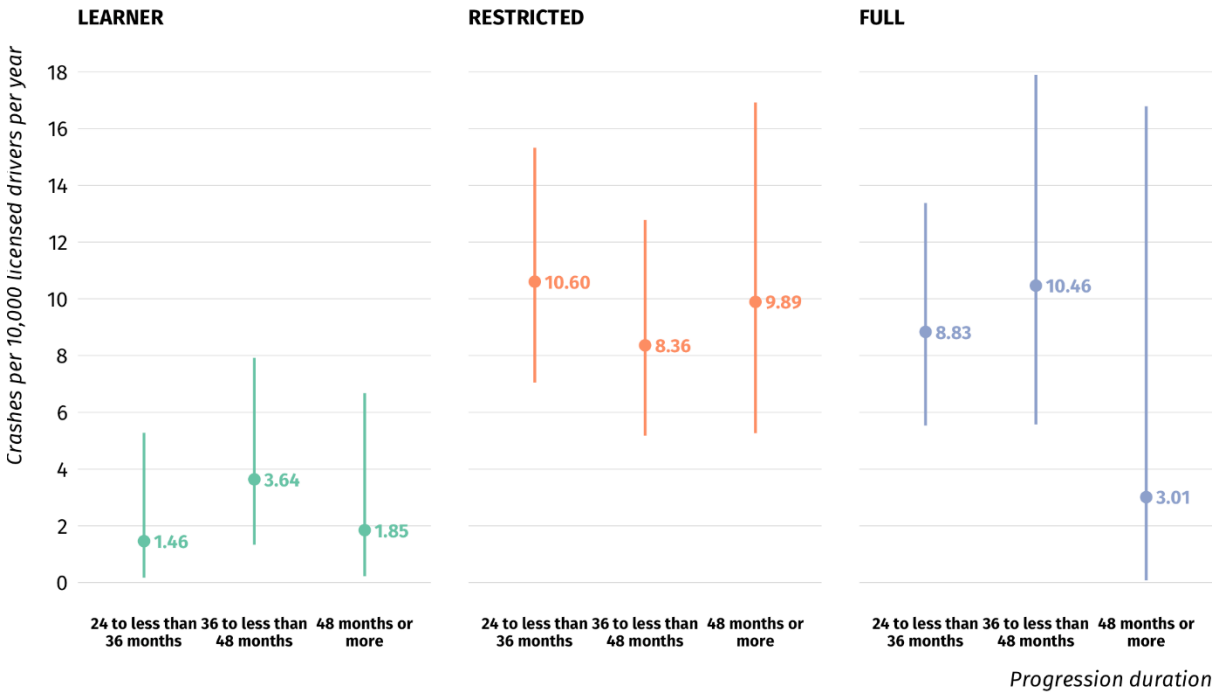
- Males took slightly less time than females to progress (0.4 months less from learner to full), but this difference is statistically significant (p-value < 0.005).
- Progression duration initially rises, then falls, with the driver's age at the time of obtaining their learner licence (see the figures in section 3.4.5 of the Technical Report). For example, drivers who obtained their learner licence at 17 years old took 6.2 months longer to reach their full licence (p-value < 0.005), and drivers who obtained their learner licence at 21 years old took 9.6 months longer (p-value < 0.005). However, drivers who obtained their learner licence aged 24 to 29 years old took a similar amount of time as drivers who obtained their learner licence at 16 years old.
- There is very little variation in progression duration across regions.

4.6.4. Progression duration: Relationships to crash rates

Figure 17 shows a simple comparison of crash rates versus progression duration, at each licence stage (see section 3.4.6 of the *Technical Report* for further analysis). Given the complexities of progression duration, the results in this figure are based on drivers who obtained a learner licence in 2012 to 2014 (combined), were aged under 30 at the time, and who progressed to a full licence by the end of 2017 in at least 24 months (i.e. did not shorten their progression by being aged 25 or older at the time of obtaining their full licence or by having an advanced certificate).

In each case we compare the crash rate for drivers who progressed from a learner to a full licence in 24 to 36 months (i.e. within one year of the standard minimum time) with those who took longer to progress. At all licence stages there is some variation in crash rates by progression duration, but the crash rates are similar and none of the differences in our analysis are statistically significant (*p*-values range from 0.43 to 1.00). Thus, at a high level, it appears that progression duration for drivers who do progress is not strongly related to crash rates at any licence stage.

Figure 17 Fatal and serious at-fault light motor vehicle crash involvements per 10,000 licensed drivers per year for drivers aged under 30 who obtained a learner licence in 2012 to 2014 and progressed to a full licence by the end of 2017 without an advanced driving certificate and who progressed to a full licence in at least 24 months, by duration of progression from learner to full licence and licence stage, with 95% confidence intervals.



To further investigate the relationship between progression duration and crash rates, we used data on individual drivers who obtained a learner licence in 2012 to 2014 and were aged under 30 years old at the time, who progressed to a full licence by the end of 2017, and who did not have an advanced driving certificate. We estimated a logistic regression model that predicted crash involvements of such drivers between when they obtained their learner licence and the end of 2017 as a function of how long it took each driver to progress from a learner to a full licence and driver age, gender, region of residence, and the total amount of time holding a driver licence (see section 3.4.6 of the *Technical Report* for more

details). The results of the model suggest no statistically significant difference in the odds of being involved in a crash for drivers who progressed from a learner to a full licence in 24 to 36 months versus those who progressed in 36 to 48 moths or 48 months or more (*p*-values 0.19 and 0.33 respectively).

We also modelled crash involvements of individual drivers while on a full licence for all drivers who obtained a learner licence between 2003 and 2014, who were aged under 30 at the time of obtaining their learner licence, and who progressed to a full licence by the end of 2017 without an advanced certificate (see section 3.4.6 of the *Technical Report*). Controlling for driver age, gender, region of residence, the year in which the driver obtained their learner licence, and time trends, we found that the number of months taken to progress from a learner to a full licence had no statistically significant effect on the odds of being involved in a crash while on a full licence (*p*-value 0.65).

5. Evaluation results for the motorcyclist licensing system (Class 6)

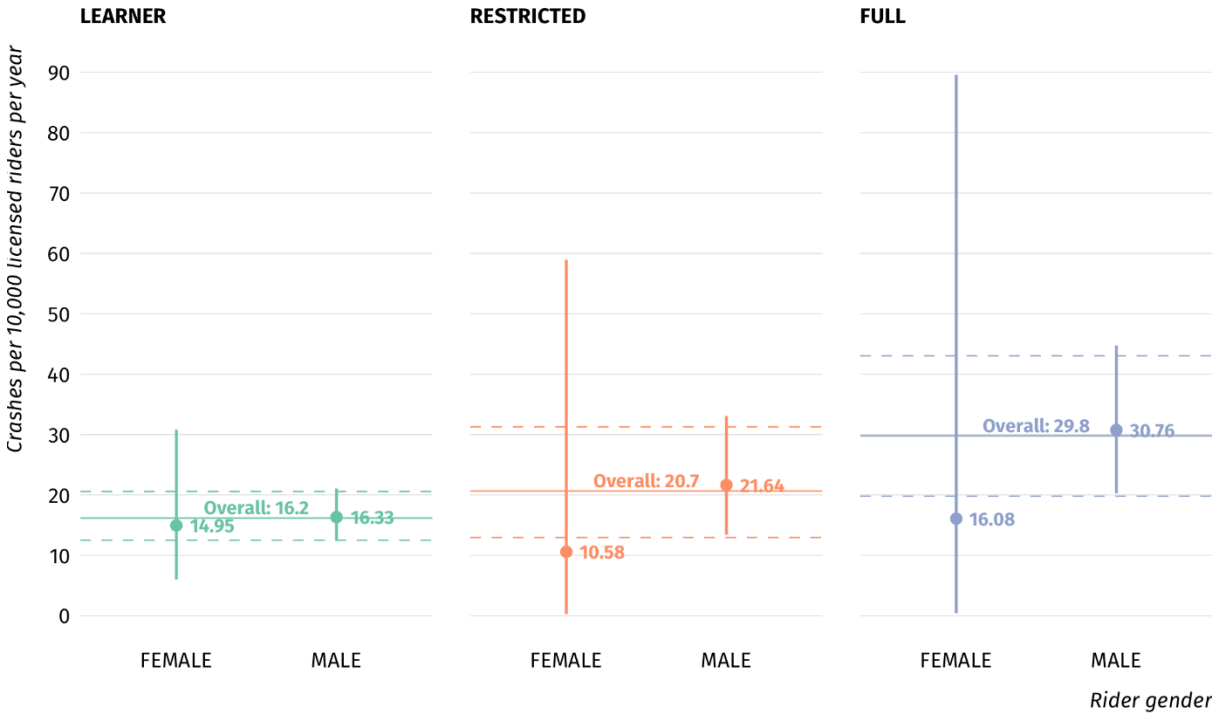
5.1. Context: Overall patterns and trends in crash rates

As described in more detail in section 4.1 of the *Technical Report*, we undertook detailed analysis of crash rates for motorcycle riders by licence stage, age, gender, and region of residence, and analysed trends in these crash rates over time. As noted in section 3.3, for motorcyclists it is more difficult to compare crash rates for disaggregated groups due to the small numbers involved.

5.1.1. Crash rates by licence stage and rider gender

Figure 18 shows how crash rates vary by gender among riders aged 16 to 27 years old for the combined period from 2015 to 2017, by license stage (the horizontal lines show the crash rate at each licence stage for both genders combined and the corresponding 95% confidence intervals). The crash rate for fully licensed riders is around 1.9 times higher than that for learner riders and this difference is statistically significant in our analysis (*p*-value 0.01), but other differences, including between genders at each licence stage, are not statistically significant (all *p*-values > 0.05). Crash rates for females have relatively wide confidence intervals (i.e. are estimated relatively inaccurately) due to the small number of female riders relative to males, and for that reason we do not present further breakdowns of motorcycle crash rates by gender.

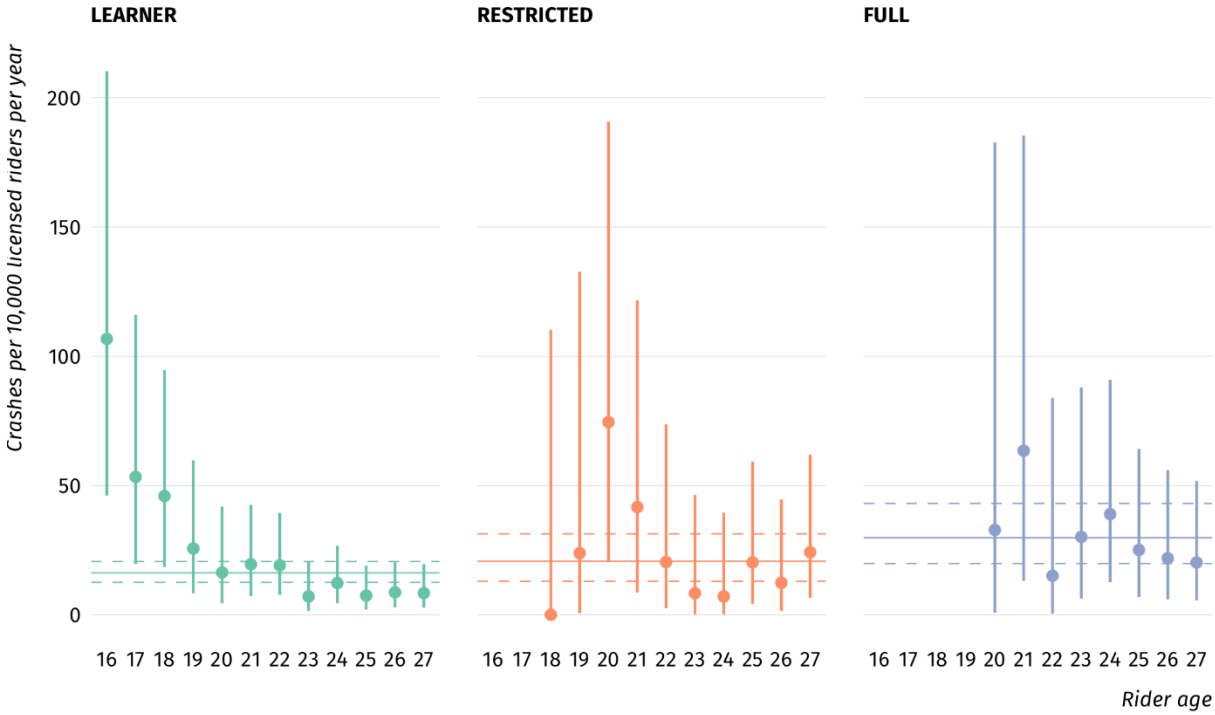
Figure 18 Fatal and serious at-fault motorcycle crash involvements per 10,000 licensed riders aged 16 to 27 per year by rider's gender and licence stage with 95% confidence intervals (2015 to 2017).



5.1.2. Crash rates by licence stage and rider age

Figure 19 breaks down the per-rider crash rates between 2015 and 2017 by the rider's age. At the learner stage, crash rates are relatively high for riders under 19 years old (horizontal lines show the overall crash rate for each licence stage across all riders aged 16 to 27; crash rates have been suppressed for age and licence stage combinations with fewer than 100 licensed riders per year on average). At the restricted and full licence stages stage, relatively wide confidence intervals due to the smaller numbers of riders make it difficult to find reliable patterns, but crash rates appear to be relatively high for riders in their early 20s.

Figure 19 Fatal and serious at-fault motorcycle crash involvements per 10,000 licensed riders per year by rider age and licence stage with 95% confidence intervals (2015 to 2017).



5.1.3. Crash rates by licence stage and rider region of residence

As described in section 4.1.7 of the *Technical Report*, across regions of residence there is considerable variation in crash rates, but, in our analysis, most are not statistically significantly different from the overall rate for each licence stage across all regions. The only statistically significant case in our analysis is the crash rate for fully licensed riders (aged 16 to 27 years old) in the Bay of Plenty. Such riders were involved in 3.2 times as many crashes as fully licensed riders of the same age across all regions between 2015 and 2017 (*p*-value 0.04).

5.1.4. Trends in crash rates

The small number of riders also makes it difficult to identify trends in crash rates. The statistically significant trends we found are (see sections 4.1.3, 4.1.4, and 4.1.9 of the *Technical Report*):

- The per-rider crash rate for learner riders aged 16 was almost 6 times higher in the period from 2015 to 2017 compared to the period from 2008 to 2010 (p-value 0.05).
- The crash rate for all learner riders aged 16 to 20 (combined) was more than twice as high in the period from 2015 to 2017 compared to the period from 2009 to 2011 (p-value 0.01).
- Among riders aged 16 to 20 (combined) with learner licences in Auckland, the per-rider and per-capita crash rates were around 8 times higher in the period from 2015 to 2017 compared to the period from 2009 to 2011 (p-value 0.03). Given that the changes in per-rider and per-capita involvement rates for this group are similar, this suggests that the increase in crash involvements is due to an increase in risk.

