Clear Zone Effectiveness and Crash Risk

Author

Keith Midson  BE MTransport MITE MIE Aust CPEng
Manager Transportation, Tasmania
GHD Pty Ltd
2 Salamanca Square
Hobart TAS 7000
e: Keith.midson@ghd.com.au  p: +61 3 6210 0649
Abstract

The provision of an adequate clear zone width is an integral consideration of any road design. There are a number of references that are used to determine the appropriate clear zone width for a given set of circumstances in both Australia and overseas. This paper provides an overview and comparison between various key references on clear zones, as well as providing a background on some of the fundamental principles and theories behind clear zone provision.

GHD undertook a study for VicRoads that reviewed over 30 road links across metropolitan Melbourne with varying functional classifications, speed limits and clear zone widths. The run-off-road crash rates were assessed for each road link and the results compared across several road categories. The variance from the VicRoads clear zone guidelines was compared to the actual clear zone provision and the road safety performance was critically assessed. This paper presents the key findings from this study.

About the Authors

Keith Midson
Keith is a traffic engineer and transport planner with thirteen years experience in local government and consulting. He is currently Manager Transportation with GHD in the Tasmanian Operating Centre. Keith is also an Honorary Associate with the University of Tasmania and lectures Transportation Engineering on a part-time basis. He has a Master of Traffic and Master of Transport with Monash University and has worked on large and small scale projects throughout Australia and the Middle East. He is currently the Secretary on the Executive Board of the Institute of Transportation Engineers, Australia/ New Zealand. Keith has a strong background in road safety, and has been involved in numerous projects including road safety strategies, road safety audits, counter-measure design, road safety investigations, road safety research, crash analysis, crash investigation expert witness and transport studies involving a high degree of road safety investigations.

Daniel Gregor
Daniel is an experienced Traffic Engineer and Transport Planner who has worked in consulting, local government and secondments at public transport operators and government land developers, where he gained practical and technical expertise in this field. Daniel’s key areas of interest include road safety, sustainable mobility planning and general traffic engineering.

Daniel has a strong road safety background, with qualifications in road safety auditing and involvement in schemes such as traffic management for large infrastructure projects; implementation of reduced urban speed limits; pedestrianisation within activity centres, and a variety of road safety audits.

Nicole Guy
Nicole recently started with GHD as a graduate, where she has worked on a variety of transport planning and road safety projects. On this project, Nicole assisted with much of the data collection, analysis and reporting.
1. Introduction

GHD were engaged by VicRoads to investigate an outcome-based approach to determining appropriate clear zones on a case-by-case basis, for use in Victoria. This study was commissioned in conjunction with three similar studies undertaken by Hyder, Monash University Accident Research Centre (MUARC) and ARRB Group, although it is noted that vastly alternative approaches were adopted by each consulting firm. The various studies were to investigate an approach to determining “Outcome Based Clear Zone Requirements”, with a view to further develop a preferred approach.

The project originated following recommendations to investigate the traditional approach of the application of clear zones following a Coronial Inquest. It is understood that the Parliamentary Road Safety Committee (PRSC) supports a more conservative safety approach than that accepted for many years through the application of the various standards.

Through this project, GHD have defined “Outcome-based Clear Zone Guidelines” as defining a potential crash risk for a provided clear zone on a given road classification and speed limit. This varies from the traditional ‘chart based’ approach where a ‘recommended’ clear zone is defined by relevant guidelines that are not always achievable for various reasons. In this way, a more educated understanding of the type of clear zone that should be provided for a given set of parameters such as road classification, speed limit and terrain can be obtained that provides a defined crash risk rating.

GHD tested a general approach to investigating the application of clear zones, but it must be emphasised that the findings of this study were not conclusive, but suggested that an alternative approach may be feasible.

GHD’s approach to the study involved the application of an evidence based approach to investigating the effect of clear zone widths on run-off-the-road single vehicle crash rates, along with a comprehensive review of current clear zone guidelines currently in practice in Australia and overseas.

The key findings of this report were as follows:

- Overview of clear zone guidelines literature review;
- Run-off-the-road crash risk increases with increasing traffic volume (exposure measure);
- Run-off-the-road crash risk increases with decreasing clear zone width (except for Activity Centres); and
- An outcome-based clear zone approach is possible, by categorising risk profiles for road types and speed limits. It is possible to obtain an understanding of run-off-the-road crash risk by defining clear zone width. Then an assessment of the road design (or existing road profile) will determine the likelihood of a crash.

This report recommends that further investigation be undertaken, including to determine the crash risk for higher speed roads (100km/h and 110km/h) with a higher sample rate of Victorian roads.

Overall, the approach adopted as part of this investigation has the potential to be very insightful, however it is recognised that a much larger sample of road lengths is required to produce findings of any significance.
2. Adopted Approach

In order to have an evidence based approach to the application of clear zone widths for a range of road types, the crash history for a selection of roads with varying clear zone widths, road classification, speed zones and other factors have been investigated to determine their significance in single vehicle run-off-the-road crash rates.

