Recreational Road Accidents in New Zealand

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Key Findings

- Road Accidents during the vacation periods are similar to those on ordinary weekends
- Accidents follow clear temporal patterns during a day and during a week
- There are temporal patterns for accidents occurring under the influence
- Intoxicated driving is shifting to weekdays

Abstract

This study investigates how the road safety in New Zealand is influenced by recreational factors, such as holiday weekends, alcohol and time/spatial patterns. The results of our analysis show that the number of accidents during holiday periods are similar to those on normal weekends. There are clear patterns of accidents during commuting times and accidents occurring under the influence on weekends. In recent years, accidents that occur with intoxicated drivers also occurs more frequently during the work week.

Keywords: accidents; new zealand; holidays; intoxication; alcohol

1 Introduction

Road traffic accidents are a major source of damages to property and people. Their impact on the economy and the livelihood of people is substantial. In New Zealand, hundreds of people loose their lives on the road and many more are injured every year. According to the OECD 71.6 people per 1 million inhabitants died in 2019 on New Zealand's roads, which is considerably higher compared to Australia (47.1) Germany (36.6) and the UK (27.6 in 2018) (OECD, 2021).

The Ministry of Transport in New Zealand estimated in 2017 that the the average social cost is NZD 4.916 million per fatal crash, NZD 923,000 per reported serious crash, and NZD 104,000 per reported minor crash. The total social cost of motor vehicle injury crashes in 2016 is estimated at approximately NZD 4.17 billion (of Transport, 2017).

There is an inherent risk in participating in road traffic, may it be as a motorist, cyclist or pedestrian. While many use the roads for commercial purposes, such as to transport goods or to commute to work, there is also a considerable traffic due to recreational objectives, such as to attend social gatherings or to go on vacations, although this type of traffic has been impacted by the Covid-19 crisis in the past year. In this study we focus on road accidents that are related to recreational activities in New Zealand from the years 2000-2019.

1.1 Holidays

The Ministry for Transport is operating a holiday road toll statistics[1] that counts the number of deaths and injuries during four special vacation periods in New Zealand:

- **Easter holiday**
  - The Easter period ranges from the Friday before Easter Sunday to the Monday following Easter Sunday. Easter Sunday is calculated using the "Computus" [2]. This results in a moving holiday that is typically on the first Sunday following the full Moon that occurs on or just after the spring equinox.
  - The official Easter holiday period begins at 4pm on the Thursday before Good Friday and ends at 6am on the Tuesday after Easter Monday.
- **Queen's Birthday**
  - 1st Monday in June
  - The official Queens birthday weekend holiday period begins at 4pm on the Friday before the weekend and ends at 6am on the Tuesday after Queens Birthday.

[1] https://www.transport.govt.nz/statistics-and-insights/safety-road-deaths/holiday-periods/

[2] https://en.wikipedia.org/wiki/Computus

- **Labour Day**
  - 4th Monday in October
  - The official Labour day weekend holiday period begins at 4pm on the Friday before the weekend and ends at 6am on the Tuesday after Labour Day.
- **Christmas & New Year**
  - When Christmas Eve and New Year's Eve falls on a week day the holiday starts at 4.00 pm on 24 December
  - If the holiday begins on a Monday or a Tuesday it ends at 6am on 3 January (9.6 days)
  - If the holiday begins between Wednesday and Friday it ends at 6am on 5 January (11.6 days)
  - When Christmas Eve and New Year's Eve falls on a Saturday the holiday starts at 4pm on Friday 23 December and ends at 6am on Wednesday 4 January (11.6 days)
  - When Christmas Eve and New Year's Eve fall on a Sunday the holiday starts at 4.00pm on Friday 22 December and ends at 6.00 am on Wednesday 3 January (11.6 days)

The published statistics are accompanied by safety advertising campaigns[3] that are widely broadcast in the New Zealand media. During the vacation period, radio stations continuously report on the vacation road toll. Tay (2001) showed that the publicity campaign helped reducing accidents while van Lamoen (2014) showed that the "Safer Summer" campaign helped to reduce speeding offences. We were, however, unable to find rigorous statistical evidence about the road toll during vacation periods in New Zealand. We are interested if driving during these special holiday periods is more dangerous than during other weekends in the year.

1.2 Intoxication

It is perceived that traveling during these holiday periods is more dangerous and Anowar et al. (2013) showed that traffic accidents in Alberta, Canada during festive periods (2004-2008) are over represented despite publicity road safety campaigns. They identified risk factors, such as driver intoxication, speeding and restraint use. While non-use of restraint is more prevalent during these holidays in Alberta, driver intoxication and speeding are less prevalent. Such road safety models can be used to help allocating police resources to specific time periods and places (Guria and Mara, 2000). Keall et al. (2005) showed that in New Zealand alcohol contributes almost half of the risk for young male drivers

[3] `https://www.nzta.govt.nz/safety/what-waka-kotahi-is-doing/our-advertising/road-safety-advertising-calendar/`

on open roads during night times but contributes little to the overall risk on busy roads. This indicates that drunken drivers have a tendency to use lower volume roads to avoid police. Scuffham and Langley (2002) created a model for traffic accidents in New Zealand for the period of 1970-1994 that showed the connection between the number of crashes and other economic indicators, such as gross domestic product per capita, unemployment rate and alcohol consumption. They showed that change in alcohol consumption per capita is an important factor in traffic crashes.