5.1.5. Implications for rider licensing

As with Class 1, the above analysis demonstrates that there are relatively large variations in crash rates across riders of different genders, ages, and regions of residence, and at different licence stages, but again there are practical constraints on how finely the GDLS can be adjusted to address these issues. However, for motorcycle riders there are some areas where it would be useful to investigate if licensing changes could lead to improved safety outcomes:

- Fully licensed riders appear to have relatively high crash rates compared to riders with learner and restricted licences.
    - This may be due to various factors including more active involvement of fully licensed riders in motorcycle riding than riders at other licence stages (noting that this difference is not captured in the data used for this analysis), 'returned' riders,36 or the fact that fully licensed riders can ride larger and more powerful motorcycles.
    - It would be useful to investigate whether the licensing rules for obtaining a full Class 6 licence could be changed to better preparing this group for the risks they will face as fully licensed riders, which could lead to improved safety outcomes.
- Riders with learner licences aged under 19 also appear to have relatively high crash rates. There is a question of whether the licensing rules for obtaining a learner Class 6 licence could be changed to help offset this.
- There is evidence of relatively large increases over time in per-rider crash rates among learner riders aged 20 and under. This also raises a question of whether the criteria for obtaining a learner licence could be changed to help mitigate this trend.

5.2. Estimated safety impacts of the 2009 to 2012 GDLS changes

5.2.1. Context for analysis of the changes

As described in section 4.6.1 of the *Technical Report*, changes in rider demographics occurred around the same time as the changes to the GDLS:

- The median age of riders receiving learner licences increased gradually from around 25 years old in 2003 to around 29 years old in 2010, then declined slightly to around 28 years old by 2017. The median age of riders receiving restricted licences followed

[36] 'Returned' riders are those who have held a motorcycle licence for a long time but have had a substantial break from riding and have subsequently returned to riding. There is some evidence that the performance of returned riders is lower than both riders that have ridden continuously and riders who have just obtained a motorcycle licence (Symmons & Mulvihill, 2011).

a similar pattern, increasing from around 30 years old in 2003 to just under 35 years old in 2011, before falling slightly to around 34 years old in 2016. The median age of riders receiving full licences has tended to increase consistently over time, from around 33 years old in 2003 to around 37 years old in 2017. The introduction of CBTA in late 2012 appears to have led to a temporary increase in the number of relatively young riders obtaining full licences.

- The proportion of motorcycle licences issued to males (at all three stages) generally increased between 2003 and 2017, from around 82% to 85% at the learner stage, 85% to 89% at the restricted stage, and 86% to 90% at the full stage. Most of these changes occurred after 2010.
- The introduction of CBTA in late 2012 appears to have caused a reduction in the amount of time that riders spend on learner and restricted licences, with most of the reduction occurring at the restricted stage. In 2003, the median rider (aged under 20) spent around 18 months on their restricted licence, and this increased to 24 months prior to the introduction of CBTA. Subsequently, the median restricted licence duration reduced to about 15 months.

5.2.2. Estimated effects on crash rates of increasing the minimum riding ages (August 2011)

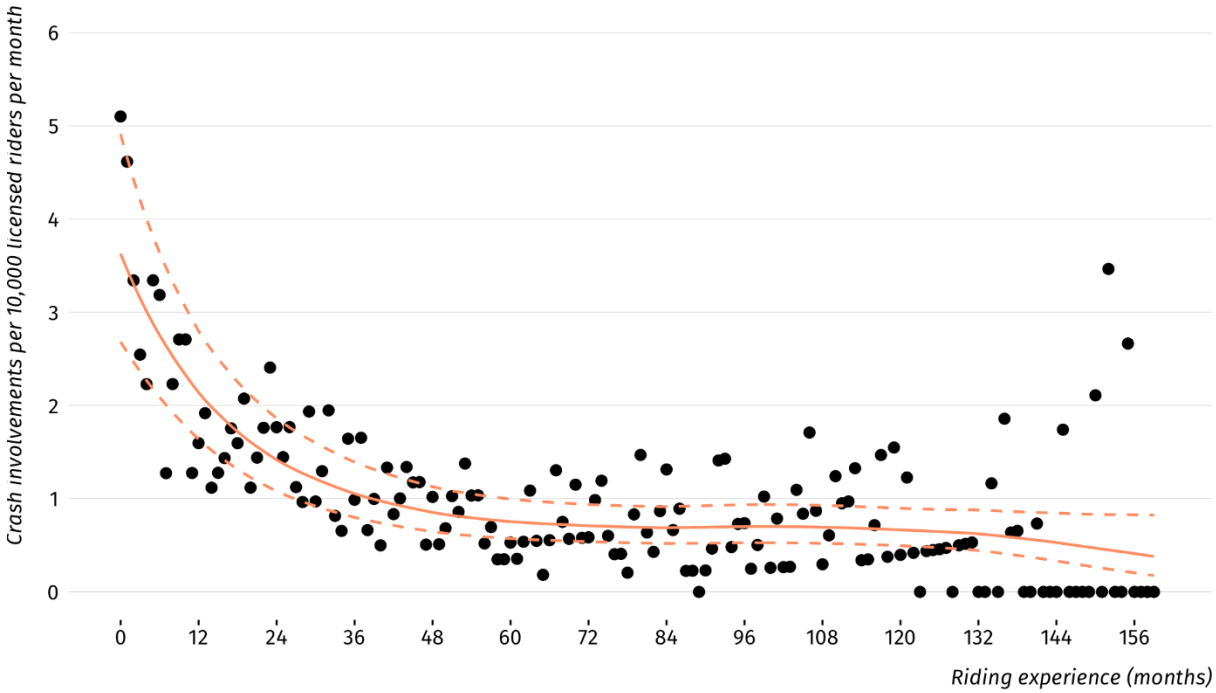
As with Class 1, it is likely that the changes to the Class 6 minimum ages had both temporary and long-term effects on the profile rider demographics and crash rates. However, the majority of motorcycle learners were unaffected by the changes to the minimum ages since very few 15-year-olds were obtaining learner licences prior to the change anyway (see below), and the temporary effects of this change are impossible to distinguish from general random variation in crash rates. As with Class 1, in terms of long-term crash rates, increasing the minimum age for obtaining a learner licence from 15 to 16 years old will prevent crashes among 15-year-old riders and may also cause an increase or decrease in crashes among riders aged 16 and older due to changes in the age and experience profile of those riders (again, we measured experience by the amount of time since each rider obtained their motorcycle learner licence).

Prior to the minimum learner age increasing, only about 5% of motorcycle learner licences issued each year were to 15-year-olds (see section 4.6.2 of the *Technical Report*). The change to the minimum age therefore had a relatively minimal impact on the distribution of ages at which people obtained learner licences.

On average between 2004 and 2010, licensed 15-year-old riders were involved in 1.5 crashes per year. Based on trends in the proportion of the 15-year-old population with a motorcycle licence and the actual population of 15-year-olds in 2017, we estimate there would have been around 150 15-year-old licensed riders in 2017. Using a model of crash involvements (described in section 4.6.2 in the *Technical Report*), we estimate that these 15-year-old riders would have been involved in 1.3 crashes in 2017 (with a 95% confidence range from 1.0 to 1.9 crashes).

Figure 20 shows the actual and modelled relationship between experience (measured as the amount of time since obtaining a learner licence) and the crash rate (see section 4.6.2 of the *Technical Report*). In contrast to Class 1, the overall crash rate generally declines with experience, particularly during the first 60 months (contrast with Figure 5 above). This is possibly because riders are exposed to solo riding immediately, unlike drivers.

Figure 20 Actual (black dots) and modelled (red line, with 95% confidence bands) monthly crash rates for riders aged under 30 versus riding experience (measured as the amount of time since obtaining a learner licence), from 2008 to 2017 combined.



Among riders aged 16 and older, due to the relatively small number of riders and crashes, the effects of changes in the age and experience distribution of riders are difficult to estimate accurately. In theory, any additional crashes among riders aged 16 and older should not be greater than the reduction in crashes among 15-year-old riders estimated above, assuming that the effect of the change to the minimum age is to cause riders who would have started learning at 15 years old to start at 16 years old instead. In addition, modelling of crash rates indicates that 16-year-old riders are only marginally less likely to be involved in a crash compared to 15-year-olds. Overall, our analysis implies that the main effect of increasing the minimum age for Class 6 was to shift crashes from 15-year-olds to 16-year-olds (and possibly older age groups) with very little change in the overall number of crashes. Accordingly, we estimate that the change to the Class 6 minimum age in 2011 prevented less than one crash per year.

5.2.3. Estimated effects on crash rates of strengthening the learner and restricted practical tests (October 2012)

The motorcycle learner and restricted practical tests were strengthened in October 2012. We used data on around 80,000 riders who received learner licences and 27,000 who received restricted licences between 2003 and 2017 to estimate whether the odds of crash involvement while on a learner or restricted licence were different for riders who obtained their licence after the tests were strengthened compared to riders who received their licence earlier, controlling for differences in rider age, gender, and region of residence (see section 4.6.3 of the *Technical Report*).[37] The models predict that the strengthened tests did not have a statistically significant effect on crash rates:

[37] CBTA was introduced at the same time as these tests were strengthened, so the model for restricted riders is based only on those who did not have a CBTA 6R certificate.

- The learner licence model estimates that the odds of crash involvement on a learner licence for riders who obtained their licence after the test was strengthened are very similar to the odds of crash involvement for riders who obtained their learner licence earlier (the estimated odds ratio is 1.14, p-value 0.57).
- The restricted licence model estimates that the odds of crash involvement on a restricted licence for riders who obtained their licence after the test was strengthened are also very similar to the odds for riders who obtained their restricted licence earlier (the estimated odds ratio is 1.04, p-value 0.92).

5.2.4. Estimated effects on crash rates outcomes of rebalancing penalties for licensing breaches (December 2009)

As with Class 1, this change affected all riders with learner and restricted licences from 1 December 2009 onwards. To test the effects of this change we used similar analysis to that described in section 4.2.4 above. As with Class 1, we found no evidence that changes to penalties caused any change in crash rates that cannot be explained by general safety trends and changes in rider characteristics around the same time.

5.3. Comparison of crash rates for restricted and fully licensed riders

As with Class 1 (see section 4.3 above), we modelled crash rates for riders with restricted and full licences to investigate whether the crash rate for fully licensed riders is different from that for restricted riders in ways that cannot be explained by differences in the amount of time since obtaining a learner licence and other observed characteristics such as age, gender, and region of residence. We estimated a logistic regression model of crash involvements for riders in the licensing dataset who obtained a learner licence and who had progressed to at least a restricted licence by the end of 2017. There are around 34,000 such riders in the dataset.

The model (see section 4.3 of the *Technical Report*) predicts crash involvement of individual riders on restricted and full licences as a function of the amount of time they have held a restricted or full licence, their age, gender, region of residence, and amount of time since obtaining a learner licence, as well as year indicators to pick up general external safety trends. The key result from this model is that, after controlling for differences in the above rider characteristics, the odds of crash involvement are 52% *higher* for riders with full licences compared to riders with restricted licences, and this difference is statistically significant (p-value < 0.01).

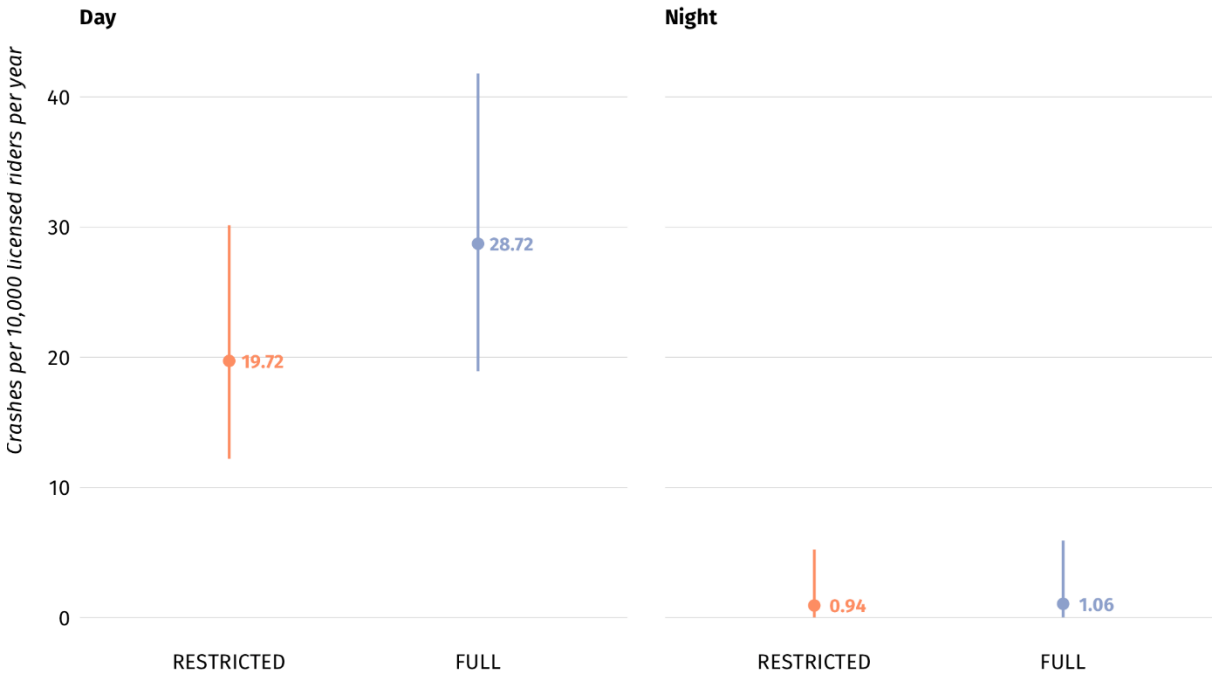
As with our other findings of higher crash rates for fully licensed riders, this may be due to various factors including that riders with full licences may be more active motorcyclists than those with restricted licences. Thus, while the greater crash rate for fully licensed riders may be explained by differences in their riding activity (noting we have no way to test that assumption), there is still a question of whether the Class 6 GDLS adequately prepares fully licensed riders.

5.4. Is the night-time riding restriction for restricted riders effective?

Riders with restricted licences are effectively prohibited from riding between the hours of 10pm and 5am (unlike Class 1, supervision on a motorcycle is not possible). If the night riding restriction is fully effective, we expect to see no crashes for restricted riders between 10pm and 5am. To test this, we compared the rate of crash involvements during the day

(5am to 10pm) and night (10pm to 5am) for restricted versus fully licensed riders aged 16 to 27 years old for the combined period from 2015 to 2017 (Figure 21; see section 4.2 of the *Technical Report* for details).[38]

Figure 21 Fatal and serious at-fault motorcycle crash involvements per 10,000 licensed riders aged 16 to 27 per year by licence stage and crash time period with 95% confidence intervals (2015 to 2017).



Despite the prohibition on night-time riding, there was one crash between 10pm and 5am involving a rider on a restricted licence aged 16 to 27 years old in the combined period from 2015 to 2017, corresponding to a crash rate of 0.94 crashes per 10,000 licensed riders per year.[39] Similarly, there was one night-time crash involving a fully licensed rider of the same age range in the same time period, giving a crash rate of 1.06 crashes per 10,000 licensed riders per year. This suggests that the night-time riding restriction is not fully effective, but since the crash rate for restricted riders aged 16 to 27 at night is very low and is similar to that for fully licensed riders, this does not appear to be a significant potential safety issue.

