Investigating the Possibilities of Specific Crash Type at Roundabouts

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Abstract: A comprehensive analysis of road crashes is extremely supportive in identifying existing deficiencies and in proposing new design strategies. There are several research studies carried out for improving safety at roundabouts with the aim to altering conflict types, reducing the drivers’ speeds and crash severity, and highlighting a considerable differences in the safety performance of individual or group of roundabouts. The main purpose in this study was to explain the correlation between the types of crashes to the geometry of the roundabouts based on data collected from ten top poorly performing roundabouts in Toowoomba, Australia. Preliminary analysis revealed the following as top three types as prominent at these identified roundabouts such as angle crashes (74%), hit-object crashes (13%), and Rear-end crashes (9%). Excess proportion of specific crash method has been used as methodological tool to estimate the potential possibilities for a specific crash type exceeding threshold at each roundabout. Results show that eight out of ten roundabouts were regarded for a particular type of crash but only two roundabouts were viewed for two types of crashes such as angle and hit-object.

Key words: Road crash, roundabout, Toowoomba, crash types.

1. Introduction

Roundabouts are associated with a favourable influence on traffic safety. Converting junctions to roundabouts in rural areas or law traffic conditions continue to be commonly applied strategy in many places to improve safety. Still at roundabouts road crashes occur because of various factors including the driver, vehicle, roadway and environment. There are several road safety researches conducted with the aim to: estimate the effects of roundabout geometric features [1-5], identify the potential locations for safety improvement [6-11], improve the vehicular operation [12-14], account the driver behaviour [15, 16], and examine the before-and after scenarios [17-19]. Modifying geometric feature of the roundabouts has been found to reduce the number of crashes, in particular these treatments can be design to support a particular type of potential crashes. However results from appropriate analysis need to support the redesign of the element at roundabouts, thus an in-depth analysis on road crashes at roundabouts is extremely supportive in identifying existing deficiencies and in proposing new the design strategies. The aim of this study was to examine the possibilities for potential road safety concern connected to a set of specific types of crashes at various roundabouts.

2. Preliminary Data Analysis

The preliminary data analysis was conducted for a five-year period of crash data at all of the roundabouts in Toowoomba with the aim of identifying the severity of roundabout crashes throughout Toowoomba. Fig. 1 presents the overall crash severity frequency and distribution for the five severity categories at all of the roundabouts in Toowoomba. As can be seen in Fig, there is only one fatality in the five-year period. This is supported by the literature as roundabouts are one of the best intersection types for reducing the severity of crashes. The most common severity level seen at Toowoomba roundabouts is ‘property damage only’
with 52% of crashes falling into this category.

The frequency of crash types that the majority of crashes in Toowoomba are multiple vehicle crashes (85%), was followed by single vehicle crashes (15%) and very few hit pedestrian crashes. Analysis of road user frequency and distribution involved in crashes at roundabouts in Toowoomba shows that cars are the most common road user involved in road crashes at roundabouts in Toowoomba. Bicycles and motorcycles are the next most common road user involved in road crashes with each of these road users representing approximately 5% of crashes. Trucks are involved in approximately 4% of crashes and the remaining road users: bus, pedestrian and other account for less than 1% of road crashes at roundabouts in Toowoomba.

Crash nature is determined by the initial event in any sequence of events in a road traffic crash. Subsequent events have no bearing on the determination of the crash nature. The crash nature categories defined by Department of Transport and Main Roads (DTMR), Queensland in 2014 are: angle, rear-end, hit fixed obstruction or temporary object, sideswipe, hit parked vehicle, overturned, fall from moving vehicle, motorcycle, moped or bicycle overturn, fall or drop, head-on, hit pedestrian, hit animal including ridden horse or carriage, struck by external load, Struck by internal load, collision – miscellaneous, and non-collision – miscellaneous. A crash type is a logical category into which one or more similar crash natures are classified. Crash type is determined by the initial event in any sequence of events in a road traffic crash [9, 20].

The frequency and distribution of crash nature at roundabouts in Toowoomba are presented in Fig. 2. It is clear that the majority of road crashes (74%) are ‘angle’ crashes which is supported by literature as the main type of road crash at roundabouts. The other two crash types that have any significant number include ‘hit object’ and ‘rear-end’ which are 12.6% and 8.9% respectively. All of the other crash types contribute less than 5% combined.