Specifically, the approach that has been adopted by GHD includes the following key steps:

- Review of existing available literature and research;
- Based on the review of available literature and research, establish suitable objectives for the development of Outcome-based Clear Zone Guidelines;
- Based on the project team’s experience, identify features that are key factors in run-off-the-road type crashes;
- Select a small sample of road lengths in metropolitan Melbourne to test for key factors in run-off-the-road crashes and to verify an evidence based approach to identifying outcome-based clear zone guidelines;
- Visit each selected road length to establish existing conditions;
- Undertake crash analysis for each road length (using CrashStats) to identify crash trends for all crash types and specifically run-off-the-road crashes;
- Report on the findings of the approach adopted and its suitability to identify Outcome-based Clear Zone Guidelines.

In total, 25 road lengths from across Melbourne with varying features were selected, with at least four road lengths in each category. Each site selected was visited to record the typical and minimum offset (in metres) to any existing roadside hazards along the length as well as other information such as speed zone, kerb type, adjoining land use, road surface, horizontal geometry, etc. Two-way traffic volume data for each road length was estimated from the strategic Melbourne Integrates Transport Model (MITM), and accordingly, the traffic volume data is a broad estimate only. Table 3 lists road sections and their associated classification.

The road lengths selected in this study are not considered to be fully representative of all Victorian Roads. Given the preliminary nature of this investigation project and the limited resources available to undertake site inspections, only sites within Melbourne have been selected for analysis. Accordingly, ‘Rural Highways’ or ‘Rural Roads’ have not been assessed as part of this investigation. It is recommended that this form part of a future piece of work, however it is acknowledged that the existing clear zone guidelines are more likely to be applicable in ‘rural highway’ settings.
3. Literature Review

To enable a greater understanding of clear-zones and the application of clear zone widths for various functional road designs used within other states of Australia and other countries around the world a literature review was undertaken.

The Literature review included the following documents:

- VicRoads Guidelines – Road Design Guidelines;
- Austroads Guidelines;
  - Austroads Rural Road Design Guide;
  - Austroads Urban Road Design Guide;
  Note The Austroads Guide to Road Design Part 6 is currently in preparation, this guide is believed to cover Road Safety and contain a section on clear zones, this may update the clear zone guidelines within both the Urban and Rural Road Design Guides
- Interstate Practice;
  - Road Design Guidelines, Section 3: Road Cross Section (NSW);
  - Main Roads Western Australia: Assessment of Roadside Hazards (WA);
  - Chapter 8 Safety Barriers and Roadside Furniture (Department of Main Roads Road Planning and Design Manual, QLD);
  - Road Hazard Management Guide (Department of Infrastructure, Energy and Resources, TAS);
- Overseas Practice/Research;
  - United States – AASHTO;
  - British Columbia – Ministry of Transportation and Highways Technical Bulletin: Clear Zone Standards;
  - New Zealand – Transit New Zealand: State Highway Geometric Design Manual, Section 6: Cross Section;
  - Europe – European Best Practice for Roadside Design: Guidelines for Roadside Infrastructure on New and Existing Roads (RISER);

The regions (Australian states and other countries) incorporated within the literature review revealed that the clear zone guidelines for the regions were based upon either the Austroads Urban and Rural Design Guidelines or AASHTO, or RTA NSW Road Design Guidelines. Table 1 summarises the guidelines that each region bases the clear zone widths upon and the document that this is outlined for each state this in.
<table>
<thead>
<tr>
<th>State/Country</th>
<th>Guidelines Used for clear zones</th>
<th>Guidelines Used for Safety Barriers</th>
<th>Document Name</th>
<th>Document Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>AustRoads</td>
<td>AustRoads</td>
<td>VicRoads Road Design Guidelines Cross Section: 3.9 Clear Zones &amp; 3.10 Safety Barriers</td>
<td>2002</td>
</tr>
<tr>
<td>New South Wales</td>
<td>NSW RTA</td>
<td></td>
<td>RTA NSW Road Design Guidelines, Section 3 Road Cross Section; 3.7 Clear Zones</td>
<td>1999</td>
</tr>
<tr>
<td>South Australia</td>
<td>Austroads Rural and Urban Design Guides</td>
<td>Austroads Rural and Urban Design Guides and Government of South Australia - Department of Transport, Energy and Infrastructure Guide to selection of safety barriers.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Western Australia</td>
<td>AustRoads</td>
<td>AustRoads</td>
<td>Main Roads Western Australia: Assessment of Roadside Hazards</td>
<td>2007</td>
</tr>
<tr>
<td>Queensland</td>
<td>AASHTO</td>
<td>AS/NZS 3845:1999 Road Safety Barrier Systems and the National Cooperative Highway Research Program</td>
<td>Department of Main Roads Road Planning and Design Manual: Chapter 8 Safety barriers and roadside furniture</td>
<td>2005</td>
</tr>
<tr>
<td>State/Country</td>
<td>Guidelines Used for clear zones</td>
<td>Guidelines Used for Safety Barriers</td>
<td>Document Name</td>
<td>Document Date</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------</td>
<td>-------------------------------------</td>
<td>---------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Tasmania</td>
<td>AustRoads</td>
<td>AS/NZS 3845:1999 Road Safety Barrier Systems</td>
<td>Road Hazard Management Guide</td>
<td>unknown</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>AustRoads</td>
<td>-</td>
<td>No response received</td>
<td>-</td>
</tr>
<tr>
<td>United States</td>
<td>AASHTO</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>British Columbia</td>
<td>Based upon AASHTO but the actual clear zone widths are slightly different</td>
<td>-</td>
<td>Ministry of Transportation and Highways Technical Bulletin: Clear Zone Standards</td>
<td>1996</td>
</tr>
<tr>
<td>New Zealand</td>
<td>AASHTO</td>
<td>-</td>
<td>Transit New Zealand: State Highway geometric design manual, section 6-Cross section</td>
<td>2002</td>
</tr>
<tr>
<td>Europe</td>
<td>-</td>
<td>-</td>
<td>European Best Practice for Roadside Design: Guidelines for Roadside Infrastructure on New and Existing Roads</td>
<td>2005</td>
</tr>
</tbody>
</table>
The main objectives that have been identified within a number of the guidelines reviewed are presented in Table 2.