5.5. Comparison of characteristics and crash rates for riders choosing CBTA versus those choosing traditional practical tests

We analysed characteristics and crash rates of all riders who received a learner licence between when CBTA was introduced on 1 October 2012 and the end of 2017, and who had progressed to at least a restricted licence by the end of 2017. There are 10,425 riders in this

[38] Crashes for the most recent three years were combined to improve the statistical reliability of the comparison. The time of crash was not recorded for around 1% of crashes in the dataset and such crashes were excluded from this analysis.
[39] Without imposing any age restrictions, the crash dataset includes 8 night-time crashes of riders with restricted licences between 2003 and 2017. However, the dataset does not include all riders who held restricted licences during this period (only those who obtained a licence during the period), thus the actual number of crashes is likely to be greater.

cohort and, by the end of 2017, 44% had progressed to a full licence while 56% remained on a restricted licence.[40]

CBTA can be chosen at either or both the restricted and full licence stages and hence there are four possible pathways from a learner licence to a full licence:

- No CBTA: Standard practical tests to progress from both learner to restricted and restricted to full licences.
- CBTA 6R only: CBTA to progress from learner to restricted and the standard practical test to progress from restricted to full.
- CBTA 6F only: Standard practical test to progress from learner to restricted and CBTA to progress from restricted to full.
- CBTA 6R & 6F: CBTA to progress from both learner to restricted and from restricted to full.

Learner riders who obtain a CBTA 6R certificate can progress to a restricted licence at any time (provided they are at least 16.5 years old), whereas riders without a CBTA 6R certificate must remain on their learner licence for at least six months before attempting the standard restricted licence practical test. Riders who obtain a CBTA 6F certificate can progress to a full licence after holding their restricted licence for at least 12 months, while riders without a CBTA 6F certificate must spend at least 18 months on the restricted licence before attempting the standard full licence practical test. Choosing CBTA at both stages can thus reduce the minimum time for progressing from a learner licence to a full licence from 24 months to 12 months, provided the rider meets the minimum age requirements.

We compared rider characteristics and crash rates for riders choosing the three CBTA pathways against riders choosing the pathway of practical tests at both the restricted and full licence stages. At the end of 2017 among riders who obtained a learner licence and who had progressed to at least a restricted licence:[41]

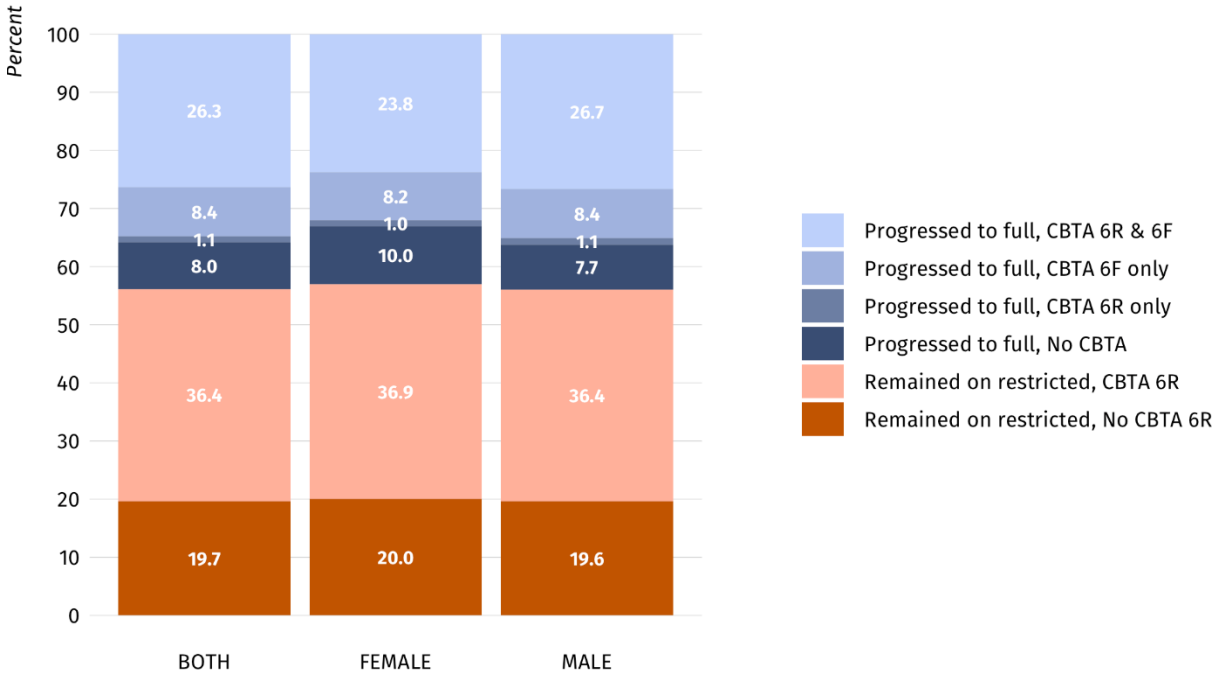
- 27% had no CBTA certificate.
- 31% had a 6R certificate only.
- 10% had a 6F certificate only.
- 33% had both 6R and 6F certificates.

5.5.1. Characteristics of riders choosing CBTA versus those choosing practical tests

Overall, since CBTA was introduced, the majority of riders progressing beyond a learner licence have chosen CBTA. As shown in Figure 22, around two-thirds of riders in the cohort who remained on a restricted licence at the end of 2017 had a CBTA 6R certificate. Among those riders who had progressed to a full licence by the end of 2017, only about 18% did not have any kind of CBTA certificate, and around 60% had both 6R and 6F certificates. The uptake of CBTA is very similar across genders, with females only slightly less likely than males to choose CBTA.

[40] Around two-thirds of the riders who received a learner licence after 1 October 2012 had not progressed beyond a learner licence by the end of 2017. Such riders were excluded from this analysis as most had not obtained a CBTA certificate.
[41] At that time, not all riders had used their CBTA certificate to progress to the next licence stage. Obtaining a CBTA certificate does not lead to automatic progression to the next stage. The rider must apply to progress and hence there is typically a short delay between when a rider receives a CBTA certificate and when they progress to the next licence stage.

Figure 22 Progression status and CBTA status as at the end of 2017 for all riders who received a learner licence between 1 October 2012 and the end of 2017.



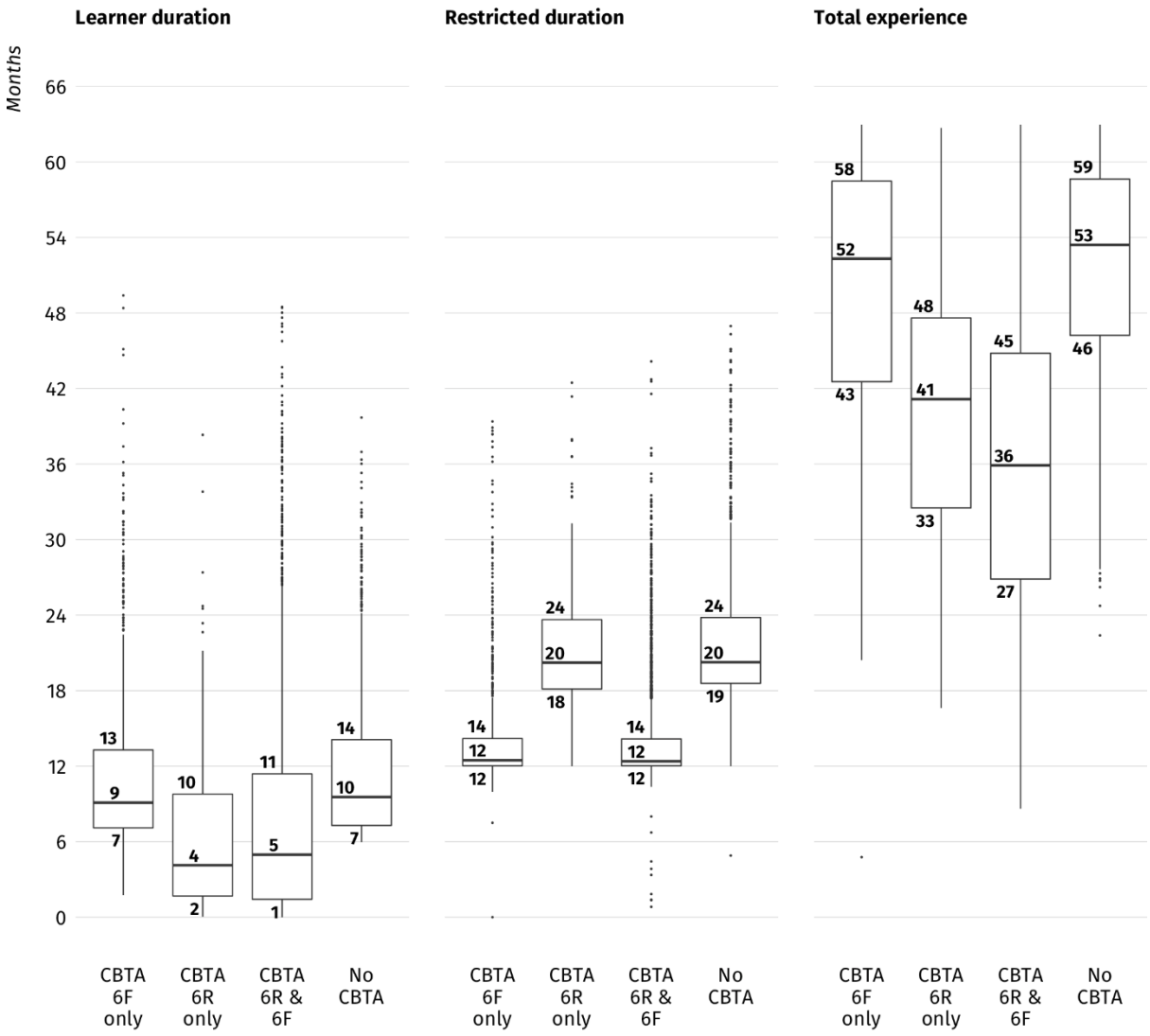
CBTA uptake has been relatively higher among older riders. As shown in section 4.5.2 of the *Technical Report*, uptake of CBTA generally declines with the rider's age at the time of obtaining their learner licence:

- Among riders aged 20 and under when they obtained their learner licence and who remained on a restricted licence at the end of 2017, just over half had a CBTA 6R certificate. Among similar riders aged 30 and over when they obtained their learner licence, around 30% had a CBTA 6R certificate and around 70% did not.
- Among riders aged 20 and under when they obtained their learner licence and who progressed to a full licence by the end of 2017, around 30% had no CBTA certificates, compared to around 20% for riders who obtained their learner licence at age 30 and over.

Across regions, CBTA uptake has been relatively low among riders living in Wellington, Otago, Taranaki, Marlborough, and Southland, and relatively high among riders living in Bay of Plenty, Gisborne, and Tasman regions.

CBTA appears to have a relatively large effect on how quickly riders progress through the licence stages. For example, riders in the cohort who progressed to a full licence by the end of 2017 spent a median of around 4 to 5 months on their learner licence if they chose CBTA, compared to 10 months for riders who did not choose CBTA (Figure 23; the labelled values are the upper quartile, median, and lower quartile of duration in each case). Similarly, riders who progressed to a full licence spent a median of 12 months on their restricted licence if they chose CBTA, compared to 20 months if they did not. This is partly by design, for example there is no minimum learner licence duration for riders who use CBTA to obtain their restricted licence.

Figure 23 Distribution of time spent at each licence stage as at the end of 2017 of riders who obtained a learner licence between 1 October 2012 and the end of 2017 and who progressed to a full licence, by CBTA status (months).



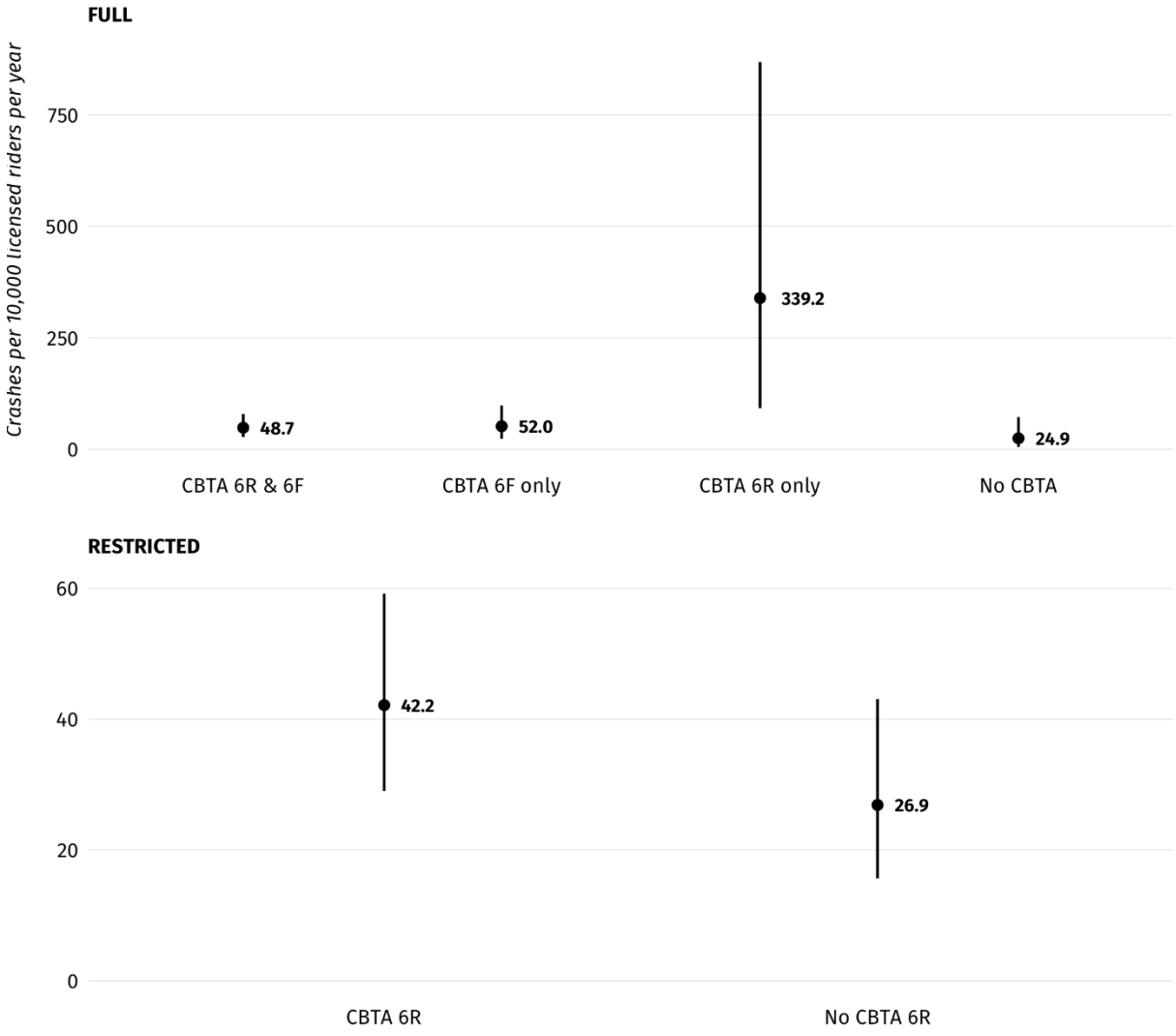
5.5.2. Comparison of crash rates for riders choosing CBTA versus those choosing practical tests

Figure 24 shows a simple comparison of crash rates by licence stage and CBTA status for the period from 1 October 2017 until the end of 2017, among riders who obtained a learner licence after CBTA was introduced. With the exception of fully licensed riders with only a CBTA 6R certificate, in our analysis the differences in crash rates for riders who chose CBTA are not statistically significantly different from those for riders who did not choose CBTA (*p*-values range from 0.17 to 0.42). Bearing in mind the lack of statistical significance, this analysis does however indicate that crash rates for riders choosing CBTA have been around twice as high as those for riders who did not choose CBTA since it was introduced.