1.3 Research Questions

This study investigates the following research questions:

1. Do more accidents occur during Easter, Queens Birthday and Labour Weekend compared to ordinary weekends?
2. Has the proportion of accidents on open roads increased over time?
3. Has the severity of accidents on open roads and urban roads changed over time?
4. What is the influence of intoxication?
5. How are accidents spread across the week/time?
6. How are accidents associated with intoxication spread across weekday/time?

2 Data

The data for this study was acquired from the New Zealand Transportation Agency's Crash Analysis System (CAS)[4]. It includes a wide spectrum of information related to all crashes that have been recorded by the New Zealand police. All of the data used in this study is also publicly available through their Open Data platform and hence no Human Ethics application at the *** removed for anonymity *** was necessary. We included CAS data from the years 2000-2019, which contains the details of 36,890 recorded accidents. The variables included in this study are:

- Time and date of the accident
- Road type (open or rural road)
- Severity of the accident defined by the worst recorded injury:
  - No injuries
  - Minor injuries

[4] https://cas.nzta.govt.nz

  - Serious injuries
  - Fatal injuries
- Intoxication – driving under the influence of either alcohol or drugs (DUI).

In addition, we included some social-economic indicators for New Zealand that are publicly available from the Ministry of Business, Innovation & Employment and from Statistics New Zealand.

- Petrol prices
- Vehicle Kilometers Driven (VKT)
- Population

Due to the high variability and extended length of the Christmas & New Year vacation period we decided to exclude it from the analysis. While the long weekend holidays can be compared to other weekends, it would have been difficult to identify a period of time to which the Christmas & New Year period could have been compared.

3 Methods

To answer the research questions posed above, we have used Bayesian framework, which is often considered more flexible and intuitive than the classical methods. Bayesian inference combines the information available about the parameters before the study, the prior, with the data-generating mechanism, the likelihood, to produce the posterior distribution for the parameters of interest. If no prior information is available, a non-informative prior can be used and the results will usually be numerically similar to those of the classical maximum likelihood estimation. The posterior means and the 95% credible intervals (CIs), derived from the posterior distribution, usually provide the point and the uncertainty estimates respectively. Instead of the classical p-values, posterior probabilities that a specific statement is true given the data (sometimes called Bayesian P-values) and the modeling assumptions can be evaluated. For the comparison of weekend tolls, we have fitted a Poisson generalised linear model (GLM):

$$x_{y,wtype,i} \sim Poisson(\lambda_{y,wtype}),$$

where $x_{y,wtype,i}$ is the number of accidents recorded in year y on a weekend of type *wtype*. Note, that there will be only one observation per year for a non-BAU (Business As Usual) weekend. We assumed a non-informative $Gamma(0.01, 0.01)$ prior for the intensity parameters $\lambda_{y,wtype}$. We then used simulations to evaluate the posterior probabilities that the toll for a specific weekend type was higher than that for BAU, $Pr(\lambda_{y,wtype} > \lambda_{y,BAU})$, for each year y. As well as for all the years: $Pr(\cap_y(\lambda_{y,wtype} > \lambda_{y,BAU}))$.

To model the annual proportion of accidents on urban roads, we have fitted a binomial logistic regression with linear trend in years. The model was implemented in WinBUGS Lunn et al. (2000) and the R2WinBUGS Sturtz et al. (2005) was used to interface it with the R-software.

To investigate possible differences in factors contributing to accidents during business-as-usual weekends and holiday weekends respectively, we have generally followed the methodology of Anowar et al. (2013), and fitted a binary logistic regression within the Bayesian framework.

In order to test, whether the distribution of crash severity frequencies has changed over years, we have implemented a multinomial model (for the four response categories: Fatal crash, Serious crash, Minor crash, and Non-injury crash) with Dirichlet prior for the category-specific probabilities. Two models were fitted (with and without the above probabilities depending on the year) and compared using the Deviance Information Criterion (DIC) Spiegelhalter et al. (2002) to check for the statistical effect of year. DICs are used for Bayesian model comparison in a manner similar to the use of AICs in classical model comparison. Smaller DICs correspond to statistically better models, and a difference of at least 3 is considered sufficient to infer difference. A similar comparison was done for the models with and without the urban/rural division respectively, to see whether the distribution of frequencies of various types of crashes was different for the urban and the rural roads.

Finally, we have taken a look at the distribution of the recorded time of accidents within a calendar week. Only business-as-usual days were included (Easter, Labour Weekend, Queen's Birthday, Christmas and New Year holidays were excluded). We have postulated that the observed distribution of times of accidents t_i consists of a mixture of normal components with unknown parameters, and, furthermore, that the number of components itself is unknown. Such Bayesian cluster analysis is described in detail in Richardson and Green (1997), and has been implemented in R via mixAK package Komárek and Komárková (2014). We have applied it to all accidents and DUI accidents only for each year to identify the likeliest number of normal components and their parameters. Although the results of cluster analysis are often not directly interpretable, in this case they might have corresponded to different traffic surges (such as morning commute to work, evening commute from work, early Saturday morning commute from a party etc.)

4 Results

There are three societal factors that could play a role and that are at a level of magnitude that they could influence accidents in a major way. This would be the population fluctuation, the vehicle kilometers driven, and the fuel prices in New Zealand. Best and Burke (2019) showed that the number of crashes on New Zealand's roads is correlated to the fuel prices. This could be based on the fact that petrol prices and vehicle kilometer driven are correlated (Kennedy and Wallis, 2007).