Table 2  Key Objectives

<table>
<thead>
<tr>
<th>Name of Document</th>
<th>Date</th>
<th>Organisation</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban / Rural Road Design Guide</td>
<td>2003</td>
<td>AustRoads</td>
<td>The clear zone is a compromise between the recovery area for every errant vehicle, the cost of providing that area and the probability of an errant vehicle encountering a hazard. Ideally the clear zone should be kept free from non-frangible hazards where economically possible; alternatively, vehicles should be protected from hazards within the clear zone.</td>
</tr>
<tr>
<td>Roadside Infrastructure for Safer European Roads (RISER)</td>
<td>2003</td>
<td>RISER</td>
<td>If the goal of the safety zone is to eliminate impacts with objects for impact speeds above 40 km/h, then the lateral distance of the safety zone must accommodate the motions of the vehicles until this speed is reached.</td>
</tr>
<tr>
<td>State Highway Geometric Design Manual, Section 6</td>
<td>2003</td>
<td>Transit New Zealand</td>
<td>About 80 percent of vehicles that run-off-the-road to regain control with minimum damage to both vehicles and occupants Shoulder, verge and batter design must ensure a clear zone, which will allow an errant vehicle to traverse this area with minimum damage to itself and occupants.</td>
</tr>
<tr>
<td>AASHTO Roadside Design Guide 3rd ed.</td>
<td>2003</td>
<td>American Association of State and Highway Transportation Officials</td>
<td>To the extent practical, all roadsides should be traversable and contain no objects likely to cause severe injuries when struck by a motorist. This concept is the cornerstone of the ‘forgiving roadside’ philosophy. Roadside hardware that cannot be removed or located farther from the roadway should be designed to yield when struck, decreasing the likelihood of serious injury. Whenever a hazardous terrain feature or fixed object cannot be eliminated through redesign or made to yield on impact, shielding with an appropriate traffic barrier should be considered.</td>
</tr>
</tbody>
</table>
3.1 Clear Zone Guidelines

The following sections outline the basic methodology on how a clear zone is determined for a given road type and speed zone for the most commonly used Guides in Australia.

3.1.1 Austroads Urban and Rural Road Design Guide

The Austroads Urban and Rural Road Design Guidelines both outline identical methodologies to determine the clear zone width for a road and are therefore discussed as the one document in the following section.

The Austroads Road Design Guide provides an indication of appropriate clear zone widths for a straight section of road. Within the guidelines it states, “The clear zone is a compromise between the recovery area for every errant vehicle, the cost of providing that area and the probability of an errant vehicle encountering a hazard. Ideally the clear zone should be kept free from non-frangible hazards where economically possible; alternatively, vehicles should be protected from hazards within the clear zone”.

The calculation of the clear zone width is completed with the aid of the graph shown in Figure 1. The clear zone width is dependent on the 85-percentile speed, one-way AADT traffic volumes and the batter slopes. For roads that have a horizontal curve an adjustment factor, $F_c$, is used to increase the clear zone width. This factor is dependant upon the operating speed of the road and radius of the curve. The curve adjustment factor, $F_c$, ranges between 1.0 – 1.9 and is shown in Figure 2.
Figure 1: Austroads Urban Road Design Guide, Clear Zone Width
Figure 2: Austroads Urban Road Design Guide, Horizontal Curve Factor

3.1.2 NSW RTA – Road Design Guide, Section 3: Cross Section

Section 3.7 of the NSW RTA Road Design Guide, stipulates the clear zone widths to be applied for NSW roads. These guidelines follow a similar approach to that used within the Austroads guidelines; Figure 3 shows the diagram that is used to determine the clear zone widths.