The only statistically significant difference in our analysis is the crash rate for fully licensed riders who only had a CBTA 6R certificate. This group of riders had a crash rate 13.6 times higher than those without a CBTA certificate (*p*-value < 0.005). However, there are very few riders who progressed to a full licence with only a CBTA 6R certificate after CBTA was

introduced, and thus this high crash rate reflects a small number of crashes and has a relatively wide confidence interval.[42]

Figure 24 Fatal and serious at-fault motorcycle crash involvements per 10,000 licensed riders per year by licence stage and CBTA status for riders who received a learner licence from 1 October 2012 until the end of 2017, with 95% confidence intervals.



We also estimated logistic regression models of crash involvement for individual riders to further explore the relationships between CBTA status and crash rates while controlling for rider age, gender, region of residence, and length of time since obtaining a licence (see section 4.5.3 of the *Technical Report*). These models produced similar results in terms of the relationships between CBTA status and crash rates at the restricted and full licence stages as those shown in Figure 24 above. That is, the differences in crash rates for riders choosing CBTA versus those choosing practical tests were not statistically significant in our analysis (except for riders who progressed to a full licence with only a CBTA 6R certificate). However,

[42] Among the cohort of 10,425 riders used for this analysis, only 115 riders progressed to a full licence by the end of 2017 with a CBTA 6R certificate but without a 6F certificate. These riders were involved in four crashes during that time, which is a disproportionately large number of crashes for such a small group of riders.

notwithstanding the lack of statistical significance, these models also estimated that riders choosing CBTA were up to twice as likely to be involved in crashes as riders who did not choose CBTA.

Given the relatively recent introduction of CBTA we do not yet have sufficient data to precisely estimate crash rates by CBTA status. However, given the relatively high crash rates observed for CBTA so far, we make the following recommendations:

- CBTA crash rates should be closely monitored in the coming years, to determine whether crash rates for riders choosing CBTA are higher than those not choosing CBTA.
- Further investigation of the differences in the characteristics of riders choosing CBTA versus those choosing traditional tests should be undertaken to determine the extent to which these could be underlying causes of any difference in crash rates.

5.6. Relationships between progression through the motorcycle licensing stages, rider demographics, and crash rates

As with Class 1 (see section 4.6 above), we analysed relationships between progression through the motorcycle licensing stages and rider characteristics and crash rates. Compared to Class 1, a much larger proportion of riders do not progress beyond a learner licence (within a given period of time). Figure 25 gives a snapshot of the progression pathways taken by riders who obtained a learner licence in 2013, as at the end of 2017. By that time, 60% remained on a learner licence, 16% had progressed to a restricted licence but not yet obtained a full licence, and 23% had progressed to a full licence. For this cohort, around one-third progressed via CBTA to obtain a restricted licence, and around two-thirds progressed via CBTA to obtain a full licence.

Figure 25 Snapshot of progression by the end of 2017 for riders who obtained a learner licence in 2013.

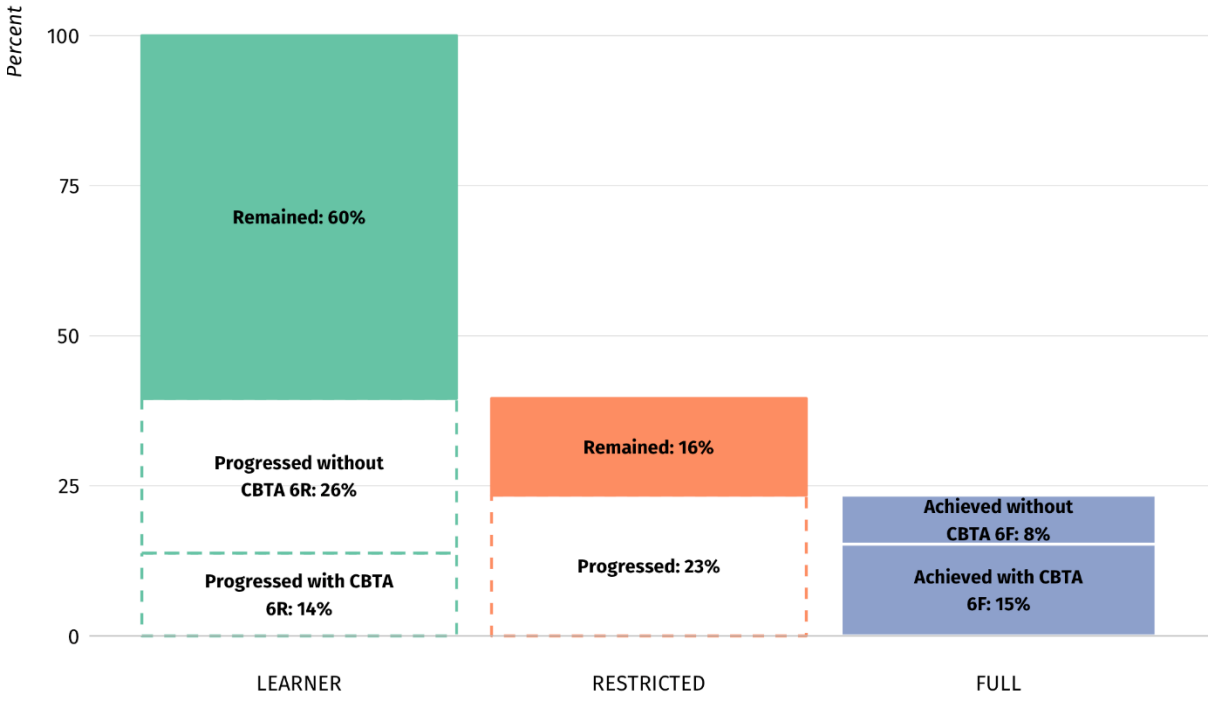
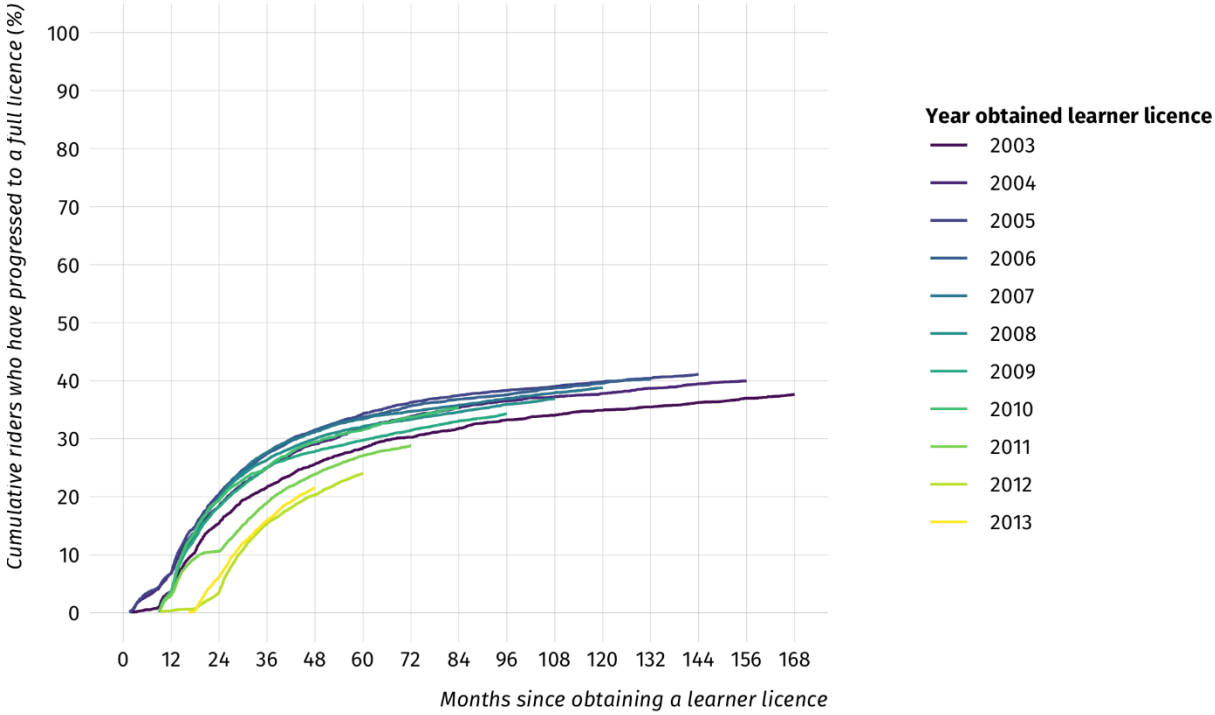


Figure 26 illustrates rider progression more generally by showing cumulative progression of cohorts of learners to a full licence (for each cohort, progression is measured up to the end

of 2017, so the curves for later cohorts are shorter). Historically, it has taken around 72 months (6 years) for one-third of each cohort of learners to have progressed to a full licence. Furthermore, the progression curve for the 2003 cohort is still increasing after 168 months (14 years). Thus some riders in that cohort are expected to continue to progress in years after 2017. For Class 6, rates of progression to a full licence have increased then decreased over time. For example, of the cohort of riders who obtained a learner licence in 2003, after 48 months 26% had progressed to a full licence. For the 2006 cohort, 32% had progressed to a full licence after 48 months, but for the 2013 cohort, 22% had progressed.

Figure 26 Cumulative proportion of riders who received a learner licence and who had progressed to a full licence in a given amount of time, by year of learner licence start date.

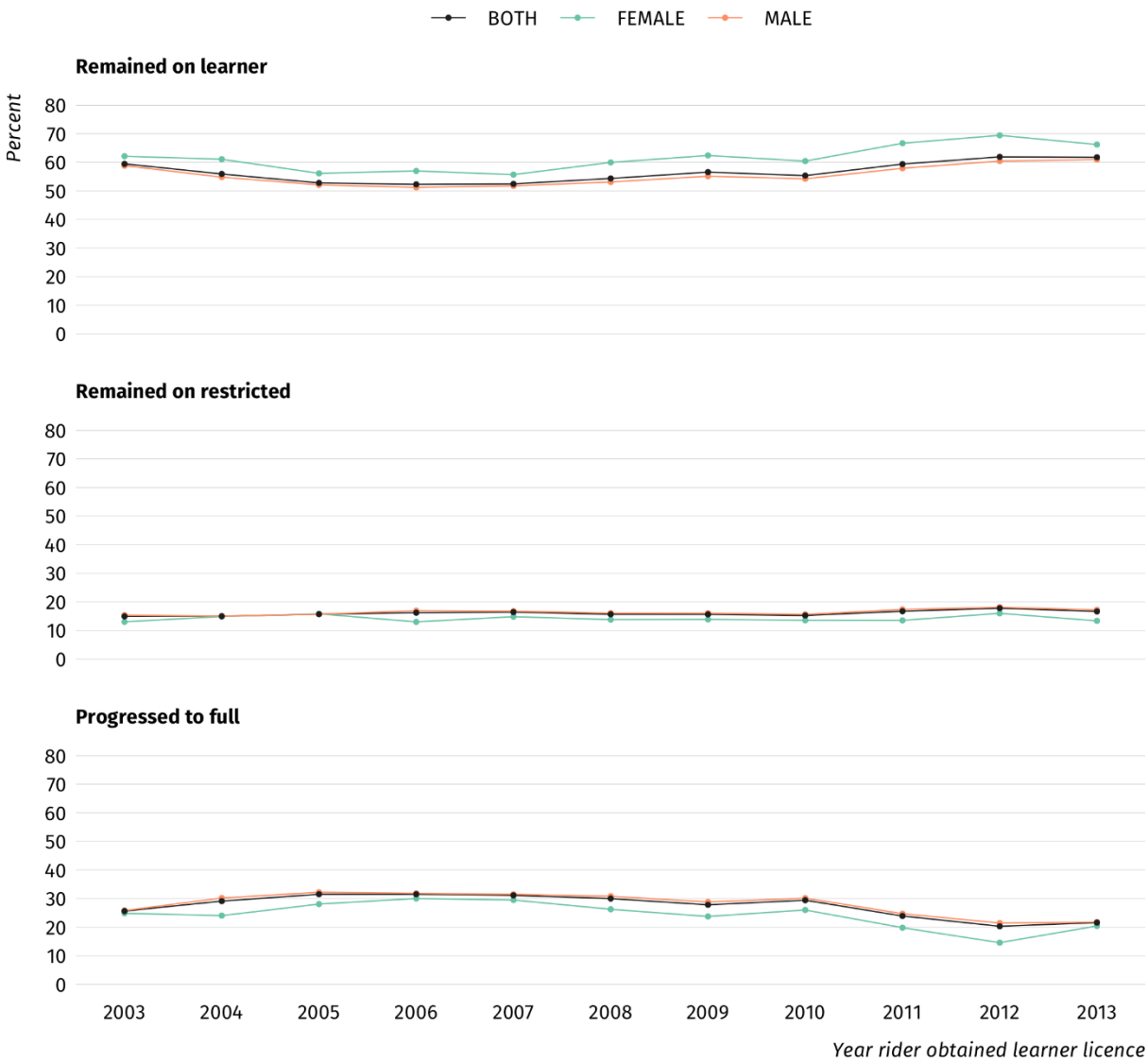


5.6.1. Four-year progression status: Relationships to rider characteristics

As with Class 1, the definition of non-progression is arbitrary, so we defined a rider's *four-year progression status* as their progression on the fourth anniversary of obtaining their learner licence and analysed the relationship between four-year progression status and crash rates. Figure 27 shows trends in the four-year progression status for cohorts of riders who obtained their learner licence in each year from 2003 to 2013.

Overall, the proportion of riders who progressed to a full licence in four years was highest for those who obtained their learner licence in 2006 (31.5%) and this subsequently declined (to 21.6% for those who received their learner licence in 2013). Conversely, the proportion who remained on a learner licence after four years increased from a low of 52.3% for those who received their learner licence in 2006 to reach 61.8% for those who received their learner licence in 2013. Four-year progression status is similar across genders. Males are slightly more likely than females to progress beyond a learner licence, and the biggest difference in progression across genders is at the learner to restricted stage. Of riders who do obtain a restricted licence, the proportion who subsequently progress to a full licence is almost identical across genders.

Figure 27 Four-year progression status for riders who obtained a learner licence between 2003 and 2013, by gender and year of obtaining a learner licence (percent).



We also examined how rider characteristics relate to four-year progression status by estimating logistic regression models of progression status for the combined 2011 to 2013 cohort of learners, (see section 4.4.3 of the *Technical Report*).[43] We found:

- The odds of progressing to a restricted licence within four years were 12% higher for males compared to females (p-value < 0.005). For those who progressed to a restricted licence, the odds of then progressing to a full licence were 4% higher for males than for females (p-value 0.03).
- Four-year progression status varies with the rider's age at the time of obtaining their learner licence. For example, of the people who obtained their learner licence in 2013:

[43] These models predict indicators of whether the rider remained on a learner licence, remained on a restricted licence, or progressed to a full licence after four years. The coefficients of the estimated models correspond to multiplicative differences in the odds of the relevant four-year progression status occurring for an individual rider. Since the progression outcomes are not low-probability events, the odds ratios estimated by these models are not equivalent to differences in probabilities of progression status.

    - Of those aged under 20 at the time of obtaining their learner licence, only 15% had progressed to a full licence within four years.
    - Of those aged 45 to 49 at the time of obtaining their learner licence, 40% had progressed to a full licence within four years.
- Rates of progression to a full licence have generally been falling for most age groups, with the biggest changes observed for riders aged between 25 and 44 at the time of obtaining their learner licence.