The trends in petrol prices, population, vehicle kilometers driven, the total number of crashes as well as the number of victims involved in them are shown in Figure 1. Note the high negative correlation between the petrol prices and the total number of crashes: -0.37 for the entire study period of 2000-2019, -0.70 for the last ten years.

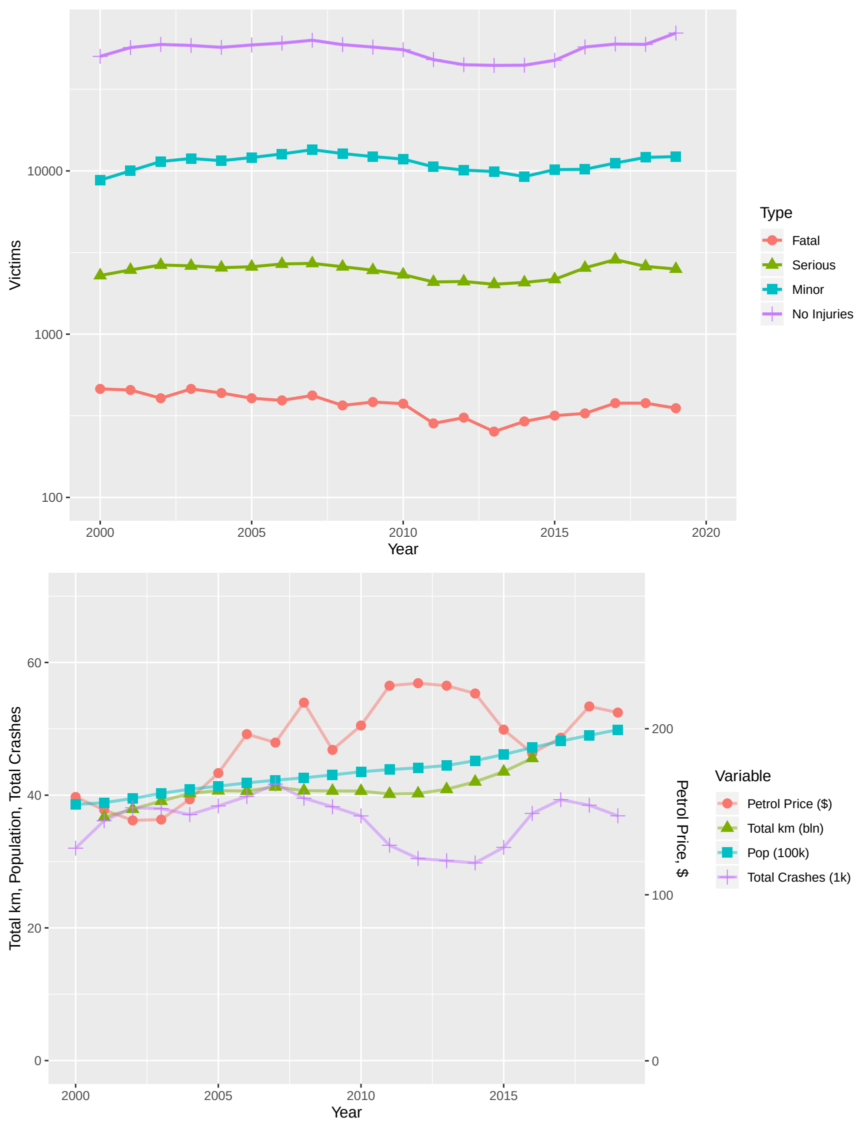

Figure 1: Trends in Petrol Prices, Total km driven, population, total number of crashes, and the number of victims involved. Note the logarithmic scale on the upper graph.

Our results confirm the work done by Best and Burke (2019) for the period of 1989-2017, although their work focused on fatalities only. While any loss of life is a traumatic event, the total social costs of accidents are much heavier influenced by taking into account all casualties and property damages. Fatal accidents are thankfully rare. Hence our correlation between the number of crashes and the petrol prices seem to be more meaningful than the correlation between fatal injuries and fuel prices as proposed by Best and Burke (2019). Still, finding a similar but not identical correlation validates our model.

The observed dip in the number of crashes in the years 2013 to 2017 could be related to a variety of factors. Walton et al. (2020) showed that the increase in crashes after 2013 can be attributed to alcohol, learner license holders and regional effects for Auckland.

4.1 Large Scale Temporal Trends

We compared holiday periods (Easter, Queen's Birthday, Labour Day) to Business-as-Usual (BAU) weekends. The later are defined as all non holiday weekends. In addition, we compared the holiday periods to the weekends before and after the holiday periods.

4.1.1 Number of accidents

The results of accident incidence modeling for the Easter Weekend are shown in Figure 2. The posterior estimated mean ratio of Easter Weekend accidents to Business-as-Usual Weekend ranged from 0.85% in 2006 to 1.10% in 2003. There did not appear to be a consistent trend in the ratio. Overall, across the years, the posterior estimated mean for the ratio was 0.96 with the 95% CI of 0.77 to 1.18.

2003 was the only year for which the posterior estimated probability of the Easter Weekend number of fatal injuries being higher than BAU weekend number of fatal injuries was above 95% . We repeated the analysis comparing the number of fatal injuries at Easter with the previous weekend with the same result. However, the probability of the number of fatal injuries at Easter being higher than during the following weekend was above 95% for the years 2000,2003,2005,and 2014.

