The effects of Random Breath Testing and lowering the minimum legal drinking age on traffic fatalities in Australian states

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ABSTRACT. Objective: This study aims to apply time series analysis techniques to examine the effects of RBT on three age-specific traffic fatalities in four Australian states while considering the effects of lowering the minimum legal drinking age (MLDA).

Methods: Long-term time series of age-specific traffic accident deaths in four Australian states were used to analyse the impact of RBT implementation while considering the population growth, increase in motor vehicle registrations and the effects of lowering the MLDA. Results: The results of intervention analysis indicate that RBT has substantially reduced traffic fatalities in all four states since it was introduced, particularly among 17-20 and 21-30 year olds. New South Wales received the biggest total net effect from RBT implementation on traffic deaths. In contrast, RBT produced only a modest reduction in traffic fatalities among 30-39 year olds. Lowering the MLDA was associated with significant increases in traffic fatalities among 17-39-year olds in Queensland and Western Australia.

Conclusions: Controlling for the declining trend in traffic fatalities, the effects of changes in the MLDA law, the implementation of RBT has generated a huge effect, preventing an estimated 5279 traffic accident deaths in four Australian states. This provides further evidence that the implementation of RBT and increases in the MLDA are effective policies for reducing traffic fatalities.

Key words: Random Breath Testing, traffic fatalities, minimum legal drinking age, time series
INTRODUCTION

Random Breath Testing (RBT) is a widely used drink-driving countermeasure in many countries and is particularly common in Australia.\textsuperscript{1,2} In Australia, RBT was implemented at the state level. Following Victoria (VIC) in 1976, RBT was implemented in New South Wales (NSW) in December 1982; Western Australia (WA) in October 1988 and Queensland (QLD) in December 1988.\textsuperscript{3} An early study evaluated the effects of the introduction of the RBT program in NSW, and found that RBT caused an immediate 90% decline in road deaths and reduced fatal road crashes by 48% during the first year, and further reduced all fatal accidents by 22% and alcohol-related accidents by 36% over a ten year period.\textsuperscript{2} A meta-analysis on the effects of drink driving checkpoints was conducted by Erke et al.,\textsuperscript{4} the authors found that drink-driving check points (including RBT) significantly reduced the number of vehicle crashes by a minimum of 17%. Similar prevention results were found in many other countries, such as, Netherland, Finland, Ireland, Canada, US, New Zealand.\textsuperscript{5}

Changes to the minimum legal drinking age (MLDA) are also considered a key policy measure that can reduce traffic accidents and related mortality among young people. The raising of the MLDA from 18-21 in the U.S. led to statistically significant reductions in per capita traffic death rates.\textsuperscript{6,7} Toomey and Wagnaar \textsuperscript{8} reviewed more than 200 empirical analyses of the MLDA and concluded that 58% of reviewed studies reported a higher MLDA related to decreased traffic accidents. For example, reducing the minimum drinking age in Massachusetts lead a 40% increase in traffic accident rates among 18-20 year olds while no significant prevention impact were found among 21-23 and over 23 age groups.\textsuperscript{9} In contrast, a survey of drinking and drinking problems among high school students found that there was only minimal effect for the changes in the legal drinking age in Ontario.\textsuperscript{10} The Australian
state governments in QLD and WA lowered the minimum legal drinking age from 21 to 18 in October 1970 and in December 1974 respectively, while New South Wales has had an 18 year drinking age since 1905, and Victoria since 1906. Lowering the MLDA to 18 years significantly increased male juvenile crime in QLD and WA."11

Although a number of studies on the effects of RBT have been conducted in many countries, few have used a long-term time series analysis, especially in different age groups, while the effects of changes in the MLDA on traffic accidents in Australia has not been studied. Furthermore, the combined long-term effects of RBT and lowering the MLDA among age-specific traffic accidents have never been explored. The existing key Australian analyses used time-series methods based on daily data to estimate the impact of RBT in NSW, WA and QLD, estimating a total reduction of 2,583 fatal accidents over a ten year period (1982-1992).3 We extend this work by examining a longer time-series (albeit based on annual data for 60 years) and by using age-specific mortality data to ascertain how the effects of RBT were distributed across three different age groups in four Australian states, while considering the concurrent effects of the changes in the MLDA laws in two states.