The factors the clear zone width is dependent upon are the 85\textsuperscript{th} percentile speed, one-way AADT traffic volumes and the batter slopes, the same factors used within the Austroads guidelines. However the weighting each factor is given, to effect the clear zone width is different to the weighting of given to the factors within the Austroads guidelines. The clear zone widths calculated from the NSW RTA guidelines are generally smaller than the widths calculated from the Austroads guidelines for lower speed roads,
Figure 3: NSW RTA, Clear Zone Nomograph

NOTE: 1. These distances (*) are the Weighted Average Distance when used on complex batter arrangements.
2. Design Speeds shown are the 85th percentile value, measured (or predicted) for the site being considered.
3.1.3 AASHTO Roadside Design Guide

The AASHTO Roadside Design Guide is similar to both the Austroads and NSW RTA guidelines as it also provides an indication of appropriate clear zone widths for a straight section of road. The clear zone width is dependent on the 85th-percentile speed, the one-way AADT approach volume and the slope of the cut or fill. The graph used is shown in Figure 4. The clear zone width is adjusted for roads that:

- Have a horizontal curvature;
- Are two-land two-way road; and
- Are dual carriageways.

Figure 5 displays the adjustment factors that must be applied if any or all of the features are present along the road section. The largest of the factors is used to determine the adjusted clear zone distance.

When compared to the Austroads guidelines, the AASHTO clear zones are relatively similar for vehicles travelling at high speeds, however where the design speed is lower than 80km/hr the clear zone width are generally smaller when using the AASHTO guidelines.
Figure 4: AASHTO Roadside Guidelines, Clear Zone Width
Figure 5: AASHTO Roadside Guidelines, Adjustment Factors
4. Development of Outcome-Based Clear Zone Guidelines

4.1 Summary of Adopted Approach

In order to have an evidence based approach to the application of clear zone widths for a range of road types, the crash history for a selection of roads with varying clear zone widths, road classification, speed zones and other factors have been investigated to determine their significance in single vehicle run-off-the-road crash rates.

In total, 25 road lengths from across Melbourne with varying features were selected, with at least four road lengths in each category. Each site selected was visited to record the typical and minimum offset (in metres) to any existing roadside hazards along the length as well as other information such as speed zone, kerb type, adjoining land use, road surface, horizontal geometry, etc. Two-way traffic volume data for each road length was estimated from the strategic MITM, and accordingly, the traffic volume data is an estimate only.

The road lengths selected in this study are not considered to be fully representative of all Victorian Roads. Given the preliminary nature of this investigation project and the limited resources available to undertake site inspections, only sites within Melbourne have been selected for analysis. Accordingly, ‘Rural Highways’ or ‘Rural Roads’ have not been assessed as part of this investigation. It is recommended that this form part of a future piece of work, however it is acknowledged that the existing clear zone guidelines are more likely to be applicable in ‘rural highway’ settings.

4.1.1 Recognised Limitations of This Investigation

It is acknowledged that the evidence-based approach to identifying Outcome-based Clear Zone Guidelines adopted in this assessment has some limitations. These are as follows:

- **Small Sample Size**: A small sample of road lengths analysed. It is acknowledged that the size of the sample selected for this investigation is too small to draw any statistically significant conclusions, however the purpose of the sample and investigation is to identify whether crash history trends for a variety of factors can be used to determine Outcome-based Clear Zone Guidelines for a variety of factors and road types. It is recommended that any future analysis include a much larger sample size to provide more statistically reliable results;

- **Metropolitan Roads only**: Given the preliminary nature of this investigation project, the limited resources and time constraints to undertake site inspections, only sites within Melbourne have been selected for analysis. The sample of road lengths has included roads from a variety of different environments, but only within a metropolitan Melbourne context. This means that the size of sub-categories within the small sample of road lengths are maximised. It is recommended that any future analysis include roads from a broad range of areas, locations and environments;

- **Limited Number of Factors Assessed**: The analysis has focused on a number of different factors that may be related to run off road crashes. This has included the adjoining road environment, the terrain and speed zone. It is acknowledged that these are no the only factors that contribute to run off the road crashes and it is recommended that future analysis include other factors (e.g. delineation, street lighting, pedestrian volumes, etc.);
Limited Site Data: Given the limited time available to undertake this investigation, only very basic information was collected at each site (i.e. speed zone, typical offset to existing roadside hazards, etc.). There may be benefit in any future analysis incorporating more detailed and accurate site information (e.g. measure roadside hazards with GPS, measure lane widths, etc.); and

Estimated Traffic Volume: The two-way traffic volume estimated for each site has been estimated based on the MITM model and accordingly, the volumes are estimates only.

4.2 Site Selection
To assess the significance of a variety of factors in run-off-the-road type crashes, a number of roads were selected based on the following categories:

- **Arterial Road within an Activity Centre**: These roads usually have high to moderate pedestrian activity and drivers are highly alert.
- **Urban Road**: These roads usually have moderate access; low to moderate pedestrian activity, moderate to high traffic volumes and drivers are alert.
- **Urban-Hills**: These roads usually have moderate traffic volumes, narrow shoulders if any, no kerb and channel, high vegetation and curves and grades.
- **Rural Highway**: These roads usually have high speed, moderate traffic volume, lower driver alertness.
- **Rural Road**: These roads typically have high speed, low traffic volume, low driver alertness, and frequent roadside hazards within the clear zone.