The results of accident incidence modeling for the Queen's Birthday and Labour Weekend are shown in Figure 3. The posterior estimated mean ratio of Queen's Birthday accident incidence to that for BAU ranged from 0.88% in 2003 to 1.15% in 2019. Across the years, the posterior estimated mean ratio was 1.02 with the 95% CI 0.79 to 1.27.

The posterior estimated mean ratio of Labour Weekend number of accidents to BAU number of accidents ranged from 0.73% in 2011 to 1.20% in 2006. Across the years, the posterior estimated mean ratio was 0.93 with the 95% CI 0.69 to 1.23.

The posterior estimated probability of the Queen's Birthday weekend number of accidents being higher than that of BAU number of accidents was above

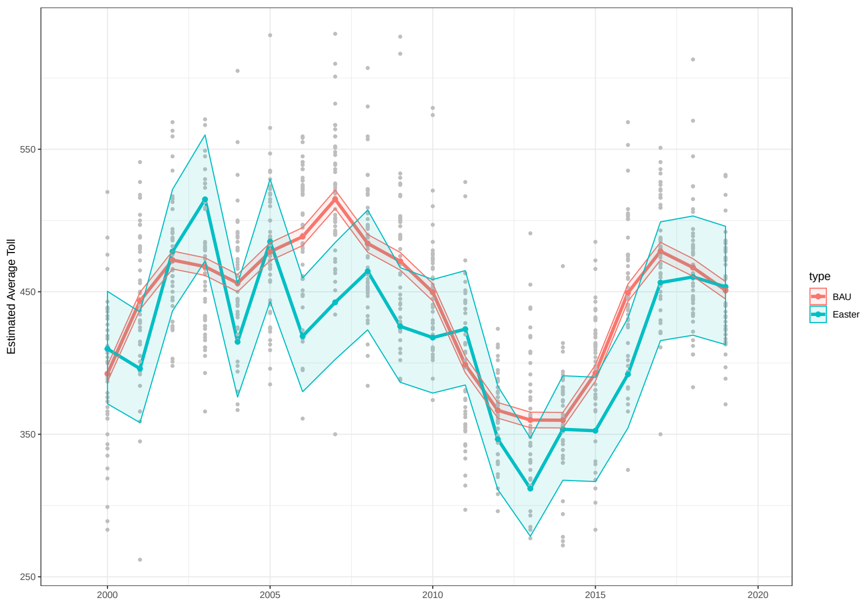

Figure 2: Easter Weekend accidents vs. Business-as-Usual Weekend accidents. The The graph shows the posterior means estimated by the model, and the 95% credible envelopes. The only year for which $P(\lambda_{Easter} > \lambda_{BAU}|data) > .95$ was the year 2003. The gray points are the observed weekend-specific accidents.

95% for the years 2000, 2001, 2008, 2009, and 2019 whereas the number of accidents for the Labour Weekend was only certainly higher than BAU for the year 2006.

4.1.2 Road type

The proportion of accidents on urban roads has been steadily going down (see Figure 4). The odds of having an accident on the urban rather than open road have been found to decrease at an average of 1.40% per year with the 95% CI of 1.31% to 1.49%.

4.2 Crash Severity

The distribution of crash severity for the open and urban roads is shown in Table 1, and the temporal dynamics is illustrated in Figures 5 and 6. Our modeling showed no substantial difference in distribution of crash severity over years ($\delta DIC = 342981.5$), but substantial difference in distribution of crash severity for the open vs. urban roads ($\delta DIC = -14158.54$). The proportion of non-injury crashes on urban roads is much higher compared to open roads and the proportion of fatal and serious crashes much lower.

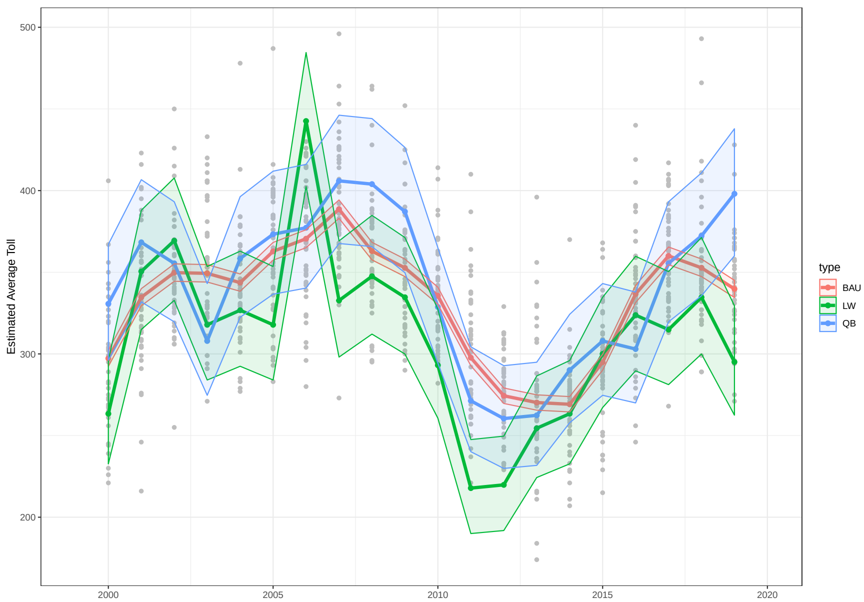

Figure 3: Labour Weekend and Queen's Birthday Weekend Toll vs. Business-as-Usual Weekend number of accidents. The The graph shows the posterior means estimated by the model, and the 95% credible envelopes. The gray points are the observed weekend-specific number of fatal injuries.