This study is limited to four Australian states, namely, NSW, VIC, QLD and WA due to data availability and focuses on three specific research questions:

1. What were the long-term effects of the introduction of RBT on traffic fatalities in four Australia states?
2. How did the effects of RBT vary across three different age groups among 17-39-year olds?
3. How did the lowering of MLDA affect traffic fatalities in QLD and WA?
METHODS

Data

Data on age-specific state-level traffic accident deaths were obtained from Department of Motor Transport, Australian Bureau of Statistics (ABS) and the Australian Road Death Database for each year from 1951 to 2010. These resources report annual traffic accident fatalities (deaths stemming from crashes on public roads, where the death occurs within 30 days of the traffic accident) with three categories, including deaths of driver, passenger and pedestrian, all of which are included in our measure. As we were focussed on the combined effects of RBT and MLDA, we limited the study to three younger age groups: 17-20 year olds, 21-29 year olds and 30-39 year olds. Prior to 1989, data on age-specific traffic fatalities were compiled from Department of Motor Transport and Commonwealth Bureau of Census and Statistics (changed name to ABS in 1973). For the years from 1989 onwards, data were available in the Australian Road Deaths Database. All data are annual – monthly data was not available for the period under analysis. Due to vagaries in reporting standards between states and over time, pre-1989 traffic fatality data were not available for consistently defined age groups. In particular, estimates for fatalities among 17-20 year olds in WA (between 1951 and 1959), NSW (between 1951 and 1952) and VIC (between 1951 and 1954) and QLD (1951-1985) were not available and had to be derived by estimating proportionally from other age groups. For example, the Queensland data generally provided deaths for 15-19 year olds and for 20-24 year olds. Using years where more detailed breakdowns were available, we estimated the proportion of 15-19 year old deaths likely to involve 17-19 year olds and the proportion of 20-24 year old deaths involving 20 year olds to produce an estimate for 17-20 year old deaths, which allowed for a longer time period estimation and consistent analyses with the remaining states. Aside from Queensland, these estimates were
only required in the years preceding the policy interventions studied. Without the impetus of policy changes, it is unlikely that the proportion of, for example, 15-19 year olds killed in traffic accidents who were aged 17-19 would change substantially.

The annual age specific state population data from 2007 to 2010 were taken from the ABS and from Australian Institute of Health and Welfare before 2007 and included in the models to control for the effects of population growth on traffic fatalities. Additionally, the state-level annual motor vehicle registration data were collected from ABS and to control for motor vehicle growth over the period 1951-2010.

**ARIMA model with dummy variables**

The autoregressive moving average model (ARIMA) with intervention dummy variables (see Appendix) was employed to analyse the long-term effect of RBT and lowering MLDA on traffic accidents. This approach includes moving average (MA) or autoregressive (AR) terms in the statistical model and enables modelling of any systematic impact of measurement errors and factors not included in the model on the independent variable.\(^{18}\) The one-off event dummy variables have been widely applied in many studies to analyse the effect of seasonality, major changes in policy and financial crises.\(^{19-21}\) The prior condition for time series analysis is that all the series be stationary, with time trends removed to reduce the risk of obtaining a spurious estimation.\(^{22}\) In most cases, a differencing of the time series is sufficient to eliminate non-stationarity.\(^{23}\) The Augmented Dickey-Fuller (ADF) unit root test, developed by Dickey and Fuller \(^{24}\) was employed to test stationarity for the time series.