As detailed previously, in total, 25 road lengths from across Melbourne with varying features were selected, with at least four road lengths in each category. Each site selected was visited to record the typical and minimum offset (in metres) to any existing roadside hazards along the length as well as other information such as speed zone, kerb type, adjoining land use, road surface, horizontal geometry, etc. Two-way traffic volume data for each road length was estimated from the strategic MITM, and accordingly, the traffic volume data is an estimate only. Table 3 lists road sections and their associated classification.

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Road Name</th>
<th>Suburb</th>
<th>Road Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial Road within an Activity Centre</td>
<td>Whitehorse Road</td>
<td>Box Hill</td>
<td>Elgar and Dorking Road</td>
</tr>
<tr>
<td></td>
<td>Burke Road</td>
<td>Camberwell</td>
<td>Between Riversdale Road and Canterbury Road</td>
</tr>
<tr>
<td></td>
<td>Whitehorse Road</td>
<td>Kew</td>
<td>Between Burke Road and Denmark Street</td>
</tr>
<tr>
<td></td>
<td>Lonsdale Street</td>
<td>Dandenong</td>
<td>Between Clow Street and Foster Street</td>
</tr>
<tr>
<td>Road Classification</td>
<td>Road Name</td>
<td>Suburb</td>
<td>Road Section</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Ascot Vale Road</td>
<td>Ascot Vale</td>
<td></td>
<td>Between Racecourse Road and Maribyrnong Road</td>
</tr>
<tr>
<td>High Street</td>
<td>Preston</td>
<td></td>
<td>Between Bell Street and Dundas Street</td>
</tr>
<tr>
<td>Mount Alexander Road</td>
<td>Travancore</td>
<td></td>
<td>Between Qty Link and Maribyrnong Road</td>
</tr>
<tr>
<td>Urban Roads</td>
<td>Buckley Street</td>
<td>Essendon</td>
<td>Between Railway Line and Waverley Street</td>
</tr>
<tr>
<td>Andersons Creek Road</td>
<td>East Doncaster</td>
<td></td>
<td>Between Blackburn Road and Heidelberg-Warrandyte Road</td>
</tr>
<tr>
<td>Blackburn Road</td>
<td>East Doncaster</td>
<td></td>
<td>Between King Street and Reynolds Road</td>
</tr>
<tr>
<td>King Street</td>
<td>East Doncaster</td>
<td></td>
<td>Between Victoria Street and Blackburn Road</td>
</tr>
<tr>
<td>George Street</td>
<td>East Doncaster</td>
<td></td>
<td>Between Victoria Street and Blackburn Road</td>
</tr>
<tr>
<td>Plymouth Road</td>
<td>Corydon Hills</td>
<td></td>
<td>Between Kalinda Road and Yarra Road</td>
</tr>
<tr>
<td>Barkers Road</td>
<td>Kew</td>
<td></td>
<td>Between Burke Road and Denmark Street</td>
</tr>
<tr>
<td>Canterbury Road</td>
<td>Surrey Hills</td>
<td></td>
<td>Between Union Road and Balwyn Road</td>
</tr>
<tr>
<td>Burke Road</td>
<td>Camberwell</td>
<td></td>
<td>Between Toorak Road and Riversdale Road</td>
</tr>
<tr>
<td>Balwyn Road</td>
<td>Balwyn</td>
<td></td>
<td>Between Doncaster Road and Whitehorse Road</td>
</tr>
<tr>
<td>Springvale Road</td>
<td>Forest Hill</td>
<td></td>
<td>Between Canterbury Road and Burwood Highway</td>
</tr>
<tr>
<td>Burwood Highway</td>
<td>Burwood East</td>
<td></td>
<td>Between Blackburn Road and Morack Road</td>
</tr>
<tr>
<td>Hoddle Street</td>
<td>Richmond</td>
<td></td>
<td>Between Wellington Parade and Johnston Street</td>
</tr>
</tbody>
</table>
### 4.3 Crash Analysis Overview

#### 4.3.1 Crash History Assessment

An assessment of the casualty crash history, sourced from VicRoads’ publicly available database CrashStats, was completed for all the sections of roads listed in Table 3, including any intersections within the subject road length, for the five year period 2001-2005.

A focus on single vehicle run-off-the-road crashes was adopted for this assessment. The following data was extracted for each road length and each crash site from the CrashStats output:

- Total number of crashes along the subject road length;
- Number of run-off-the-road crashes along the subject road length;
- Direction of errant vehicle from the carriageway (e.g. left or right);
- Alignment of road (curve or straight);
- Type of object struck (e.g. pole, tree, etc.); and
- Whether the kerb was mounted.

In addition, the following features have also been attributed to each specific site:

- Adjoining environment (e.g. Activity Centre);
- Road type (e.g. Arterial);
- Length of the road assessed;
- Traffic volume;
- Speed zone;
- Terrain; and
- Street lighting.
As each road section that has been assessed were of different lengths, it would be inappropriate to compare the total number of crashes per road directly. Accordingly, the number of run-off the road crashes has been compared based on the number of crashes per kilometre of road length. Some assessment was also undertaken on the crash exposure rates by investigating the Two-Way Average Daily Traffic Volume on each of the selected road links.