	Fatal Crash	Minor Crash	Non-Injury Crash	Serious Crash
Open	4774 (2.1%)	61015 (26.2%)	147180 (63.3%)	19512 (8.4%)
Urban	1799 (0.4%)	101781 (20.8%)	366074 (74.7%)	20597 (4.2%)
Total	6573 (0.9%)	162796 (22.5%)	513254 (71.0%)	40109 (5.5%)

Table 1: Crash Severity for Open and Rural Roads, 2000-2019.

We fitted a logistic generalised linear model to see whether certain types of crashes were likelier to happen on a holiday weekend (defined, in this case, as Saturday or Sunday occurring during either of the following: Christmas, New Year, Queen's Birthday, Labour Weekend or Easter) as compared to the non-special Saturday or Sunday.

The resulting posterior mean estimated odds ratios, accompanied by 95% credible intervals and Bayesian P-values, i.e., the posterior probabilities of the of the odds ratios being above 1, are shown in Table 2. Note, that if the 95% CI includes 1.0, there is no evidence that crashes of a particular type are more relatively prevalent during the holiday periods than the non-holiday ones.

The results show that the crashes on urban roads and crashes at night time (defined as 12am-6am) were significantly less prevalent on the holiday periods. On the other hand, crashes while driving under the influence (DUI) were,

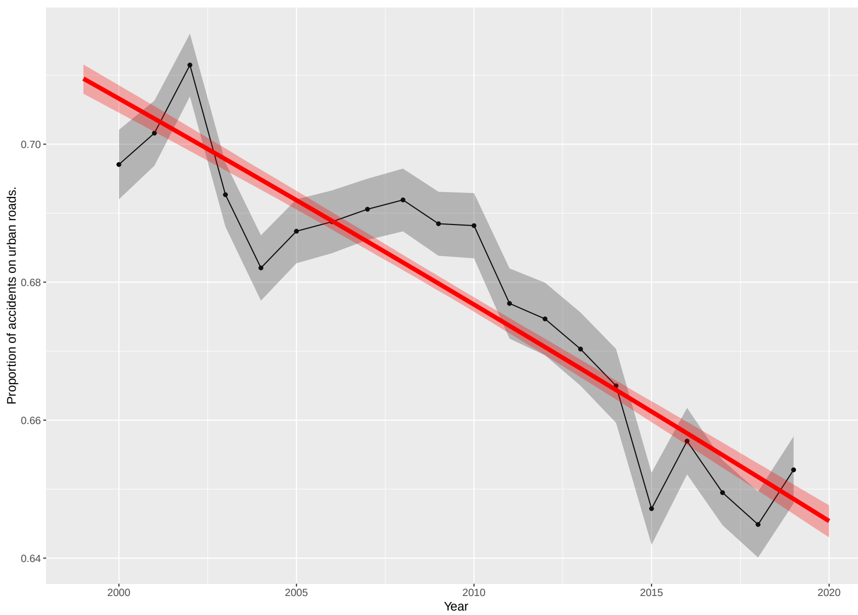

Figure 4: Proportion of accidents on urban roads out of the total. The gray ribbon corresponds to the year-specific estimates, while the red line illustrates the linear fit.

Factor	post. mean OR	95% CI	$Pr(OR > 1.0)$
Severity (Ref: No Unjury)			
Minor Crash	0.9817	(0.9427, 1.0262)	0.196
Serious Crash	0.9806	(0.9253, 1.0413)	0.235
Fatal Crash	1.1244	(0.9744, 1.3014)	0.938
Zone (Ref: Open Road)			
Urban Road	0.8551	(0.8244, 0.8862)	< 0.001
Time (Ref: 6am - 12pm)			
Night, 12am-6am	0.8181	(0.7721, 0.8586)	< 0.001
Afternoon, 12pm - 6pm	0.9583	(0.9157, 1.0035)	0.028
Late Evening, 6pm - 12am	1.0079	(0.9604, 1.0532)	0.635
DUI (Ref: No)			
Yes	1.0512	(1.0092, 1.0985)	0.995

Table 2: Comparison of crash factors during holidays and BAU weekends. Results of a Bayesian logistic regression model: posterior estimated odds ratios (ORs), 95% credible intervals and the posterior probabilities of the odds being greater than 1.

perhaps unsurprisingly, more prevalent during the holiday periods. The DUI accidents were defined as those where either alcohol or drugs were recorded as factors in the CAS data.

4.3 Small Scale Temporal Trends: Weekly Patterns.

We investigated the weekly dynamics in all and DUI accidents. An example for half-hourly counts over week for the year 2015 are shown in Figure 8 (for all accidents) and Figure 7 (for DUI).