The development of RBT and MLDA dummy variables for estimating traffic fatalities in the four states is presented in Figure 1. The implementation of RBT in NSW was on December 1982; VIC (July 1976); QLD (December 1988) and WA (October 1988). Thus, the
intervention period of RBT on these four states can be defined as 1982-2010 in NSW; 1976-2010 in VIC; 1988-2010 in QLD and 1989-2010 in WA. The coding of the event dummy for the MLDA is different than that used for RBT, as the MLDA were higher in QLD and WA before 1970s, thus we assume that there was a controlling effects in the period of a higher MLDA as 1951-1970 July in WA and 1951- October 1974 in QLD while a lower MLDA after 1970s were expected to boost the consumption of alcohol and alcohol-related traffic fatalities. Therefore the MLDA dummy variable started at 1 between 1951 and 1970s (the prevention event-on) and then changed from 1 to 0 when the MLDA reduced (the prevention event-off) in 1970s. In order to better estimate the effects of RBT and lowering the MLDA, we code the intervention dummies start from the effective month of event, for example, with RBT introduced in July, 1976 in VIC, we code the intervention dummy as 0 before 1976, 0.5 in 1976 and 1 after 1976.

<Insert Figure 1 here>

The MLDA was only changed in QLD and WA between 1951 and 2010. Therefore, only the models estimating the effects of RBT and on fatal traffic accidents in QLD and WA considered the effects of lowering the MLDA. The paper basically tests three things: 1) the impact of the introduction of RBT laws in four states, 2) the impact of a lowering of the drinking age in 2 states, and 3) the combined impacts of RBT and the lowering of the MLDA in the 2 states over the study period. The robustness of the models derived in this study were checked via the serial correlation Lagrange multiplier (LM) test of 12 lags, Jarque-Bera test for normality of residuals and Box-Ljung test of the first 10 autocorrelations.

The established models were further used to predict numbers of fatal traffic accidents and compared with actual values for analysing the effects of introduction of RBT while considering the concurrent effects of changes in MLDA. The dynamic prediction technique
was employed to predict number of fatal traffic accidents based on the assumption that no RBT programs were introduced in these states.

RESULTS

Trends in traffic accident fatalities in Australian four states for the 60-year-period are shown in Figure 2. Figure 2 shows that the traffic accident fatalities increased from 1951 to the 1970s, then decreased steadily after the introduction of RBT in NSW and VIC, particularly among the 17-20 and 21-29 age groups. It also can be observed that since the MLDA was lowered in QLD and WA, the number of traffic accident deaths per year increased in WA while generally remaining stable in QLD during the 1970s and 1980s. However, the number of traffic accident deaths per year decreased in these two states after the introduction of RBT among both the 17-20 and 21-29 year age groups.

The stationarity of the selected variables were tested and the results suggest that all of the time series were stationary after first differencing $I(1)$, $(p<0.05)$. The effects of RBT on age-specific fatal traffic accidents across different states were estimated using ARIMA models with dummy variables and the estimates are summarised in Table 1. The estimates suggest that the introduction of RBT was associated with significant reductions in fatal traffic accidents among all three age groups in these four states. Comparing the independent effects of introduction of RBT in the four states, the largest effects were found in NSW for all three age groups with -8.7, -13.4 and -4.3 deaths per year respectively, while the smallest reduction effects were found in WA for all three age groups. The estimates also suggest that, 21-29-
year olds received greater prevention effects from the implementation of RBT programs, particularly in NSW and VIC with effect sizes of -13.4 and -9.4 deaths per year.

<Insert Table 1 here>

The following analyses focus on QLD and WA, the two states where the MLDA changed. The independent effects of RBT for these two states were provided previously (Table 1) and will not be repeated here. Table 2 summarizes the results of estimation of the effects of changes in MLDA combined with the effects of RBT implementation in QLD and WA. The results suggest that the policy of lowering the MLDA generally increased fatal traffic accident deaths not only in 17-20-year group, but also among 21-39 year-olds in QLD and WA. When the MLDA changes and the introduction of RBT were included in the same models, the effects of the introduction of RBT and changes in the MLDA were both significant while the impacts of changes in drinking age were broadly similar to those found in the initial models. Nevertheless, the coefficient values of MLDA in the models incorporating the introduction of RBT and changes in the MLDA law were all smaller than the coefficients in the original models (i.e. from 7.000 to 6.189 among 17-19-year olds in QLD). These reductions in degree of the effects suggest that the positive effects of lowering the MLDA on traffic accident deaths were reduced by the implementation of RBT in these two states. The model specification for each ARIMA model is reported in the tables and model fit was evaluated by Box-Ljung portmanteau test for uncorrelated residuals in each model (at 10 lag).