It is noted that the analysis only focused on those casualty crash details that relate to the road design element. On this basis, factors such as time of day, seasonal and weather factors have not been included in the analysis.

4.3.2 Crash History Assessment – Overview and Comparison

Of all the road lengths assessed, the roadside hazards were on average offset from the edge of the nearest traffic lane a distance of 2.46m. For each of the different categories the average offset was:

- 1.2m for ‘Activity Centres’;
- 2.7m for ‘Urban’; and
- 3.0m for ‘Urban-Hills’.

For the road lengths investigated, a total of 1,311 casualty crashes were recorded for the 5-year period between 2001-2005, of which 114 (8.7%) were run-off-the-road type crashes. On average, there were approximately 32.6 casualty crashes per km, and approximately 2.4 run-off-the-road type crashes per km.

The analysis indicates that roads within an ‘Activity Centre’ had the largest number of total casualty crashes per kilometre, with on average approximately 66.1 casualty crashes per kilometre and 2.2 run-off-the-road crashes per km.

Roads classified as ‘Urban’ had on average approximately 28.5 crashes per km and 2.3 run-off-the-road crashes per km. ‘Urban-Hills’ roads had on average approximately 7.5 casualty crashes per km and 3.2 run-off-the-road type crashes (the highest per km of all road categories). This information is presented in Figure 6.

It is noted that, ‘Urban Hills’ roads have the highest proportion of run-off-the-road crashes with 43% of its total crashes being run-off-the-road crashes, while ‘Activity Centre’ roads, and ‘Urban roads both have below 10% of total casualty crashes being classified as run-off-the-road crashes.

As depicted in Figure 7, based on the road lengths assessed, the severity of run-off road type crashes are typically higher for the ‘Activity Centre’ and ‘Urban’ type roads compared to the ‘Urban-Hills’.
Average Number of Casualty and Run-Off-Road Crashes (per km) For Each Road Classification

Figure 6: Average Number of Casualty Crashes per km

Comparision Of The Total Number of Crashes, per Km, Classified Fatal Or Serious and Other For Each Road Type

Figure 7: Crash Severity for Run-Off Road Crashes
For ‘Activity Centre’ and ‘Urban’ road classifications, the majority of run-off-the-road crashes occur on straights, while for ‘Urban-Hills’ roads the most common type of run-off-the-road crash is to the left of the carriageway and on a curve. This is presented in Figure 8. Although this is a function of the actual road lengths selected, as expected it appears that there is a high correlation between the presence of bends and the run-off-the-road crash risk per km.

Figure 8: Comparison of Each Run-off-the-road Type Crashes for Each Road Classification Crash History Assessment – Overview and Comparison

When an errant vehicle leaves the carriageway, there are a variety of objects that the vehicle may collide with; the objects that are present usually depend on the topography of the land, facilities that are required within the area (electricity poles, bus stops), surrounding land uses and the type of road.

The roadside hazards that are typical along many roads (and is recorded by CrashStats) include:

- Pole (utility or lighting);
- Tree;
- Traffic Signal;
- Traffic Sign;
- Traffic Island;
- Fences;
- Buildings;
- Guard Rail;
- Guide Post;
Fire Hydrant;
Open drains;
Roadside furniture; and
Embankment.

The above list of hazards was used within the crash assessment to determine if there is one particular roadside hazard that has a greater occurrence of being struck.

Figure 9 shows the roadside hazards that have been struck by vehicles that have left the carriageway for all of the assessed road lengths investigated in this study.

‘Poles’ had the highest percentage of being hit of all the objects at 39%; ‘Tree’ has the second highest percentage with 18% of all reported crashes. It demonstrates that poles and trees are the most struck roadside hazards. This is largely because they are the predominant roadside object and are often located within the clear zone and can be difficult and expensive to remove, relocate or shield.

Traffic islands, fire hydrants, guideposts and guardrails all were only struck 1% or 2% of the collisions within the assessed road lengths.
Figure 9: Frequency of Roadside Hazards Being Struck From All Run-off-the-road Crashes

Figure 10 is a scatter plot that presents the relationship between the number of run-off-the-road type crashes per km (for all road lengths investigated) against the VicRoads clear zone requirement for each subject road length. It is noted that the clear zone requirements have been calculated based on the estimated one-way traffic volume for each road and the posted speed zone.

Of the 25 road lengths investigated, only 5 typically met or exceeded the VicRoads Clear Zone requirements. For these roads, the number of crashes per kilometre was generally below 1.5 run-off-the-road crashes per kilometre.

By comparison, 20 of the 25 road lengths did not meet the VicRoads clear zone requirements. The range was a shortfall of between 0.3m up to 4.0m. For these sites, the run-off-the-road crash rate was between 1.2 and 6.2 run-off-the-road crashes per km.