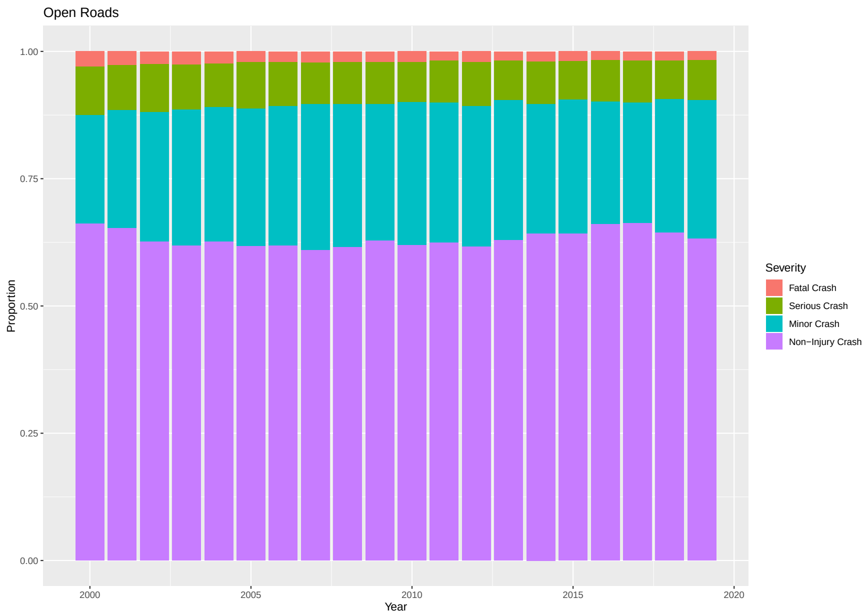

Figure 5: Annual Crash Severity Counts on the Open roads.

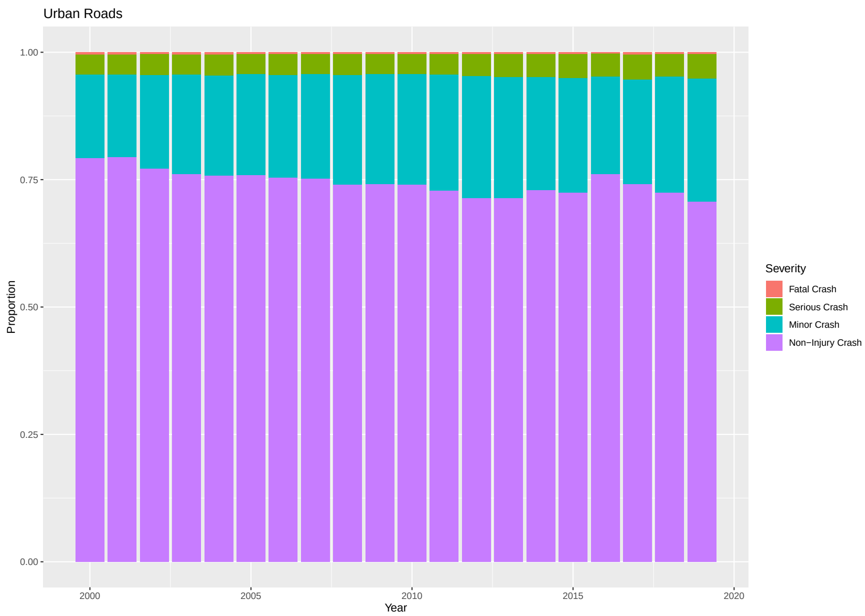

Figure 6: Annual Crash Severity Counts on the Urban roads.

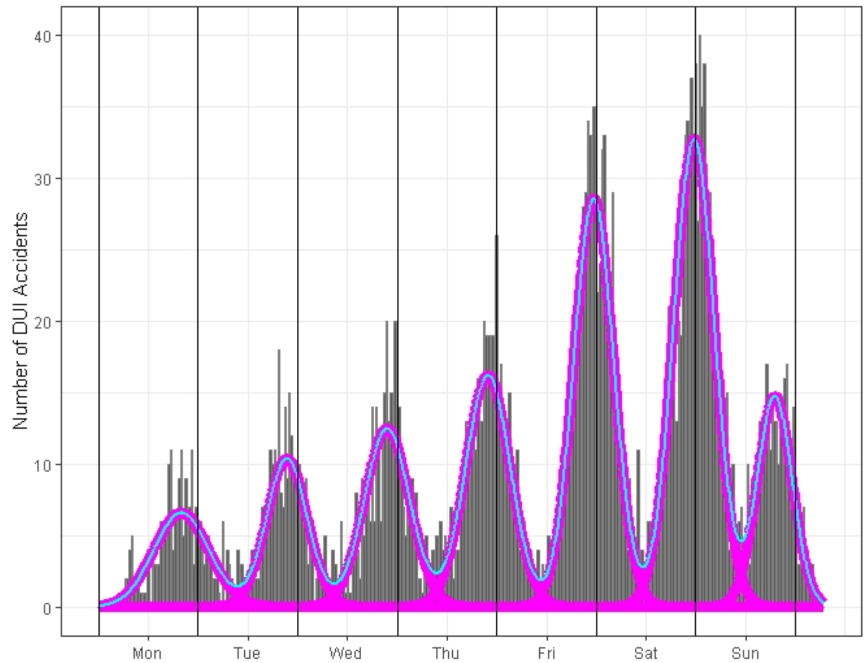

Figure 7: Weekly dynamics in DUI accidents, 2015. The gray histogram reflects the recorded counts. The magenta curves corresponds to individual normal components, whereas the blue curve is the resulting marginal distribution.

For consistency reasons, only non-holiday days were included. The gray histogram reflects the recorded counts. The magenta curves corresponds to individual normal components, whereas the blue curve is the resulting marginal distribution. The DUI counts exhibited seven clear peaks, corresponding to the nights. The probability mass associated with each peak was higher for the Friday and Saturday nights.