For riders who obtained a learner licence in the combined period from 2011 to 2013, the odds of progressing to a restricted and/or full licence were around 25% higher for riders who obtained their learner licence aged in their 40s and 50s compared to riders aged under 30. Similarly, for those who progressed to a restricted licence, the odds of progressing to a full licence within four years were around 25% higher for riders who obtained their learner licence in their 40s and 50s compared to riders aged under 30.[44]

5.6.2. Progression vs non-progression: Relationships to crash rates

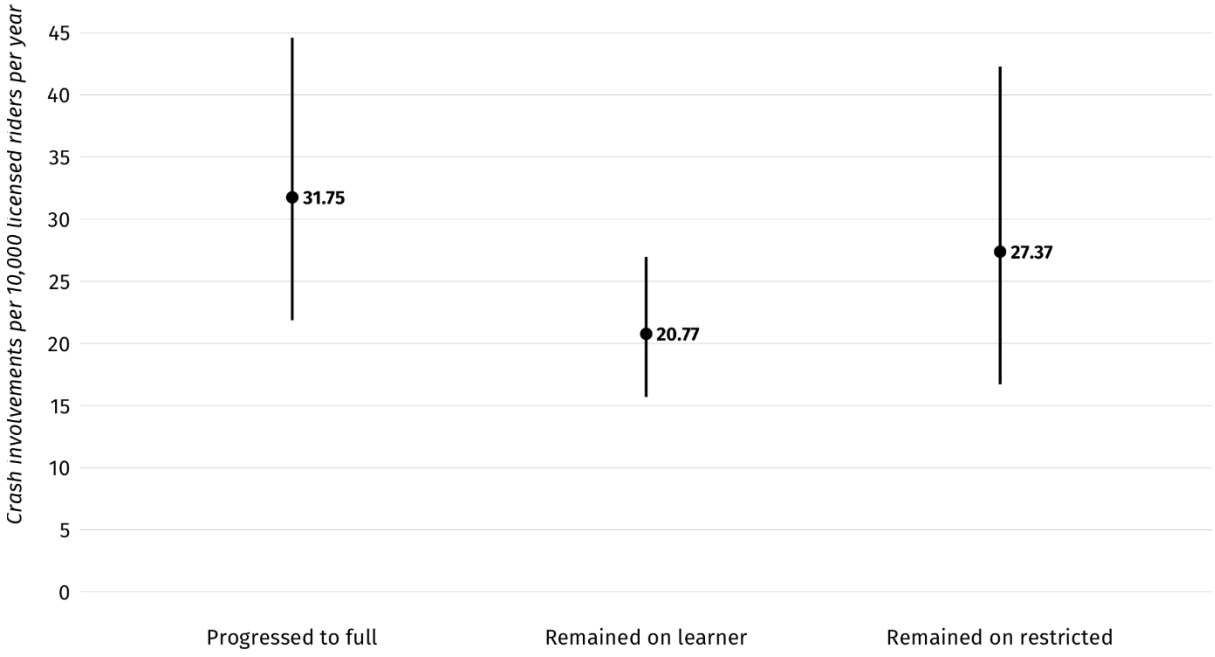
We tested whether progression was predictive of involvement in motorcycle crashes by analysing:

1. For the cohort of riders who obtained a learner licence in 2013 and 2014 (i.e. under the licensing system that applied after the introduction of CBTA) whether their progression status at the end of 2017 was predictive of involvement in crashes up to that time.
2. For riders who obtained a learner licence between 2003 and 2013, whether four-year progression status was predictive of involvement in crashes while holding a learner or a restricted licence.

For the cohort of riders who obtained a learner licence in 2013 and 2014, we found no statistically significant relationships between crash rates and progression status as at the end of 2017 (Figure 28; *p*-values range from 0.78 to 1.00). Essentially the same results were obtained when controlling for differences in rider gender, age, and region of residence (see section 4.4.4 of the *Technical Report*). For all riders who obtained a learner licence between 2003 and 2013, we found no evidence that four-year progression status is predictive of crash involvements while on a learner or restricted licence, after controlling for rider age, gender, and region of residence (see section 4.4.4 of the *Technical Report*).

[44] See Figures 64, 65, and 66 in the *Technical Report*. In most cases, the confidence intervals for the odds of progression for drivers aged in their 40s and 50s do not overlap with the confidence intervals for the odds of progression for drivers aged in their 20s and 30s, indicating that these age-related differences in progression are statistically significant at the 5% level.

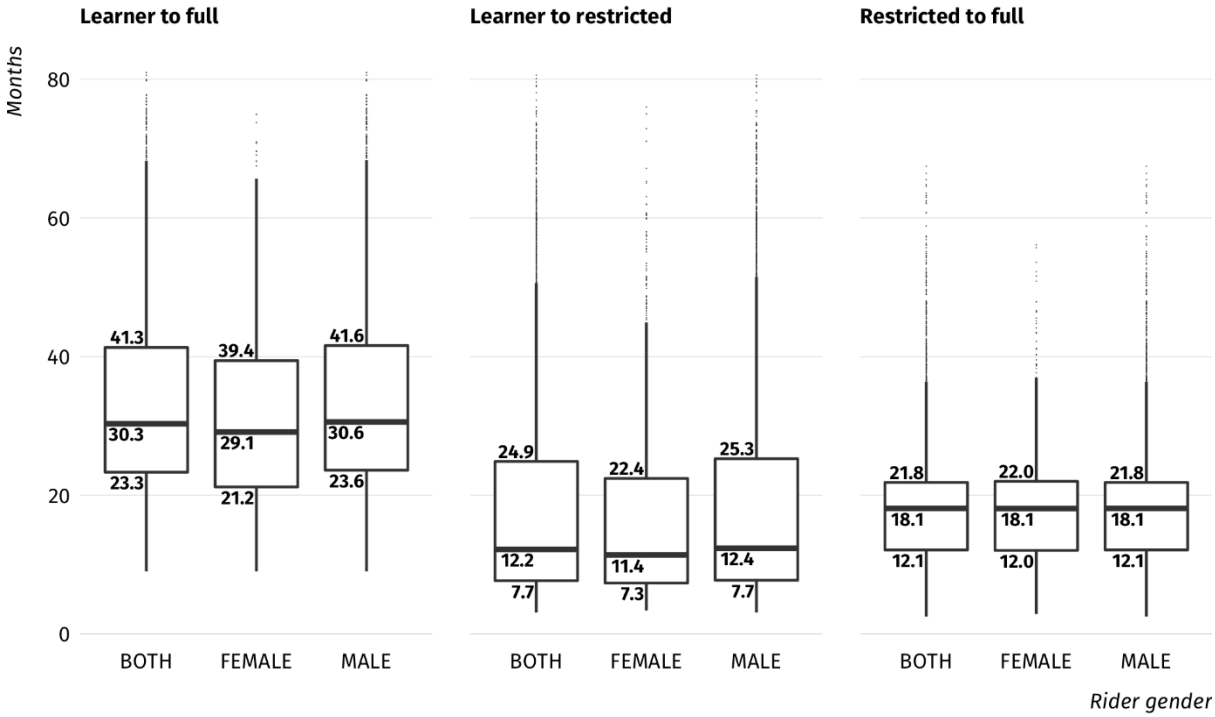
Figure 28 Fatal and serious at-fault motorcycle crash involvements per 10,000 licensed riders per year to the end of 2017 for riders who obtained their learner licence between 2013 and 2014, by progression status as at the end of 2017 and licence stage.



5.6.3. Progression duration: Relationships to rider characteristics

As with Class 1, to simplify the analysis of progression duration we focussed on a single cohort: those riders who obtained a learner licence in 2011 to 2013 and who progressed to subsequent stages by the end of 2017. Figure 29 shows the distribution of progression durations for this cohort, overall and by gender (the labelled values are the lower quartile, median, and upper quartile of progression duration for each progression step and gender). For riders who did progress from a learner to a full licence, there is virtually no difference in duration across genders. The median rider progressed from learner to full licence in around 30 months, with half of riders progressing between around 23 months and 41 months. At the restricted stage, the median rider who progressed to a full licence took just over 18 months.

Figure 29 Distribution of progression durations for riders who obtained a learner licence in 2011 to 2013 and progressed to subsequent stages by the end of 2017 by gender (months).



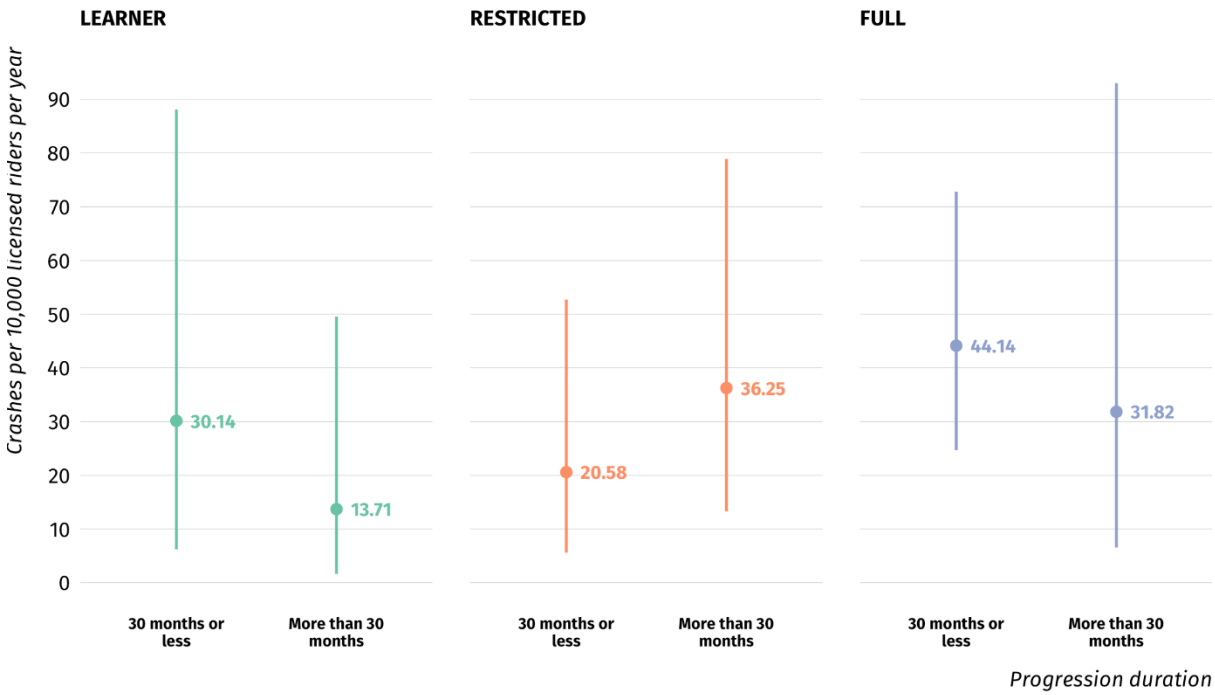
To estimate the combined effects of gender, age, and region of residence on progression duration, we estimated linear regression models of progression duration for the cohort of riders who obtained a learner licence in 2011 to 2013 and who had progressed to subsequent stages by the end of 2017 (see section 4.4.5 of the *Technical Report*). This shows that the baseline rider (a female living in Northland who obtained their learner licence at 16 years old) took an average of 41.4 months (just under 3.5 years) to progress from a learner to a full licence. In addition:

- There is no statistically significant difference in progression duration for males versus females (p-value 0.32).
- Progression duration generally falls with the rider's age at the time of obtaining their learner licence. Riders aged 25 to 34 took around 4 months less to progress from a learner to a full licence compared to riders aged under 25 (p-values < 0.005), and riders aged 45 and over took 8 months less (p-values < 0.005).
- There does not seem to be a consistent pattern to progression duration across regions.

5.6.4. Progression duration: Relationships to crash rates

Figure 30 compares crash rates for riders in each progression duration category at each licence stage. There is no clear relationship between progression duration category and the crash rate, at each licence stage. Our analysis found no statistically significant differences in crash rates at each licence stage when comparing riders who progressed in 30 months or less versus those who progressed more slowly (*p*-values range from 0.57 to 0.86).

Figure 30 Fatal and serious at-fault motorcycle crash involvements per 10,000 licensed riders per year for riders who obtained a learner licence in 2013 and 2014 and progressed to a full licence by the end of 2017, by duration of progression from learner to full licence and licence stage, with 95% confidence intervals.



To further explore the relationship between crash involvement and progression duration, we estimated a logistic regression model using data for the cohort of 2,503 riders who obtained a learner licence between 2013 and 2014 who had progressed to a full licence by the end of 2017. Due to the relatively small number of riders in this cohort, it was not possible to model crash involvements at each licence stage separately. The results of the model suggest no statistically significant difference in the odds of being involved in a crash for riders who progressed from a learner to a full licence in 30 months or less versus more than 30 months (*p*-value 0.32; see section 4.4.6 of the *Technical Report*).

6. Appendix: Literature review

6.1. Introduction and scope of this literature review

As part of the evaluation of the GDLS, the Ministry of Transport requested a brief review of the empirical literature on the relationship between graduated licensing systems and road safety (i.e. crash rates). The relevant literature is extensive and includes many evaluations of various aspects of GDLS in various countries. Given the size of this literature, a comprehensive review was not feasible within the scope of this project. Therefore, in this review we focus on summarising the key results of two types of literature:

- previous empirical studies of the New Zealand GDLS; and
- international meta-studies that summarise evaluations of GDLS in multiple countries.

We also briefly review some specific evaluations of GDLS in other countries to give a sense of the different empirical results obtained in the literature to date. This part of the review mainly focuses on literature published since 2010.

Many existing studies have estimated the effects of *introducing* a GDLS, that is, the effects of moving from a two-stage (learner/full) licensing system to a three-stage (learner/restricted/full) system. In contrast, the objectives of the analysis summarised in this report are to evaluate the effectiveness of the *current* system and to evaluate effects on road safety of recent *changes* to that system (e.g. increasing the minimum driving ages). Nevertheless, many of the basic empirical issues relevant for evaluating the introduction of GDLS are also relevant for our analysis, hence the existing literature serves as a useful background and as a complement to the analysis summarised in this report.