During the coding of information from the crash report form, each crash is given a code (usually known as a DCA code in Australia and a Vehicle Movement Code, or VMC, in New Zealand) indicating the movements the involved road users were making when the crash occurred.
3. Methodical Tool

The excess proportion of specific crash type method uses the proportion of a particular type of crash at each intersection compared with a threshold proportion to determine which intersections exceed the threshold proportion to identify where a specific type of crash is overrepresented (AASHTO 2010a). This method first establishes a threshold of expected performance for a site, considers variations in crash data, and allows sites of all types ranked in one form. This method was used on the identified top 10 worst performing roundabouts to determine if any of these roundabouts had an excess proportion of a particular crash type (target crash type) in comparison to the other roundabouts. This was done for the three most common crash types at roundabouts in Toowoomba, angle, hit object and rear-end. The method for calculating the excess proportion is outlined below.

The observed proportion of the target collision type was calculated using Eq. (1):

\[ p_i = \frac{N_{\text{observed},i}}{N_{\text{observed},i(\text{total})}} \]

where: \( p_i \) = observed proportion at site \( i \), \( N_{\text{observed},i} \) = number of observed target crashes at site \( i \), and \( N_{\text{observed},i(\text{total})} \) = total number of crashes at site \( i \).

A threshold proportion of the target collision type under investigation was calculated using Eq. (2):

\[ p_i^* = \frac{\sum N_{\text{observed},i}}{\sum N_{\text{observed},i(\text{total})}} \]

where: \( p_i^* \) = Threshold proportion, \( \sum N_{\text{observed},i} \) = Sum of observed target crash frequency within population, and \( \sum N_{\text{observed},i(\text{total})} \) = Sum of total observed crash frequency within population.

The sample variance (\( \text{Var}(N) \)) was calculated for each reference population using Eq. (3):

\[
\text{Var}(N) = \left( \frac{1}{n_{\text{sites}} - 1} \right) \left\{ \sum_{i=1}^{n} \left( \frac{(N_{\text{observed},i})^2 - N_{\text{observed},i}}{(N_{\text{observed},i(\text{total})})^2 - N_{\text{observed},i(\text{total})}} \right) \right\}
\]

\[ - \left( \frac{1}{n_{\text{sites}}} \right) \times \left( \sum_{i=1}^{n} \frac{N_{\text{observed},i}}{N_{\text{observed},i(\text{total})}} \right)^2 \]

for \( N_{\text{observed},i(\text{total})} \geq 2 \), where: \( n_{\text{sites}} \) = total number of sites analysed; \( N_{\text{observed},i} \) = observed target crashes for a site \( i \); and \( N_{\text{observed},i(\text{total})} \) = total number of crashes for a site \( i \).

The sample mean proportion of target crash types (\( \bar{p}_i^* \)) was calculated using Eq. (4):

\[ \bar{p}_i^* = \frac{\sum p_i}{n_{\text{sites}}} , N_{\text{observed},i} \geq 2 \]
where: \( n_{\text{sites}} = \) total number of sites analysed; and \( p_i \) = Observed proportion.

The Alpha (\( \alpha \)) and Beta (\( \beta \)) parameters for each reference population were calculated using Eqs. (5) and (6) from the Highway Safety Manual (AASHTO 2010a).

\[
\alpha = \frac{\left(\frac{\bar{p}^2 - \bar{p}^3}{\text{Var}(N)} - s^2 \bar{p}^2\right)}{\text{Var}(N)} \tag{5}
\]

\[
\beta = \frac{\alpha}{\bar{p}^3} - \alpha \tag{6}
\]

where: \( \text{Var}(N) \) = variance (equivalent to the square of the standard deviation, \( s^2 \)), and \( \bar{p}^* \) = Mean proportion of target crash types.

Finally, the probability for the particular crash type at each intersection was calculated using Eq. (7). This equation required the use of a beta distribution function such as that in Microsoft Excel.

\[
p\left(\frac{p_i > p_i^*}{N_{\text{observed},i}, N_{\text{observed},i}(\text{total})}\right) = 1 - \text{betadist}(p_i^*, \alpha + N_{\text{observed},i}(\text{total}) - N_{\text{observed},i}) \tag{7}
\]

where: \( p_i^* \) = threshold proportion, \( p_i \) = observed proportion, \( N_{\text{observed},i} \) = observed target crashes for a site \( i \), and \( N_{\text{observed},i}(\text{total}) \) = total number of crashes for a site \( i \).

The intersections were then ranked based on the probability values that are interpreted as: the probability that the long-term expected proportion of a particular type of crash at a particular intersection is greater than the long-term expected proportion of all intersections in the reference population. A high probability would suggest further investigation of that particular type of crash would be beneficial.