A linear regression line has been applied to the data, which shows that there is generally a generally negative linear relationship between the actual/required clear zone and the run-off-the-road crash rate. The coefficient of determination ($R^2$) is a statistical measure to determine how well the regression line approximates the data. For the linear regression line shown in Figure 10 it has an $R^2$ value of 0.1558, this would indicate that the regression line doesn’t approximate the data set very well. However, what the line does indicate is that where the roadside hazards along a road length meet the VicRoads clear zone requirement, the crash rate is lower.
zone requirements that the run-off-the-road crash rate is approximately 1.7 crashes per km (i.e. the Y intercept).

It is acknowledged that the data and crash analysis is based on a very small sample of sites. It is recommended that this approach be adopted for a much larger sample of sites across a variety of road types, with varying adjoining environment factors, varying terrain, varying speed zones and other factors. This will enable the development of a statistically reliable equation for the relationship of crash rate risk to specific road environment factors.

\[
y = -0.393x + 1.6716
\]

\[
R^2 = 0.1558
\]

Figure 10: Run-off-the-road Crash Rate by the Difference Between the VicRoads Clear Zone Requirements and the Actual Offset to Roadside Hazards.

4.4 Run-off-the-road Crash Comparisons Based on Different Factors

For the purpose of this assessment, a number of different factors have been selected for analysis to determine whether this approach to identifying outcome-based clear zone guidelines is appropriate. It is acknowledged that the factors chosen do not represent all the factors that may be involved in run-off-the-road type crashes, however it is recommended that future work consider other factors.

The factors investigated include the impact of:

- The adjoining roadside environment (i.e. activity centre, urban, urban-hills),
- The road terrain (i.e. level, undulating/rolling), and
- Speed zone.
4.4.1 Adjoining Road Environment

The roads selected for assessment have been categorised into three distinct groups based on the adjoining road environment. The three categories are:

- Activity Centre roads
- Urban roads
- Urban-Hills roads

These categories were selected to see if the environment within which a road is situated is a factor in run-off the road type crashes.

**Activity Centre**

Arterial roads within Activity Centres generally have a moderate to high degree of activity associated with them in the form of pedestrian movements, parking and access manoeuvres and lower speed limits.

The dominant run-off-the-road crash type for the Activity Centres studied was left-carriageway-straight, with 55% of all crashes falling in this category. The remaining crashes were right-carriageway, with 45%.

The typical roadside hazards struck in the Activity Centres studied are presented in Figure 11. Traffic signals were the most common hazard struck, with 23%, followed by pole with 17% and tree, fence, fire hydrant and traffic islands each with 12%.

![Roadside Hazards Struck - Activity Centre](image)

**Figure 11: Activity Centre Roadside Hazards**

Figure 12 shows the run-off-the-road crash rate per kilometre versus the two-way traffic volume for the five Activity Centre roads studied. The scattering of crash rates does not tend to suggest any particular
trend. The scattering of crash rates does not tend to suggest any particular trend. This is unless Lonsdale Street is regarded as an outlier and then the trend would appear upward indicating that, as traffic volume increases, so does the number of crashes per km of road length.

![Traffic Volume and Run-Off-Road Crashes - Activity Centre](image)

**Figure 12: Activity Centre Traffic Volume and Run-off-the-road Crashes**

It is likely that other factors have a more significant impact on run-off-the-road crashes in Activity Centres given the complexity of movements occurring within these roads, and therefore finding a reasonable relationship for the clear zone width along may prove to be difficult.

The distribution of run-off-the-road crashes per kilometre versus the typical hazard offset at each site (effectively the clear zone provided on-site) for the five selected road lengths studied did not tend to indicate any specific trends given the small sample size and other factors.

Overall, for the ‘Activity Centre’ classification, it is recommended that a larger sample of roads be assessed to more accurately identify whether there are any trends associated with crash rate and traffic volume and hazard offset in activity centres.

**Urban**

Roads classified as ‘Urban Roads’ are generally Primary Arterial and Secondary Arterial roads. Therefore the characteristics vary slightly within this category, however urban roads generally have moderate property access; low pedestrian activity, moderate to high volumes, moderate traffic speeds and drivers are generally alert.

The dominant run-off-the-road crash type for the ‘Urban’ roads studied was left-carriageway-straight, with 62% of all crashes falling in this category. The remaining crashes split amongst the right-carriageway-straight and left-carriageway-curve, with 37% and 1% respectively.

All 16 of the roads classified as an ‘Urban Road’ have 10% or less of the total crashes being run-off the road crashes, with George Street having no recorded run-off-the-road collisions.
The typical roadside hazards struck in the ‘Urban’ roads studied are shown in Figure 13. Poles were the most common hazard struck, with 48%, followed by trees and fences with 12% and traffic signals with 10%.

**Figure 13: Urban Roads Roadside Hazards**

Figure 14 displays the run-off-the-road crash rate per kilometre versus the two-way traffic volume for each road studied in the ‘Urban’ road category. Figure 15 takes the data from Figure 14 and shows that there is a generally positive linear relationship between the two-way traffic volume and the number of run-off-the-road crashes. For the linear regression line shown in Figure 15 it has an $R^2$ value of 0.3762, this would indicate that the regression line doesn’t approximate the entire data set very well. There does appear to be a stronger linear relationship between the two-way traffic volume and number of run-off-the-road crashes for roads with lower traffic volumes.