6.2. Studies of the New Zealand GDLS

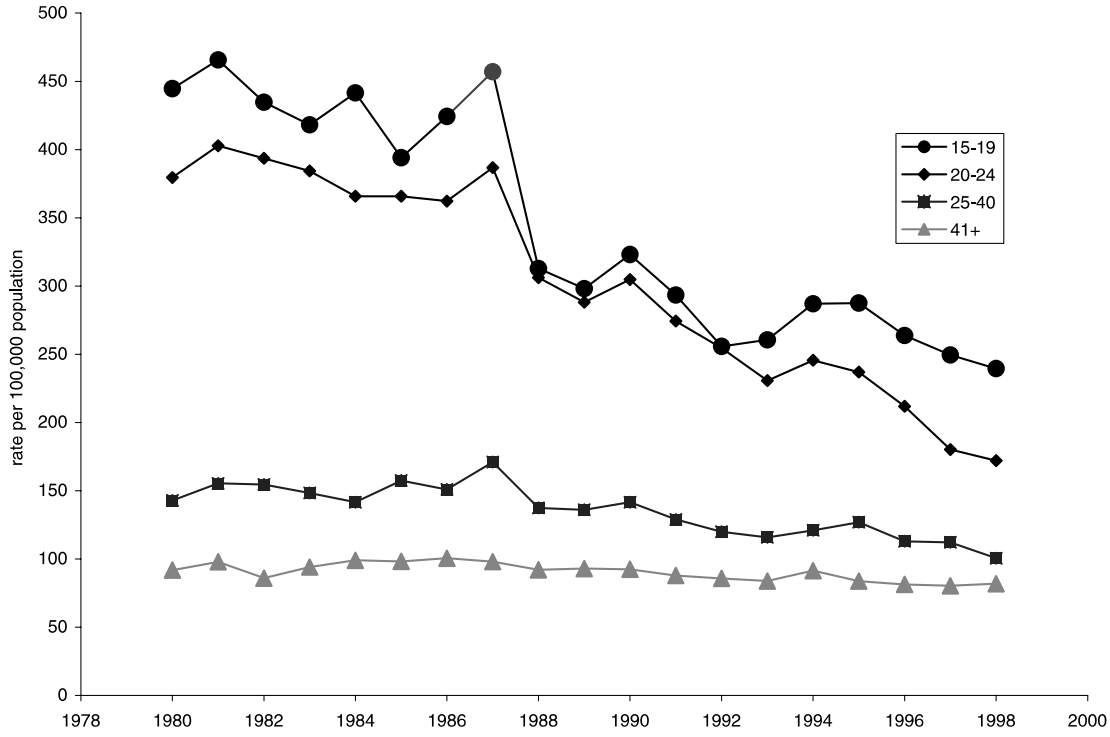
6.2.1. Effects of introducing the three-stage GDLS

Since it was first introduced in 1987, the effects of the New Zealand three-stage GDLS on road crashes have been analysed in several studies. The first post-implementation evaluation of the effect of introducing the GDLS on crash rates appears to be Frith and Perkins (1992). They compared trends in crash rates among drivers aged between 15 and 19 with those aged 25 years and older and found that by 1992 there was a continuing 8% reduction in the proportion of crashes involving young drivers that could be attributed to introducing the three-stage GDLS. Frith and Perkins (1992) also noted that the proportion of crashes involving unlicensed drivers was virtually unchanged after the introduction of the three-stage GDLS, suggesting that the new system had not led to higher rates of unlicensed driving. They did however note a significant decline in the number of licenses held by young drivers, suggesting that less driving by young people (i.e. reduced exposure to risk) was a key factor behind the reduction in crashes among this group.

Another early study was Langley *et al* (1996), based on analysis of data on hospital admissions following car crashes. They found that the introduction of a GDLS in New Zealand was “closely followed by substantial reductions in car crash injuries for all age groups, especially 15-19-year-olds”, with an estimated 7% reduction in the rate of serious injury crashes for that age group relative to drivers aged 25 and older that could be attributed to introducing a three-stage GDLS.

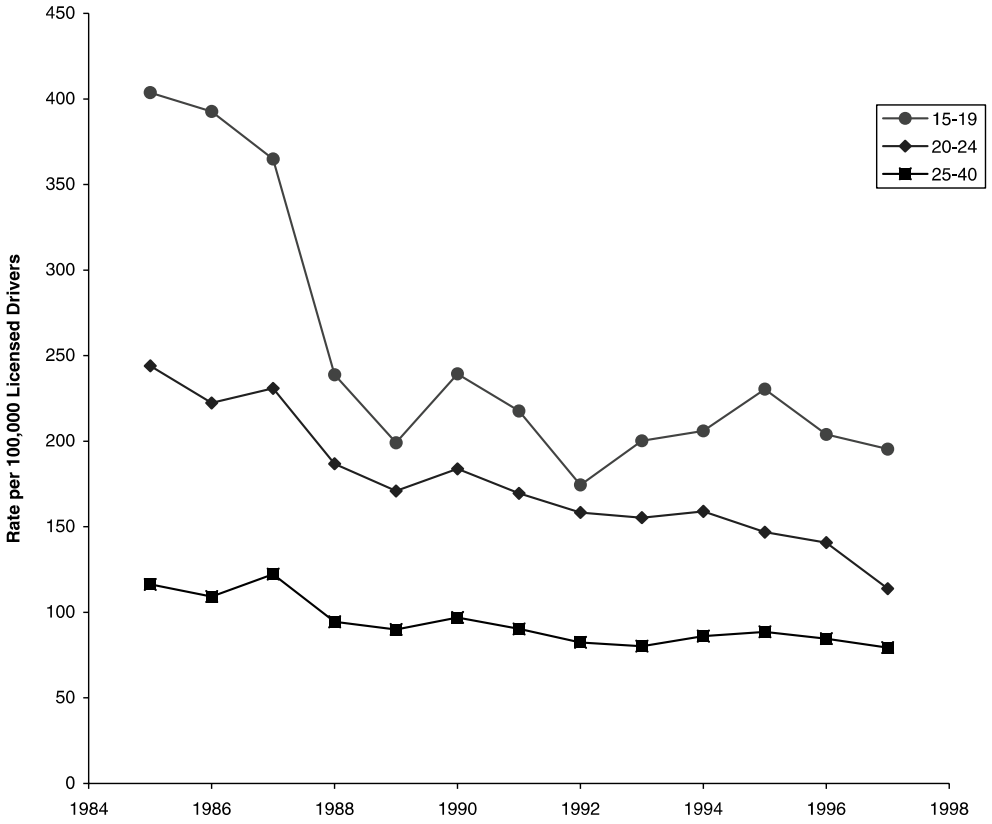
Begg and Stephenson (2003) used similar but updated time-series data as Langley *et al* (1996) and reached similar conclusions about the impact of introducing a three-stage GDLS on the rates of crash fatalities and hospitalisations among different age groups (Figure 31). They also found similar but smaller effects on the fatality and hospitalisation rates among drivers aged under 25 relative to drivers aged 25 to 40 (Figure 32) and concluded that the impacts of the GDLS were not entirely due to a reduction in driving by young people.

Figure 31 Motor vehicle traffic crash fatality and hospitalisation rates per 100,000 people in New Zealand.



Source: Begg and Stephenson (2003).

Figure 32 Rate of driver fatalities and hospitalisations per 100,000 licensed drivers.



Source: Begg and Stephenson (2003).

Kingham *et al* (2008) compared time trends in road traffic crash mortality among young adults in New Zealand from 1980 to 2001 versus similar trends in Great Britain. They argued that New Zealand and Great Britain are similar in terms of many factors that could affect traffic crash mortality, but since there were no significant changes to driver licensing in Great Britain during the period of analysis, it is a useful "control" for assessing whether the reduction in mortality in New Zealand can be attributed to the introduction of the three-stage GDLS in 1987 (and changes to the GDLS in 1999), or whether these trends reflect global trends, for example, due to improved motor vehicle safety and road engineering. Kingham *et al* (2008) found that the road traffic crash mortality rate among young adults in New Zealand declined after the introduction of the GDLS, but some of this could be attributed to other factors such as vehicle safety and road engineering, as evidenced by downward trends in mortality in Great Britain at the time. The authors also noted that (as at 2001), traffic crash mortality rates among various young adult age groups in New Zealand were still two to three times higher than in Great Britain. Kingham *et al* (2008) concluded that "This casts doubt on the belief that the implementation of the graduated licence scheme [in New Zealand] has seen a reduction in road traffic accident mortality among youth."

Using a rich dataset of police traffic crash reports linked to hospital inpatient records, Begg *et al* (2001) estimated the impact of the night-time curfew, restrictions on carrying passengers, and low blood alcohol limit imposed on drivers with restricted licenses under the GDLS. Controlling for driver age and gender, and year, Begg *et al* (2001) found that the introduction of the three-stage GDLS reduced rates of crashes at night, where passengers were involved, and where alcohol was suspected to be involved, for drivers with restricted

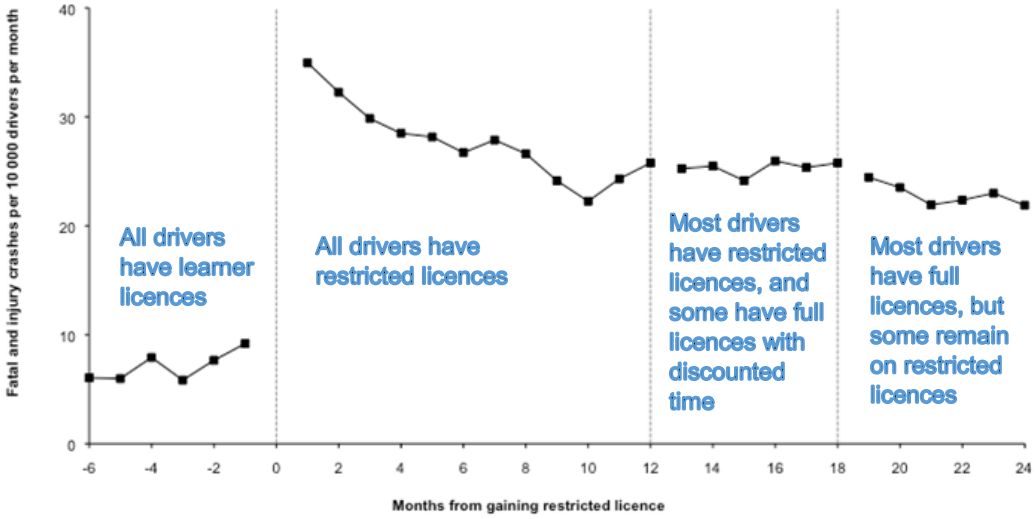
licences (i.e. all three restrictions were individually effective at reducing crashes among this group of drivers). For drivers with full licenses obtained after GDLS was introduced, Begg *et al* (2001) also found a reduction in night time crashes, but no significant effects associated with the other two restrictions applied to drivers with restricted licenses.

In terms of effects of introducing the three-stage GDLS on motorcycle riders in New Zealand, Reeder *et al* (1999) found that it was associated with a significant 22% reduction in motorcycle traffic crash hospitalisations for riders aged 15 to 19 years old, controlling for national trends in injury events. The authors noted that this reduction in crashes may be largely attributable to a reduction in participation in motorcycle riding after the introduction of the GDLS, that is, a reduction in overall exposure to motorcycle riding and associated crash risk.

6.2.2. Relationships between crash rates and driving experience or progression through the licensing stages

Lewis-Evans (2010) used matched driver licensing and crash data from 1999 to 2006 to analyse the relative probabilities of crashes for drivers with learner, restricted, and full licenses using statistical significance tests and logistic regression models controlling for driver age, gender, and driving experience. Figure 33 shows the overall profile of crash rates that he calculated for drivers who obtained a restricted license between 1999 and 2003 as they gain driving experience (measured by the amount of time since obtaining a learner licence). This clearly shows a significant increase in the rate of crashes associated with the transition from a learner to a restricted license, followed by a gradual decline as driving experience increases. This decline appears to reverse slightly before and during the period when some drivers can graduate to a full license with a time discount for completing advanced driver training (12 to 18 months). The gradual decline then appears to resume after the standard time for graduating to a full license (18 months onward).

Figure 33 Fatal and injury crashes per 10,000 licensed drivers per month for drivers who obtained a restricted licence between 1999 and 2003 in New Zealand.



Source: Lewis-Evans (2010). The blue annotations have been added for clarity.

From his analysis, Lewis-Evans (2010) reached the following key conclusions about the New Zealand GDLS:

- Moving from a learner to a restricted license was associated with an increase in the risk of fatal and serious injury crashes of between 2.6 and 7.4 times, depending on the age of the driver (all these differences were statistically significant, and the increase in risk reduced with driver age). However, some of this increase was likely due to an increase in driving by people with restricted licenses compared to those with learner licenses, but driving exposure (i.e. the amount of time that each individual driver spent driving) was not measured and not controlled for in his analysis.
- There was a statistically significant increase in the crash rate among drivers with full licenses for those who gained their license in the discounted time of 12 to 18 months versus those who gained their full license in the standard time of 18 months or more, raising questions about the effectiveness of the driver education programmes to qualify for the time discount. However, he also noted that drivers in the time-discount group may be people who tend to drive more often and have a stronger incentive to get a full license earlier ("highly motivated" drivers), and this is a possible explanation for the increase in the crash rate among this group.
- There was no significant difference in crash rates between people who had not gained their full license by the end of the study period (December 2006) versus people who gained their full license during the study period in the standard time of 18 months. Lewis-Evans (2010) concludes this "brings into question the value of having a final exit test before graduating to a full license".
- Among drivers with restricted licenses, crash rates were higher for younger drivers, and for male drivers, all else being equal.45

Langley *et al* (2012) examined the relationship between progression compared to non-progression through the New Zealand GDLS stages and traffic offences. Non-progressing drivers were defined as those who remained on a learner licence for at least 2.5 years (i.e. two years longer than the standard minimum time). For those who progressed, the relationship between speed of progression and traffic offences was also analysed. The authors found that, relative to those who progressed from a learner to a restricted licence in less than 9 months, those who progressed more slowly or who had not progressed after 2.5 years were between 37% and 54% less likely to have a traffic offence record while on a restricted or full licence.

Gulliver *et al* (2013) examined the links between driving experience and crash involvement while on a restricted licence. The authors found that those drivers who were in the upper quartile of learner licence duration (438 days or more) were between 9% and 57% less likely to be involved in a crash while on a learner licence compared to those who were in the lower quartile (less than 220 days), but there was no statistically significant difference in crash involvement among drivers in the lowest three quartiles of driving experience (up to 437 days).

[45] These findings are consistent with a range of other studies, for example, Bates *et al* (2014) and Shope (2006).

6.2.3. Other studies of the New Zealand GDLS

Effects of changing the minimum driving age

Begg and Langley (2009) qualitatively examined various arguments made (at the time) against raising the minimum driving age in New Zealand from 15 to 16 years old, which was subsequently implemented in 2011. Of relevance to the current study, the authors examined the argument that increasing the minimum age would simply shift crashes from 15-year-old drivers to 16- and/or 17-year-old drivers and there would be no net reduction in crashes. The authors noted the evidence that crash rates generally decline with age (all else being equal), and hence any increase in crashes among 16- or 17-year-old drivers due to reduced driving experience should be less than the number of crashes involving 15-year-old drivers that were prevented as a result of raising the minimum age, and thus there should be a net reduction in the number of crashes.

Parental influences on restricted drivers

Brookland *et al* (2014) examined the extent to which parents influenced compliance with driving conditions and crashes of their adolescent children while holding restricted licences. The authors found that various parental factors affected the compliance of their children with restricted driving conditions, including parental knowledge of these conditions, permitting their children to own vehicles, and parent crash involvement. Adolescents were also more likely to be involved in a crash while on a restricted licence if their parents actively delayed their children from obtaining a driver licence, permitted their children to own vehicles, or had been involved in a crash themselves.

Advanced driver training

Begg and Brookland (2015) analysed the relationship between participation in advanced driving courses (with and without time discounts) at the restricted licence stage and traffic offenses when fully licensed. The main finding was that drivers who received a time discount for advanced driver training were between 10% and 40% more likely to receive a traffic offense notice while on their full licence.

6.3. A selection of international literature

6.3.1. Meta-studies of the effects of introducing a GDLS

Russell *et al* (2011) reviewed 34 evaluations of introducing a GDLS in the United States, Canada, New Zealand, and Australia and reported that all of these studies found that this led to a reduction in crashes among teenage drivers. However, the estimated effects varied considerably across studies, depending on country-specific and implementation factors, as well as the data and empirical methods used. For example, among the studies that analysed all types of crashes involving 16-year-old drivers, in the first year after introducing a GDLS, population-based rates of such crashes were found to reduce by 6% and 29% after adjusting for other factors that may also have reduced crash rates at the same time. Long-term reductions in crashes were found to be similar at between 8% and 27%.