The dynamics for all the accidents was less clear-cut as is demonstrated for some spurious small individual components. However the fitted marginal distribution has two clear peaks for every weekday and one for Saturday and Sunday each.

The fitted marginal distributions for the weekly dynamics over the study period 2000-2019 is shown in Figures 10 for all accidents and 9 for the DUI accidents respectively. They show that the pattern appears to have remained the same for all accidents, but has shifted over years for the DUI.

The posterior probability distribution for the possible number of components is shown in Figures 9 for all and 10 for DUI accidents respectively. The most likely number of components for the DUI accidents was 7, although it has shifted to more in 2017-2019. The most likely number of components for all accidents

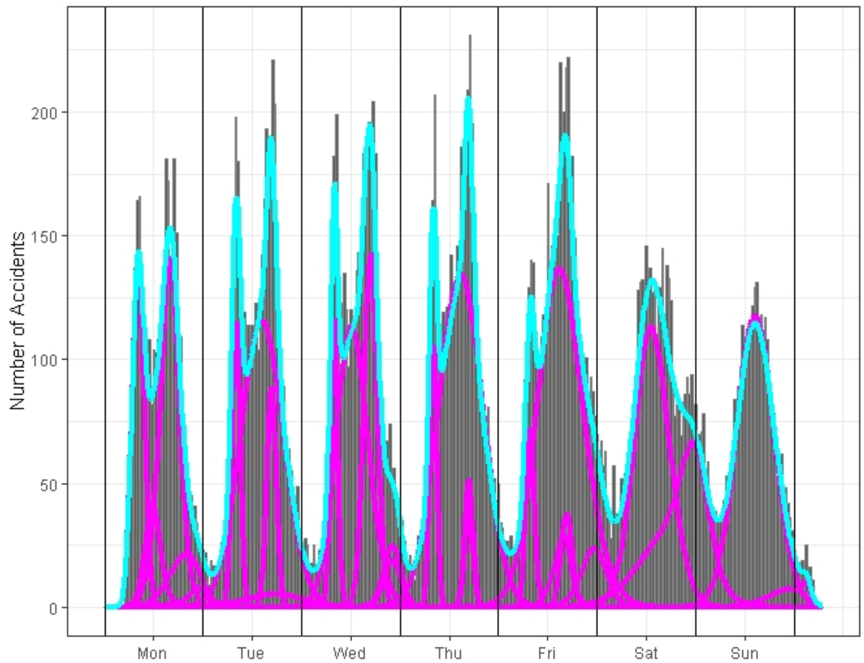

Figure 8: Weekly dynamics in all accidents, 2015. The gray histogram reflects the recorded counts. The magenta curves corresponds to individual normal components, whereas the blue curve is the resulting marginal distribution.

was 19, although there was a lot of variability.

5 Conclusion

The number of accidents during the holiday weekends was not consistently higher than that of BAU weekends, nor that of weekends before and after. This indicates that probability to die on the road during holiday periods was similar to that of other weekends in New Zealand. Further analysis indicates that there was no difference in the severity of the crashes either. The frequency of crashes on urban roads and during the night time were even decreased during the holiday periods. The only factor of concern is the increased number of accidents that involve intoxication during the holiday periods.

The total number of crashes on urban roads will naturally be higher than those on open roads due to the different population density. Still, the the proportion of accidents that occur on urban roads have decreased over time with an average of 1.4% per year. This is counter intuitive, since there is a general urbanisation trend. It is assumed that the number of people living

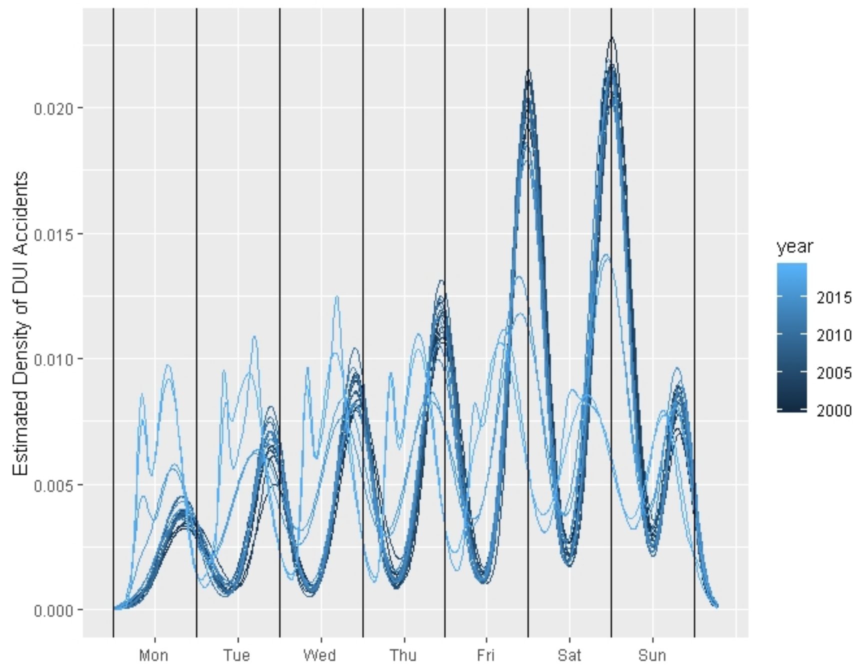

Figure 9: Fitted marginal distributions for the weekly dynamics in DUI accidents, 2000-2019.

in urban areas is slowly but steadily increasing (Grimes et al., 2016). Hence the proportion of accidents should follow this pattern. We are uncertain on why we observed the opposite trend. One possible explanation could be that people living in urban areas travel more on open roads. This could be caused by Auckland's housing market, which might force many to commute to work using the open road from the satellite cities surrounding Auckland.