<Insert Table 2 here>

The overall net effects of the introduction of RBT on fatal traffic accidents in the four states are summarized in Table 3. The total net effects of RBT on traffic fatalities in NSW
were 38%, 24% and 18% for 17-20, 21-29 and 30-39 year olds from December, 1982 to 2010. The effects of RBT in Victoria were 33% and 19% reductions in fatalities for 17-20 and 21-29 year olds respectively with much smaller effects for the 30-39 year olds with 6% between July, 1976 and 2010. The estimated effects in QLD and WA suggest that the implementation of RBT was effective for all age groups, with 588 lives saved in QLD and 317 in WA between 1988 and 2010. The effects of RBT on traffic accident deaths in these two states were stronger among 21-29 year olds, with smaller and inconsistent effects found in the younger and older age groups. Overall, the introduction of RBT program has reduced an estimated 5279 traffic fatalities in four Australian states since 1976.

<Insert Table 3 here>

DISCUSSION

This study has presented a time series analysis of the effect of the introduction of RBT on traffic fatalities in four Australian states controlling for population, road use and the effects of lowering the MLDA. The results suggest that the implementation of RBT has produced a substantial prevention effect on traffic fatalities in Australia. In NSW, VIC, QLD and WA, the impacts of RBT on traffic accident death were 26%, 20%, 13% and 13% respectively among 17-39 year olds. There was clear evidence from across the four states that RBT had a greater impact on younger drivers, with the 30-39 year old age group having only modest mortality reductions due to RBT.

The implementation of RBT program has been shown to be an effective means to control drink driving behaviour and reduce traffic accidents in many countries. It not only detects drivers under the influence of alcohol, but more importantly provides a deterrent effect
among potential offenders. This study produced similar aggregate results to some previous analyses, e.g. Henstridge et al.,\textsuperscript{3} while providing the first clear evidence of the age distribution of the effects of the introduction of RBT. Our findings suggest that the younger age group received higher prevention effects from the introduction of RBT in Australia. This makes intuitive sense, as young people are more likely to experiment with heavy and binge drinking, and put themselves at a higher risk for involvement in traffic crashes than older drivers.\textsuperscript{26 27} Furthermore, the prevention effects of introduction of RBT varied across different state and time, which may be related to variations in enforcement and public education related to RBT, to variations in the specific constraints applied to young drivers and to the broader impact of alcohol policies (e.g. liquor licensing and MLDA laws).

The effects of changes in the MLDA law in the US were widely discussed in previous studies, with consistent findings that raising the minimum legal drinking age can help to reduce alcohol-related traffic crashes.\textsuperscript{28-30} In this study, the effects of lowering the MLDA in QLD and WA on traffic accident deaths were consistent with previous work, while finding further effects among older drivers. These findings suggest that increasing the MLDA may reduce traffic fatalities not only among 17-20 year olds, but also among older drivers. The mechanism for the effect is unclear – changes to the drinking age may result in increased alcohol consumption across age ranges as alcohol consumption becomes increasingly normalised. Future research is required to replicate these effects.

It is worth noting that the positive effects of lowering the MLDA on the traffic accident mortality in QLD and WA were reduced by the implementation of the RBT. But the absolute coefficients of effects of lowering the MLDA are much greater than the introduction of RBT, which may suggest that raising the MLDA would generate large prevention effects on traffic accidents. Furthermore, the variation in estimated effects seen over time in QLD and WA is in part due to the smaller numbers being modelled, but may also relate to variations in both
enforcement and public campaigns raising awareness of RBT, both of which have been shown to be important in maintaining RBT effectiveness.\(^3\)