Williams *et al* (2012) did a similar review, focussing on research on graduated licensing published between 2010 and 2012. They report that all evaluations in their review found that introducing a GDLS was associated with a reduction in crash rates among 16-year-old drivers. They also report “more limited evidence” of positive effects for 17-year-old drivers, but unclear effects for 18- and 19-year-old drivers. In terms of the effects of specific driving

restrictions on crashes, Williams *et al* (2012) also report studies that found positive effects of night and passenger restrictions, despite mixed evidence about rates of compliance with such restrictions.

Williams (2017) updated the review cited above, covering research published between 2012 and 2016. Key safety-related findings about driver licensing from this literature were:

- Introducing a GDLS led to a reduction in total crashes of 21% for 16-year-olds and 12% for 17-year-olds, but there was evidence that a reduction in distance driven (induced by graduated licensing) was responsible for some or all of these reductions in crashes.
- Among 18- and 19-year-old drivers, Williams reports mixed evidence, with a small number of studies showing that introducing a GDLS increased crashes among this group (presumably due to reduced driving experience), while other studies found no effects on this age group, or reductions in crashes. Williams concluded that "The case is not closed, but these studies suggest that if there is any negative effect it is likely to be minimal, supporting the conclusion that the overall crash-reduction effect of GDL in the United States is strongly positive."
- Some limited evidence of safety benefits of a minimum learner licence period of 12 months versus 6 or 3 months, but no evidence of safety benefits of required hours of supervised driving at the learner stage.
- Restrictions on night-driving and carrying passengers at the restricted licence stage are generally effective at reducing crashes, but many such crashes still occur and compliance with such restrictions is not perfect.

Earlier multi-country reviews by Simpson (2003) and Shope (2007) found that introducing a GDLS was associated with crash rate reductions among young drivers from 4% to 60% and from 20% to 40%, respectively. Vanlaar *et al* (2009) reviewed studies from North America and found "strong evidence" in support of a GDLS, with an estimated reduction in relative fatality risk for 16-year-old drivers of 19%, but no significant effects for drivers aged over 16.

Zhu *et al* (2013) carried out a meta-study focussed on whether the impacts of introducing a GDLS on crash rates vary with the driver's age. Overall, they found that introducing a GDLS was associated with a 22% reduction in crash rates among 16-year-old drivers, a 6% reduction for 17-year-old drivers, and no significant effect for 18-year old drivers (however, they noted that few studies were available for older age groups).

6.3.2. Effectiveness of specific driving restrictions and compliance with restrictions

Several meta-studies have focussed on the relative effectiveness of the various restrictions that are typically imposed in the first two licensing stages under a three-stage GDLS:

- McKnight and Peck (2002) found positive effects associated with increasing the duration of the learner period, making obtaining a full license dependent on having a clean driving record, and restrictions on night driving and carrying passengers.
- Williams (2007) similarly found that longer learner periods and restrictions on night time driving and passenger carrying were effective at reducing crash rates among young drivers.
- Fell, Todd and Voas (2011) found that restrictions on night time driving and carrying passengers were effective at reducing fatal crashes by around 10% among 16- and 17-year-old drivers in the United States.

- Masten et al (2015) found that it was difficult to determine the effectiveness of individual restrictions but found no indication that any restriction was counterproductive for reducing crash rates among 16- and 17-year-old drivers.

Curry *et al* (2017) examined rates of compliance with and enforcement of restrictions on driving with passengers and driving at night that apply to drivers on intermediate licences (similar to restricted licences) in New Jersey. This was done by analysing rates of compliance with these restrictions among intermediate drivers who were involved in not-at-fault crashes, assuming that such drivers are representative of the general population of drivers on intermediate licences. The extent to which such drivers were also issued with citations (i.e. prosecuted) for breaching their licensing conditions was also analysed. Curry *et al* (2017) found that 8.3% of intermediate drivers' trips did not comply with the passenger restrictions and 3.1% did not comply with the night-time driving restriction. Furthermore, only 10.3% of drivers who were involved in a not-at-fault crash (and 19.0% of drivers involved in an at-fault crash) and who were in breach of these restrictions at the time of the crash were issued with a citation, suggesting that enforcement of restrictions in New Jersey is relatively weak.

Carpenter and Pressley (2013) examined rates of compliance with night-time driving restrictions applied to drivers aged 15 to 17 years old in the United States. Around 15% of such drivers involved in fatal crashes were non-compliant, and around 19% of all road crash fatalities in this age group were associated with non-compliance. Carpenter and Pressley (2013) also found correlations between non-compliance with night-time restrictions and drink driving and lack of use of seatbelts, suggesting that drivers who do not comply with driving restrictions are also more likely to engage in other risky driving behaviours.

Masten *et al* (2014) compared rates of conviction for GDL-related violations versus self-reported compliance with GDLS restrictions among 16- and 17-year old drivers in California. They found that around 1-2% of learner drivers were convicted of unlicensed or unsupervised driving, and around 2-3% of provisional (i.e. restricted) drivers were convicted of violating restrictions on driving at night or carrying passengers. Given that self-reported non-compliance with such restrictions is generally much higher, Masten *et al* (2014) noted that it is possible that enforcement of these restrictions is generally weak. However, they also noted that most studies of self-reported non-compliance are based on whether drivers have ever violated their driving restrictions, which may exaggerate the prevalence of non-compliance in practice.

Masten *et al* (2014) also found that an increase in the minimum learner licence period in California did not lead to an increase in convictions for unsupervised driving, suggesting that changes to such restrictions may not lead to reduced compliance. Similar results for California were found by Chapman *et al* (2014).

6.3.3. Effectiveness of targeted training for motorcycle riders

Given the challenges and risks associated with riding a motorcycle, some studies have examined the effectiveness of specific training targeted at motorcyclists at reducing motorcycle crashes. While rider training is not necessarily part of the licensing system per se, such studies are of interest given the introduction of CBTA in New Zealand with its emphasis on rider training.

A Cochrane review (Kardamanidis, 2010) of 23 studies of the relationship between rider training and crash, injury, and offence rates found very limited reliable evidence of the effectiveness of rider training. The authors noted that in many cases this was due to the poor

design of studies including poor control for confounding factors, small sample sizes, and short follow-up times after training. The authors concluded that there is some evidence that mandatory pre-licence training may reduce crashes by impeding people from obtaining motorcycle licences (i.e. by reducing exposure to crash risk), but that it is not clear whether or what type of training reduces the risk of motorcycle crashes.

A subsequent study by Ivers *et al* (2015) analysed the results of a randomised controlled trial of on-road rider coaching for newly licensed provisional (i.e. restricted) riders in Victoria, Australia. Riders who were selected for the trial were given four hours of on-road rider coaching in small groups and other related training. After 12 months, Ivers *et al* (2015) found no statistically significant difference in crash rates for the group of riders who received training relative to a similar control group of riders. In addition, riders who received the training reported increased riding exposure, speeding behaviours, and confidence, which may be associated with increased crash risk.

In contrast, Boele-Vos and de Craen (2015) analysed the effects of a one-day advanced rider training course via a randomised controlled trial of motorcyclists in the Netherlands. They found that participation was associated with improved performance on a hazard perception test and an on-road riding skills test. However, Boele-Vos and Craen (2015) did not analyse the effects of rider training on subsequent involvement in crashes.

A study by Crundell *et al* (2014) of riding performance in a simulator found that experienced riders and those who had undertaken advanced training displayed riding behaviours that could potentially reduce the risk of crashes, but again actual involvement in crashes was not analysed.

6.3.4. Selected other studies

The following is a brief summary of selected individual studies of the impacts of introducing a GDLS and various related issues. Given the size of this literature, the review in this section is not intended to be comprehensive but is intended to give a general overview of the methods and issues arising in GDLS evaluation.

Estimated effects of introducing a GDLS in the United States

Several studies have evaluated the effects of introducing a GDLS in the United States, taking advantage of the fact that graduated systems were introduced in different US states at different times. Chen *et al* (2006) used panel data for US states to estimate negative binomial regression models of the effect on quarterly per-capita crash rates of introducing a GDLS in a state, controlling for state, quarter, and year. On average across US states (noting that different states imposed different restrictions on young drivers), they estimated that introducing a GDLS was associated with an 11% reduction in the fatal crash rate for 16-year-old-drivers (with a 95% confidence interval from 1% to 20%). In comparison, no statistically significant effects on the fatal crash rate were found for drivers aged between 20-24 and 25-29. As drivers over 20 years old were not typically exposed to the GDLS, this suggests that the reduction in the fatal crash rates estimated for 16-year-old drivers could be attributed to the GDLS rather than other safety-related improvements that may have occurred at the same time.

Similar methods were used by Baker *et al* (2007) to analyse the effects of introducing a GDLS in the United States on fatal and injury crashes. For 16-year-old drivers, they estimated statistically significant reductions from introducing a three-stage GDLS of 11% and 19% for fatal and injury per-capita crash rates respectively. No statistically significant

reductions were found for drivers aged 20-24, 25-29, and 30-54, suggesting that the reduction estimated for 16-year-olds could be attributed to GDLS rather than other factors affecting all drivers.

Fell *et al* (2011) used similar data to the above studies but instead of comparing separate results for younger versus older drivers, the dependent variables in their models were crash counts for 16- and 17-year-old drivers divided by crash counts for drivers in order age groups. This division is assumed to directly adjust for other factors aside from GDLS that may have affected crash rates for all drivers. Fell *et al* (2011) estimated autoregressive integrated moving average models applied to panel data for US states, controlling for differences in other traffic-safety related interventions across states (e.g. seatbelt enforcement and drink-driving laws). They found that a GDLS was associated with between a 6.8% and 26.6% reduction in fatal crashes involving 16- and 17-year-old drivers relative to 21- to 25-year-old drivers.

Karaca-Mandic and Ridgeway (2010) estimated a sophisticated statistical model using United States crash data from 1990 to 2005 to attempt to separate the impacts of a GDLS on teenage driving behaviour from effects arising from a simple reduction in teenage driving. They estimated that most of the impacts of a GDLS on crash rates in the US could be attributed to a reduction in driving (particularly caused by restrictions on night time driving), rather than by improved teenage driving behaviour.

Effects of decals to identify restricted drivers

Curry *et al* (2015) studied the effects of changes to New Jersey's GDLS in 2010 that required young drivers on intermediate licenses (similar to restricted licenses in New Zealand) to display decals on their cars to make it easier for police officers to identify such drivers and increase enforcement of restrictions on night-time driving and carrying passengers.[46] They used data on vehicle crashes linked to driver licensing records to estimate negative binomial regression models explaining crash rates per 10,000 licensed drivers for 17-, 18-, 19-, and 20-year-old drivers. Controlling for age, gender, monthly average fuel prices, and crash rates among 21- to 24-year-old drivers, Curry *et al* (2015) found the changes to the GDLS rules were associated with an overall 9.5% reduction in crashes among drivers on intermediate licenses.

Curry *et al* (2015) also considered whether crash rates among intermediate drivers might have had unique trends prior to the GDLS changes that were not fully accounted for by the crash rate among older drivers included as a control variable in the model. They addressed this issue by estimating piecewise time-trend models for crash rates among intermediate drivers and tested whether the rates of change different types of crash rates were significant different after the GDLS changes compared to before. They found that the overall crash rate for intermediate drivers was reducing at 1.8% per year before the changes and 7.9% per year in the two years afterward, and this difference was statistically significant.

Bates *et al* (2017) surveyed the perceptions of provisional (i.e. restricted) licence holders regarding the display of "P" plates in Queensland, Australia. They found relatively high compliance with the requirement to display P plates, with 86% of drivers on first-stage provisional (P1) licences and 76% of drivers on second-stage provisional (P2) licences reporting that they nearly always displayed the required plates. A key finding of the study

[46] At the same time, the start of the night time driving restriction was moved back from midnight to 11pm, and restrictions on carrying family members as passengers were tightened. The analysis by Curry *et al* (2015) therefore reflects the combined effects of these changes, however the authors argue that the decal requirement was the most significant change since it enabled restrictions to be enforced better and increased the incentive for compliance.

was that provisional drivers identified P plates as an enforcement tool for police, and that this requirement resulted in them driving more carefully, however the study did not examine actual involvement in crashes.

Estimating impacts other than crash rates

Masten and Foss (2007) evaluated the effectiveness of introducing a GDLS in North Carolina in terms of hospital admissions, medical costs, and severity of injuries from crashes involving 16- and 17-year-old drivers. They estimated autoregressive integrated moving average models of monthly rates per capita and per licensed driver, controlling for seasonal effects and trends in corresponding rates for 25- to 54-year-old drivers. Masten and Foss (2007) estimated that introducing a GDLS in North Carolina reduced the per-capita incidence for 16-year-old drivers of crash-related hospitalisation and associated costs by 36.5% and 31.2% respectively, and a 12% reduction in per-capita hospitalisation was estimated for 17-year-old drivers. However, in both cases no improvements were found in rates per licensed driver, and there was some evidence that the severity of injuries increased among those hospitalised after the GDLS was introduced. Masten and Foss (2007) conclude that the benefits of graduated licensing in North Carolina appear to have mainly come from reduced exposure to driving, rather than better driving by 16- and 17-year-olds.

Does a GDLS make young people safer drivers?

Fohr *et al* (2015) focussed on the question of whether introducing a GDLS in Wisconsin led to safer driving behaviour by young drivers. To answer this question, they needed to control for all changes in exposure to driving risk (whether induced by the GDLS or other external factors) and all external changes in risk that were not due to the GDLS (e.g. improvements in vehicle safety and road design). As seen above, other studies have generally controlled for external changes in exposure and risk by adjusting crash rates observed for young drivers by changes in rates observed for drivers aged over 20. However, this means that the estimated effect of introducing a GDLS on crash rates for young drivers *includes* any changes in exposure that are induced by the GDLS itself (e.g. prohibiting driving at night, and the overall reduction in licensed drivers among young people typically observed after the introduction of a GDLS). That is appropriate if the objective is to estimate the overall impact of a GDLS on crash rates for young drivers, but if the objective is to focus on driving behaviour then all changes in exposure among young drivers need to be controlled for.

Fohr *et al* (2015) solved this problem by using changes in the rate of not-at-fault crashes among young drivers to adjust for all changes in exposure and risk that were not due to introducing a GDLS. As the authors note, determination of who is at fault in a crash is not always clear-cut, however this adjustment method has the advantage of capturing both external factors that affect crash rates for young drivers, and changes in exposure induced by the GDLS. Using this method, Fohr *et al* (2015) found that crash rates declined for 16- and 17-year-old drivers following the introduction of a GDLS, but all of the reduction could be explained by reductions in driving exposure (measured by reductions in the rate of not-at-fault crashes for 16- and 17-year-old drivers). The authors conclude that introducing a GDLS led to lower crash rates among young drivers by reducing their exposure to risk rather than making them safer drivers.

The links between a GDLS and driver behaviour were also explored by Poirier *et al* (2018) who analysed the relationship between license type and stated intention to violate road rules, and the social control mechanisms by which GDLS could reduce such intentions. Based on a survey of young drivers in Quebec, Canada, Poirier *et al* (2018) found that

having a restricted license was associated with a statistically significant reduction in intention to violate road rules and that this was mostly explained by restricted licenses having a moderating effect on peer pressure. However, the authors did not examine actual involvement in crashes.