The probability values for excess proportion of angle crashes, hit-objects crashes and at top ten poorly performing roundabouts in Toowoomba are shown in Table 2. Among them SW6 (Glenvale R and Greenwattle St), SW7 (Glenvale R and McDougall St) and SE12 (South St and MacKenzie St) have only had angle crashes during the study period and so a very high probability was calculated for these roundabouts. All of the crashes except one crash were an angle crash.
Table 1  Number of crashes at top 10 roundabouts.

| Ref | Notation | Roundabout                      | Angle Crashes | Hit Object Crashes | Rear-end Crashes | Other crash types | Total Crashes |
|-----|----------|---------------------------------|---------------|--------------------|------------------|-------------------|---------------|
| 1   | SW7      | Glenvale R and McDougall St     | 12            | 0                  | 0                | 0                 | 12            |
| 2   | NW6      | Anzac Ave, Russell St and West St | 19            | 4                  | 1                | 3                 | 27            |
| 3   | SW6      | Glenvale R and Greenwattle St   | 16            | 0                  | 0                | 0                 | 16            |
| 4   | NW7      | North St and Tor St             | 8             | 0                  | 0                | 1                 | 9             |
| 5   | SE21     | Spring St and Hume St           | 9             | 0                  | 0                | 1                 | 10            |
| 6   | SE14     | Alderley St and Ramsay St       | 8             | 3                  | 0                | 0                 | 11            |
| 7   | SE12     | South St and MacKenzie St       | 9             | 0                  | 0                | 0                 | 9             |
| 8   | SE13     | Alderley St and Hume St         | 7             | 1                  | 4                | 3                 | 15            |
| 9   | SE15     | Alderley St and MacKenzie St    | 7             | 0                  | 2                | 0                 | 9             |
| 10  | SW1      | Alderley St and Drayton Rd      | 4             | 1                  | 3                | 3                 | 11            |
|     | Total    |                                 | 99            | 9                  | 10               | 11               | 129           |

Table 2  Excess proportion of specific type of crashes at roundabouts

| Roundabout        | Angle Crashes | Hit Object Crashes | Rear-end Crashes |
|-------------------|---------------|--------------------|------------------|
| 1 SW7             | 0.988         | 0.108              | 0.108            |
| 2 NW6             | 0.263         | 0.814              | 0.168            |
| 3 SW6             | 0.996         | 0.078              | 0.138            |
| 4 NW7             | 0.838         | 0.138              | 0.145            |
| 5 SE21            | 0.869         | 0.127              | 0.131            |
| 6 SE14            | 0.446         | 0.909              | 0.119            |
| 7 SE12            | 0.973         | 0.138              | 0.145            |
| 8 SE13            | 0.013         | 0.353              | 0.961            |
| 9 SE15            | 0.589         | 0.138              | 0.815            |
| 10 SW1            | 0.007         | 0.437              | 0.927            |

at NW7 (North St and Tor St) and SE21 (Spring St and Hume St) which also resulted in a high probability value. SE14 (Alderley St and Ramsay St) and SE15 (Alderley St and MacKenzie St) had probabilities around 50% which indicated they most likely had an excess but not confidently.

There are two roundabouts stood out when comparing results of estimated probability values for excess proportion of hit object crashes with probabilities of 84.1% and 90.9% for NW6 (Anzac Ave, Russell St and West St) and SE14 (Alderley St and Ramsay St) respectively. Hit object crashes are usually quite rare and can be quite severe so it is important to highlight when there have been several.

The probability values for excess proportion of rear-end crashes for the top ten roundabouts in Toowoomba are shown in table 2. Roundabouts SE13 (Alderley St and Hume St), SW1 (Alderley St and Drayton Rd) and SE15 (Alderley St and MacKenzie St) were all calculated to have a high probability of having excess rear-end crashes with probabilities of 96.1%, 92.7% and 81.5% respectively. Among them the roundabout SE14 was regarded for both angle and hit object crashes while the roundabout SE15 was regarded for angle and rear-end crashes.

5. Conclusion

Studies on road safety at roundabouts mostly focused on the general investigation of crash details or statistics of total crashes but less research dedicated to investigate whether the locational and/or geometric differences make any contributions to a particular type of crash. This study aimed to examine the possibilities for potential road safety concerns connected to a set of specific types of crashes at top ten poorly performing roundabouts in Toowoomba, Australia. The results
from the preliminary analysis revealed that angle, hit object and rear end crashes were most dominant crash types on these roundabouts. A methodological analysis to estimate the excess proportion of specific crash type exceeding threshold at roundabouts helped to identify the roundabouts with a high probability for a particular crash type. It is suggested that further investigation of that particular type of crash at identified roundabouts would be beneficial. Therefore, this study can be used as tool for authorities when carrying out a focused investigation to identify reasoning for existing deficiencies, hence for proposing additional improvement and or design strategies.

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