Accidents on the open road tend to be substantially more serious compared to those on urban roads. This could be explained by the general corresponding speed limits, which are 50 km/h on urban roads and 100 km/h on open roads. Travelling at higher speeds almost automatically increase the accident severity due to the increase in kinetic energy and the decrease in available reaction times of the drivers.

When we have a more fine grained look at the distribution of accidents across weekdays for the exemplary year 2015 we notice that accidents that involve intoxication clearly increases during Friday and Saturday nights. This pattern is to be expected due to the recreational behaviour patterns of New Zealanders. When expanding the analysis to all accidents, we notice a clear commuter peak at around 9am and 5pm during weekdays which confirms earlier work by Kingham et al. (2011). The number of accidents during the weekends

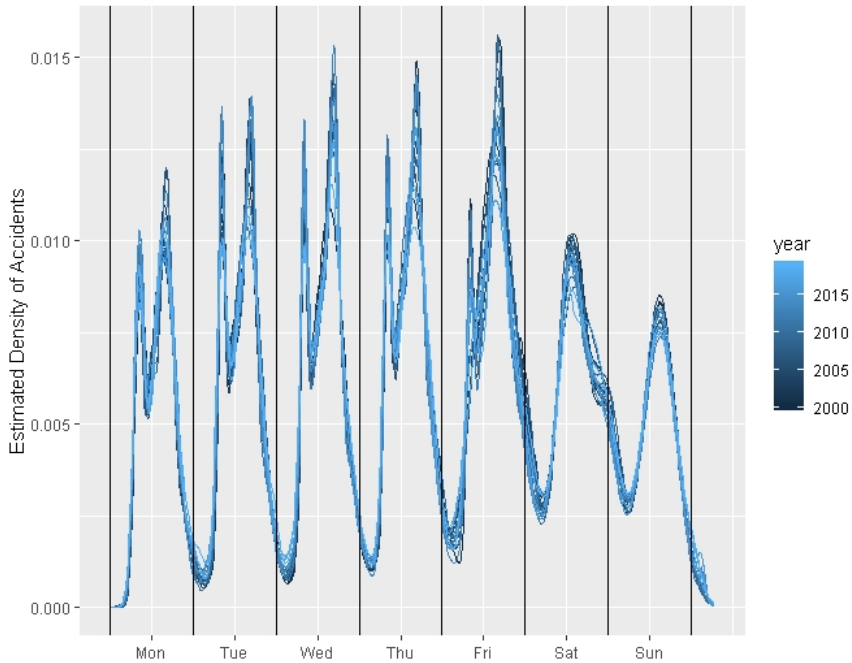

Figure 10: Fitted marginal distributions for the weekly dynamics in all accidents, 2000-2019.

is usually lower than that during the week, although the accidents are shifted to the later hours of the day. This is likely a direct result of the absence of commuting traffic. Still, a small extra peak is visible during Saturday night even when considering all accidents, which is likely due to recreational activities.

When considering all the years we notice that accidents that involve driving under the influence has in recent years become less focused on the weekends. More accidents involving an intoxicated driver are now taking places even during Mondays to Wednesday and they have shifted slightly from night time events due to a pattern that more resembles all accidents. This could hint at that more intoxicated driving is taking place during normal working hours. We have no information available as to what exact drug has been involved.

6 Limitations and future work

The CAS data is an extremely rich data source and number of potential relationships between the factors recorded are very high. A complete analysis for all the factors is not only very labour intensive, but also impractical for just one research publication. Books could be published about the possible statistical analyses. We had no choice but to focus on a few research questions that we considered important while acknowledging that the data and analysis presented is certainly incomplete.

We have no access to vehicle kilometer driven on a per day basis and hence we could not calculate traffic densities for the holiday periods or BAU weekends. We can therefore only establish a relationship between the accidents and amount of road traffic on an annual basis.

It could be argued that due to the holidays less people commute and hence the traffic and the associated accidents might have decreased. One could also argue that many New Zealanders take the opportunity of having a holiday to travel around the country and thereby increase the potential for accidents. These two factors could even cancel each other out. The road safety during the holiday periods could also be influenced by the safe roads publicity campaigns. Again, we can only speculate about the relationships between these factors.

This study did not consider the changes to the transportation law, such as the lowering of the legal limit of alcohol for driving in 2014. We can also not take into account any changes in the policing policies, such as potentially more routine intoxication checks or the availability of easy to use on the spot test for a variety of drugs. We can therefore not exclude the possibility that the temporal changes observed in Figure 9 are based on these changes.

For future work we would like to consider the influence of the weather on accidents. Many open roads in New Zealand are highly exposed to the harsh weather conditions and some holiday periods might be more affected by them than others. Furthermore, it would be interesting to investigate the relationship between risk taking behaviour, such as speeding and intoxication, and the age of the drivers. Along the same lines it would be worthwhile to consider the relationship between the intoxication and the crash severity.

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