Evaluation of changes to an existing GDLS

VicRoads (2017) evaluated the effects of enhancements to the GDLS in Victoria, Australia, that were introduced in 2007 and 2008.[47] These enhancements included a minimum requirement of 120 hours of supervised driving practice for learner drivers under 21 years old, allowing probationary (restricted) drivers to carry no more than one peer passenger (i.e. a passenger who is not an immediate family member) in the first year, and extending the overall probationary period from three to four years. Key findings were a 42.5% reduction in fatal and serious injury crashes for drivers aged between 18 and 23, compared to a 29% reduction for drivers aged over 23 in the same time period (it is unclear from the reported results if this difference is statistically significant). Statistically significant reductions in crash rates were found for drivers aged 18 to 20, but no significant effect was found for drivers aged 21 to 23.

Scully *et al* (2014) evaluated the effects of changes to the GDLS that were applied in Queensland, Australia, in July 2007. The key changes included requiring 100 hours of supervised practice for learner drivers (including 10 hours of night driving), extending the learner period from 6 to 12 months, reducing the minimum driving age from 16.5 years to 16 years, and allowing restricted drivers to carry at most one peer passenger between 11pm and 5am. Changes in crash rates per licensed driver for young drivers around the time of the changes were compared to changes in crash rates for drivers aged between 25 and 35 years old with full licenses at the same time. Fixed-effects panel data models were estimated to explain crash rates per licensed driver. Key findings of Scully *et al* (2014) include:

- Overall, the 2007 changes were associated with a 31% reduction in the rate of fatal crashes and a 13% reduction in fatal and serious injury crashes across all novice drivers (including some who started learning to drive prior to the changes), although this reduced to no significant difference in fatal crashes and a significant reduction of 9% in fatal and serious injury crashes if the analysis was restricted to drivers who had completed at least one licensing phase under the new system.
- The largest and most of the statistically significant reductions in crash rates were estimated for drivers with learner licenses. Reductions in crash rates for restricted or fully licensed drivers were generally smaller or statistically insignificant. Among the group of drivers who had fully completed all stages of the new system, a statistically significant increase in crash rates for drivers in the first year of the restricted license phase was observed.

Scully *et* al (2014) also analysed the effects of the 2007 changes to Queensland's GDLS on rates of driving-related offences for young drivers. They found:

- Rates of offences related to breaching driving conditions were very small, suggesting that novice drivers are generally compliant with the new conditions, but this could also be due to low intensity of enforcement of these conditions by police and the driver licensing authority.

[47] Only a high-level summary of the results is available, and details of the statistical methodology have not been published by VicRoads.

- Changes to the GDLS were associated with a net reduction in the rate of all driving-related offences by notice drivers, except for drink-driving offences. This seems to be due to improvements in enforcement of the zero blood-alcohol limit on provisional license holders due to them being more easily identified by displaying 'P' plates.

Another evaluation of the 2007 changes to the Queensland GDLS by Senserrick *et al* (2016) found the changes were associated with significant declines in crash-related casualties among novice drivers relative to the trends among the overall population of licensed drivers in Queensland. However, Senserrick *et al* (2016) found mixed results when comparing trends in crashes for novice drivers who completed the learner and provisional stages after the licensing system was changed versus those who progressed through the system before it was changed. A significantly lower rate of night-time crashes was found, but overall they found only a small and statistically insignificant difference in crashes. The authors noted that their ability to determine statistically significant differences in crash rates between these two groups was limited by the data available for those who started to learn to drive after the GDLS was changed, and they suggested that statistically significant differences may be found with better data. Senserrick *et al* (2016) also found that the changes to the GDLS were not associated with any increase in offences associated with violating driver licensing conditions, that is, the changes do not appear to have reduced compliance.

An earlier evaluation of the 2007 changes to the Queensland GDLS by Scott-Parker *et al* (2011) found that the changes significantly increased the amount of driving experience of learner drivers progressing through the licensing stages, and that most learners did not have difficulty obtaining the required amount of supervised driving practice.

Williams *et al* (2016) review studies of the impacts of the introduction of and subsequent changes to state-level GDLS laws in the United States. They find strong evidence that the introduction of GDLS led to a reduction in crashes among teenage drivers, and evidence of the effectiveness of restrictions on carrying passengers and night-time driving at reducing crashes. In terms of changes to driver licensing aimed at further reducing crashes relative to existing licensing laws in US states, Williams *et al* (2016) conclude that the policies most likely to be beneficial are older learner and intermediate starting ages (noting that in many US states the learner starting age remains at 15 years old), longer minimum learner licence durations, increased requirements for supervised driving hours, and introducing night-time driving and passenger restrictions (where these do not already apply).

Relationship between driving test attempts and crash risk

Boufous *et al* (2011) examined the relationship between the number of attempts a driver made at the practical driving test and hazard perception test required to obtain a provisional (restricted) licence versus subsequent crash involvements among drivers aged 17 to 24 years old in New South Wales, Australia. Controlling for driver demographic and behavioural factors, and factors related to the driver's learning experience, Boufous *et al* (2011) found that drivers who failed the practical driving test at least four times were around 1.8 times more likely to be involved in a crash compared to drivers who passed the test on their first attempt. Similarly, drivers who failed the hazard perception test at least twice were around 1.8 times more likely to be involved in a crash than those who passed the test on their first attempt.

References

Baker, S. P., L.-H. Chen, & G. Li (2007). Nationwide review of graduated driver licensing. AAA Foundation for Traffic Safety.

Bates, L. J., J. Davey, B. Watson, M. J. King & K. Armstrong (2014). Factors contributing to crashes among young drivers. *Sultan Qaboos University Medical Journal*, 14: 297-305.

Bates, L., B. Scott-Parker, M. Darvell & B. Watson (2017). Provisional drivers' perceptions of the impact of displaying P plates. *Traffic Injury Prevention*, 18: 820-825.

Begg, D. & J. Langley (2009). A critical examination of the arguments against raising the car driver licensing age in New Zealand. *Traffic Injury Prevention*, 10, 1-8.

Begg, D. & R. Brookland (2015). Participation in driver education/training courses during graduated driver licensing, and the effect of a time-discount on subsequent traffic offenses: Findings from the New Zealand Drivers Study. *Journal of Safety Research*, 55: 13-20.

Begg, D. J. & S. Stephenson (2003). Graduated driver licensing: The New Zealand experience. *Journal of Safety Research*, 34, 99-105.

Begg, D. J., S. Stephenson, J. Alsop, & J. Langley (2001). Impact of graduated driver licensing restrictions on crashes involving young drivers in New Zealand. *Injury Prevention*, 7, 292-296.

Boele-Vos, M. J. & S. de Craen (2015). A randomized controlled evaluation study of the effects of a one-day advanced rider training course. *Accident Analysis and Prevention*, 79: 152-159.

Brookland, R. D. Begg, J. Langley & S. Ameratunga (2014). Parental influence on adolescent compliance with graduated driver licensing conditions and crashes as a restricted driver: New Zealand Drivers Study. *Accident Analysis and Prevention*, 69, 30-39.

Carpenter, D. & J. C. Pressley (2013). Graduated driver licence nighttime compliance in U.S. teen drivers involved in fatal motor vehicle crashes. *Accident Analysis and Prevention*, 56: 110-117.

Chapman, E. A., S. V. Masten & K. K. Browning (2014). Crash and traffic violation rates before and after licensure for novice California drivers subject to different driver licensing requirements. *Journal of Safety Research*, 50: 125-138.

Chen, L.-H., S. P. Baker, & G. Li (2006). Graduated driver licensing programs and fatal crashes of 16-year-old drivers: A national evaluation. *Paediatrics*, 118: 56-62.

Crundall, D., A. W. Stedmon, E. Crundall & R. Saikayasit (2014). The role of experience and advanced training on performance in a motorcycle simulator. *Accident Analysis and Prevention*, 73: 81-90.

Curry, A. E., M. R. Elliott, M. R. Pfeiffer, K. H. Kim, & D. R. Durbin (2015). Long-term changes in crash rates after introduction of a graduated driver licensing decal provision. *American Journal of Preventive Medicine*, 48: 121-127.

Curry, A. E., M. R. Pfeiffer, & M. R. Elliott (2017). Compliance with and enforcement of graduated driver licensing restrictions. *American Journal of Preventive Medicine*, 52: 47-54.

Fell, J. C., K. Jones, E. Romano, & R. Voas (2011). An evaluation of graduated driver licensing effects on fatal crash involvements of young drivers in the United States. *Traffic Injury Prevention*, 12: 423-431.

Fell, J. C., M. Todd, & R. B. Voas (2011). A national evaluation of the nighttime and passenger restriction components of graduated driver licensing. *Journal of Safety Research*, 42: 283-290.

Fohr, S. A., P. M. Layde, & C. E. Guse (2005). Graduated driver licensing in Wisconsin: Does it create safer drivers? *Wisconsin Medical Journal*, 104: 31-36.

Frith, W. A. & W. A. Perkins (1992). The New Zealand graduated driver licensing system. *Conference Proceedings from National Road Safety Seminar, Wellington, New Zealand*, vol. 2, 256-278.

Gulliver, P., D. Begg, R. Brookland, S. Ameratunga & J. Langley (2013). Learner driver experiences and crash risk as an unsupervised driver. *Journal of Safety Research*, 36, 41-46.

Ivers, R. Q., C. Sakashita, T. Senserrick, J. Elkington, S. Lo, S. Boufous & L. de Rome (2015). Does an on-road motorcycle coaching program reduce crashes in novice riders? A randomised control trial. *Accident Analysis and Prevention*, 86: 40-46.

Karaca-Mandic, P. & G. Ridgeway (2010). Behavioral impact of graduated driver licensing on teenage driving risk and exposure. *Journal of Health Economics*, 29: 48-61.

Kardamanidis, K., A. Martiniuk, R. Q. Ivers, M. R. Stevension & K. Thistlethwaite (2010). Motorcycle rider training for the prevention of road traffic crashes (Review). *Cochrane Database of Systematic Reviews*, Issue 10.

Kingham, S., J. Pearce, D. Dorling, & M. Faulk (2008). The impact of the graduated driver licence scheme on road traffic accident youth mortality in New Zealand. *Journal of Transport Geography*, 16: 2, 134-141.

Langley, D., D. Begg, R. Brookland, A. Samaranayaka, H. Jordan & G. Davie (2012). Nonprogression through graduated driver licensing: Characteristics, traffic offending, and reasons for nonprogression. *Traffic Injury Prevention*, 13, 7-13.

Langley, J. D., A. C. Wagenaar, & D. J. Begg (1996). An evaluation of the New Zealand graduated driver licensing system. *Accident Analysis & Prevention*, 28: 2, 139-146.

Lewis-Evans, B. (2010). Crash involvement during the different phases of the New Zealand Graduated Driver Licensing System (GDLS). *Journal of Safety Research*, 41, 359-365.

Masten, S. V. & R. Foss (2007). The effects of graduated driver licensing on hospitalization rates and charges for 16- and 17-year-olds in North Carolina. *Traffic Injury Prevention*, 8: 35-38.

Masten, S. V., E. A. Chapman, D. B. Atkinson & K. K. Browning (2014). Non-compliance with graduated driver licensing (GDL) requirements: Changes in GDL-related conviction rates over time among 16-17-year-old California drivers. *Accident Analysis and Prevention*, 72: 230-243.

Masten, S. V., F. D. Thomas, K. T. Korbelak, R. C. Peck, & R. D. Blomberg (2015). Meta-analysis of graduated driver licensing laws. US National Highway Traffic Safety Administration report no. DOT HS 812 211.

McCartt, A. T. & E. R. Teoh (2015). Tracking progress in teenage driver crash risk in the United States since the advent of graduated driver licensing programs. *Journal of Safety Research*, 53: 1-9.

McCartt, A. T., D. R. Mayhew, K. A. Braitman, S. A. Ferguson & H. M. Simpson (2009). Effects of age and experience on young driver crashes: Review of recent literature. *Traffic Injury Prevention*, 10: 209-219.

Poirier, B., E. Blais, & C. Faubert (2018). Graduated driver licensing and differential deterrence: The effect of license type on intentions to violate road rules. *Accident Analysis and Prevention*, 110, 62-70.

Reeder, A. I., J. C. Alsop, J. D. Langley, & A. C. Wagenaar (1999). An evaluation of the general effect of the New Zealand graduated driver licensing system on motorcycle traffic crash hospitalisations. *Accident Analysis & Prevention*, 31: 6, 651-661.

Russell, K. F., B. Vandermeer, & L. Hartling (2011). Graduated driver licensing for reducing motor vehicle crashes among young drivers (Review). *Cochrane Database of Systematic Reviews*, 10, Art. No. CD003300.

Scott-Parker, B. J., L. Bates, B. C. Watson, M. J. King & M. K. Hyde (2011). The impact of changes to the graduated driver licensing program in Queensland, Australia on the experiences of Learner drivers. *Accident Analysis and Prevention*, 43, 1301-1308.

Scully, M., S. Newstead, & M. Keall (2014). An evaluation of Queensland's graduated licensing system: Analysis of police-reported crash outcomes, and individual GLS components. Monash University Accident Research Centre.

Senserrick T., S. Boufous, J. Olivier & J. Hatfield (2016). Evaluation of Queensland's graduated licensing system. Transport and Road Safety Research Report TMR9815, University of New South Wales.

Shope, J. T. (2006). Influences on youthful driving behaviour and their potential for guiding interventions to reduce crashes. *Injury Prevention*, 12(suppl_1): i9-i14.

Shope, J. T. (2007). Graduated driver licensing: Review of evaluation results since 2002. *Journal of Safety Research*, 38, 165-175.

Simpson, H. M. (2003). The evolution and effectiveness of graduated licensing. *Journal of Safety Research*, 34, 25-34.

Symmons, M. & C. Mulvihill (2011). A simulator comparison of riding performance between new, returned and continuing motorcycle riders. Public Policy Center, University of Iowa.

Vanlaar, W., D. Mayhew, K. Marcoux, G. Wets, T. Brijs, & J. Shope (2009). An evaluation of graduated driver licensing programs in North America. Traffic Injury Research Foundation.

VicRoads (2017). Examination of the impact of the graduated licensing system on young novice driver safety.

Williams, A. F. & S. A. Ferguson (2002). Rationale for graduated licensing and the risks it should address. *Injury Prevention*, 8 (Suppl II): ii9-ii16.

Williams, A. F. (2003). Teenage drivers: Patterns of risk. *Journal of Safety Research*, 34: 5-15.

Williams, A. F. (2007). Contribution of the components of graduated licensing to crash reductions. *Journal of Safety Research*, 38, 177-184.

Williams, A. F. (2017). Graduated driver licensing (GDL) in the United States in 2016: A literature review and commentary. *Journal of Safety Research*, 63, 29-41.

Williams, A. F., A. T. McCartt & L. B. Sims (2016). History and current status of state graduated driver licensing (GDL) laws in the United States. *Journal of Safety Research*, 56: 9-15.

Williams, A. F., B. C. Tefft, & J. G. Gabowski (2012). Graduated driver licensing research review, 2010 – present. *Journal of Safety Research*, 43, 195-203.

Zhu, M., P. Cummings, H. Chu, J. H. Coben, & G. Li (2013). Graduated driver licensing and motor vehicle crashes involving teenage drivers: An exploratory age-stratified meta-analysis. *Injury Prevention*, 19, 49-57.