Due to data limitations, this study has not specifically estimated the impact of the amount of actual RBT enforcement on traffic mortality, a key factor in some earlier analyses\(^3\) or the impact of changes in state aggregate alcohol consumption. It is possible that the effects presented here overestimate the impact of RBT by not considering a range of other polices (e.g. compulsory seatbelt laws) that may have reduced road deaths. There is also some uncertainty about the estimated effects of RBT on 17-20-year-olds traffic accident deaths in QLD, as the traffic fatalities data were compiled from both 15-19 and 20-24 age groups between 1951 and 1985. There were similar issues (for much shorter periods) for other states as well, raising concerns about the precision of the age specific estimates presented here. Importantly, these limitations existed only in pre-intervention periods for all states, so the impact on our findings is likely to be small. In spite of these limitations, our study adds to the robust international literature showing that the implementation of RBT greatly reduces traffic fatalities.
What is already know on the subject

- Few studies have analysed the effects of Random Breath Testing (RBT) on traffic fatalities using long-term time series data, especially in different age groups.
- The effects of changes in the minimum legal drinking age (MLDA) on the traffic fatalities also have been rarely discussed.
- None of previous studies have evaluated the concurrent effects of the changes in the MLDA laws and the introduction of RBT.

What this study adds

- This is the first time-series study that examines the concurrent effects of RBT and lowering the MLDA on age-specific traffic fatalities in Australia.
- The study provides clear evidence that the implementation of RBT has produced a substantial prevention effect on traffic fatalities in Australia.
- Lowering the MLDA has generated significant positive impacts on traffic fatalities in two Australia states.
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Competing Interests: None

Contributorship: All authors have contributed significantly to the preparation of this manuscript, including data collection, study design, data analysis and interpretation, and manuscript drafting.

Data Sharing: The data from this study reside within the Centre for Alcohol Policy Research, Turning Point. The investigators have access to the data.

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REFERENCES


2. Homel, R., Random breath testing in Australia: getting it to work according to specifications. *Addiction*, 1993; 88:27S-33S.


29. Kypri, K., Voas, R.B., Langley, J.D., Stephenson, S.C.R., Begg, D.J., Tippetts, A.S., and Davie, G.S., Minimum purchasing age for alcohol and traffic crash injuries

Figures were attached as image

**Figure 1** The construction of RBT and MLDA dummy variables in four states

**Figure 2** The trend of fatal traffic accidents in four states from 1950 to 2010 (the vertical line and dot line highlight the lowing MLDA and the introduction of RBT in four states)
Table 1 Estimation of the effects of RBT on fatal traffic accidents #

<table>
<thead>
<tr>
<th>Age Group</th>
<th>State</th>
<th>Coef.</th>
<th>95% CIs</th>
<th>ARIMA term</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-20 years</td>
<td>NSW</td>
<td>-8.698**</td>
<td>[-13.465, -3.931]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>VIC</td>
<td>-7.163**</td>
<td>[-2.604, 2.333]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>QLD</td>
<td>-4.691**</td>
<td>[-9.332, -0.050]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>WA</td>
<td>-1.571(*)</td>
<td>[-4.072, 0.930]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td>21-29 years</td>
<td>NSW</td>
<td>-13.400**</td>
<td>[-21.036, -5.764]</td>
<td>(0,1,1)</td>
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<tr>
<td></td>
<td>VIC</td>
<td>-9.353**</td>
<td>[-14.228, -4.478]</td>
<td>(0,1,1)</td>
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<tr>
<td></td>
<td>QLD</td>
<td>-4.265(*)</td>
<td>[-9.424, 0.894]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>WA</td>
<td>-1.619(*)</td>
<td>[-5.108, 1.870]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td>30-39 years</td>
<td>NSW</td>
<td>-4.268**</td>
<td>[-5.044, -3.492]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>VIC</td>
<td>-2.761(*)</td>
<td>[-6.205, 0.683]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>QLD</td>
<td>-2.284**</td>
<td>[-3.372, -1.196]</td>
<td>(0,1,1)</td>
</tr>
<tr>
<td></td>
<td>WA</td>
<td>-1.206(*)</td>
<td>[-2.553, 0.141]</td>
<td>(0,1,1)</td>
</tr>
</tbody>
</table>

Note: (*) = p<0.1; * = p<0.05; ** = p<0.01. # Box-Ljung test for residual autocorrelation, Lagrange Multiplier test for serial correlation and Jarque-Bera test for normality of residual were all satisfactory in all models.
Table 2 Estimation of changes in drinking age law and RBT on fatal traffic accidents in QLD and WA #

<table>
<thead>
<tr>
<th></th>
<th>QLD</th>
<th>WA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>95% CIs</td>
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<td>Effects of changes in MLDA</td>
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<td></td>
</tr>
<tr>
<td>17-20 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLDA</td>
<td>7.000**</td>
<td>[3.468, 10.532]</td>
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<td>21-29 years</td>
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<td></td>
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<tr>
<td>MLDA</td>
<td>4.195*</td>
<td>[0.237, 8.117]</td>
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<tr>
<td>30-39 years</td>
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<tr>
<td>MLDA</td>
<td>1.584**</td>
<td>[1.074, 2.094]</td>
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<tr>
<td>Combined effects of RBT implementation and changes in MLDA</td>
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<tr>
<td>17-20 years</td>
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<td></td>
</tr>
<tr>
<td>RBT</td>
<td>-2.539(*)</td>
<td>[-6.200, 1.122]</td>
</tr>
<tr>
<td>MLDA</td>
<td>6.189**</td>
<td>[2.494, 9.884]</td>
</tr>
<tr>
<td>21-29 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RBT</td>
<td>-3.360(*)</td>
<td>[-8.144, 1.424]</td>
</tr>
<tr>
<td>MLDA</td>
<td>3.645(*)</td>
<td>[-0.130, 7.420]</td>
</tr>
<tr>
<td>30-39 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RBT</td>
<td>-0.584(*)</td>
<td>[-1.911, 0.743]</td>
</tr>
<tr>
<td>MLDA</td>
<td>1.328**</td>
<td>[0.550, 2.106]</td>
</tr>
</tbody>
</table>

Note: (*) = p<0.1; * = p<0.05; ** = p<0.01. # Box-Ljung test for residual autocorrelation, Lagrange Multiplier test for serial correlation and Jarque-Bera test for normality of residual were all satisfactory in all models.
Table 3 Summarized the net effects of RBT on fatal traffic accidents in Australian four states from 1970s to 2010

<table>
<thead>
<tr>
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<th>Number of traffic accident death reduced</th>
<th>Percentage of traffic accident death reduced</th>
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<tr>
<td></td>
<td>17-20 years</td>
<td>21-29 years</td>
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<tr>
<td>NSW</td>
<td>1055</td>
<td>966</td>
</tr>
<tr>
<td>VIC</td>
<td>957</td>
<td>795</td>
</tr>
<tr>
<td>QLD</td>
<td>192</td>
<td>348</td>
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<tr>
<td>WA</td>
<td>96</td>
<td>207</td>
</tr>
<tr>
<td>Overall</td>
<td>2430</td>
<td>2316</td>
</tr>
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</table>
Appendix

An Autoregressive Integrated Moving Average model (ARIMA, known as Box and Jenkins (1970) Approach) with dummy variables can be written as follow:

\[ \Delta Y_t = \alpha + \beta \Delta Y_{t-1} + \mu \Delta C_{i,t} + \sum_{j}^{n} \gamma_j D_{j,t} + \delta \Delta E_{t-1} \]

where \( \Delta \) is the differencing operator, \( Y_t \) represents the dependent variable at time \( t \) (three age-specific traffic accident death in four states), \( \alpha \) is constant (which marks average annual changes due to other causes), \( \beta \) is the coefficient value of AR(1) term, \( \delta \) is the coefficient value of the MA(1) term (\( \Delta E_{t-1} \)), \( C_{i,t} \) are the control variables considered in the estimation, \( i \) is number of control variables, \( \mu \) is the coefficient values of the control variables. \( D_{j,t} \) is the one-off event dummy variable \( j \) at time \( t \), \( n \) is the number of dummy variables and \( \gamma_j \) is the estimates of the effect of the events or interventions.