Figure 16 shows the distribution of run-off-the-road crashes per kilometre versus the hazard offset (effectively the clear zone) for the road lengths studied. Figure 17 uses this data to demonstrate that there doesn’t appear to be any strong relationship between the hazard offset and the number of run-off-the-road crashes. A linear regression line and a logarithmic regression line have both been fitted to the data. For the linear regression line shown in Figure 17 it has an $R^2$ value of 0.132, the logarithmic regression line is also shown in Figure 17 and has an $R_2$ value of 0.0524. This indicates that data does not have a strong linear or logarithmic relationship.
Figure 14: Urban Roads Traffic Volume and Run-off-the-road Crashes

Figure 15: Urban Road Traffic Volume and Run-off-the-road Crashes
Figure 16: Urban Run-off-the-road Crash Rate and Hazard Offset Distance

Figure 17: Urban Run-off-the-road Crash Rate and Hazard Offset Distance – Regression.
Urban Hills

‘Urban Hill’ roads are those roads that are within Metropolitan Melbourne but are typically windy and have some rural characteristics. These roads usually have moderate volumes, narrow shoulders if any, no kerb and channel, may have high vegetation and have low to moderate accesses.

The dominant run-off-the-road crash type for the ‘Urban Hills’ studied was left-carriageway-curve, with 49% of all crashes falling in this category. The remaining crashes are split amongst the left-carriageway-straight, right-carriageway-straight, right-carriageway-curve, with 17%, 10% and 24% respectively.

The four roads classified as ‘Urban Hills’ roads incorporated within this study all between 40% and 50% of the total crashes being run-off-the-road crashes.

The typical roadside hazards struck in the ‘Urban Hills’ roads studied are shown in Figure 18. Trees were the most common hazard struck, with 44%, followed by poles and embankments each with 22%. The remaining objects that were struck were guardrails, fences and other objects; these roadside features were all struck 4% of the time.

![Roadside Hazards Struck - Urban-Hills](image)

**Figure 18: Urban Hills Roadside Hazards**

Figure 19 depicts the run-off-the-roads crash rate per kilometre versus the two-way traffic volumes of the four roads classified as ‘Urban Hills’ roads included within the study. The scattering of the crash rates doesn’t tend to suggest any particular trends.
Figure 19: Urban Hill Roads Traffic Volume and Run-off-the-road Crashes

Figure 20 shows the distribution of run-off-the-road crashes per kilometre versus the hazard offset (effectively the clear zone) for the four selected road lengths studied. Despite the low sample size does, the scattered crash rates does tend to suggest a downward trend that as hazard offset increases, the crash rate per km reduces quite dramatically. The collection of a larger sample size may assist to verify this conclusion.

Figure 20: Urban Hills Run-off-the-road Crash Rate and Hazard Offset Distance
Comparison of Run-off-the-road Crashes at All Sites

Figure 21 shows the crash rates of all sites against the two-way traffic volume. It can be seen that there is a general trend of increasing crash rates for increasing traffic volume, as the exposure increases. As mentioned in Section 4.4.1, the Activity Centres did not appear to follow this trend, although a general lack of data may be a causing factor.

![Graph showing crash rates per km and traffic volume](image)

Figure 21: Number of Run-off-the-road Crashes and Traffic Volumes

It can be seen from Figure 22 that the crash rate per kilometre generally reduces as the distance to the offset hazard increases. This demonstrates that as the clear zone increases, the likelihood of run-off-the-road crashes decreases.

This trend was not as evident for Activity Centre sites, where a slightly increasing trend was observed. Given the limited range of clear zone distances present at these sites (maximum recorded being only 2 metres), it may simply indicate that there is insufficient data to draw significant conclusions from. The increasing trend may also be due to factors such as possible increasing speed with increased clear zone at these sites.

Figure 22 tends to indicate that crash risk for run-off-the-road crashes per kilometre reduces as the clear zone increases. Whilst time constraints prevented higher speed limited roads (100km/h and 110km/h) from being investigated, it is most likely that this trend would also be observed.
4.4.2 Road Terrain

Within the analysis the 25 selected roads were classified by road terrain, as this study has been focused on the urban environment all the roads were classified either level, undulating or rolling. According to the Austroads Rural Design Guide the definitions of the road terrain classifications are as follows.

**Level Terrain:** Is that condition where road sight distance, as governed by both horizontal and vertical restrictions, are generally long or could be made to be so without construction difficulty or major expense.

**Undulating Terrain:** Is that condition where road sight distance is occasionally governed by both horizontal and vertical restrictions with some construction difficulty and major expense but with only minor speed reduction.

**Rolling Terrain:** Is that condition where the natural slopes consistently rise above and fall below the road grade and where occasional steep slopes offer some restriction to normal horizontal and vertical roadway alignment. The steeper grades cause trucks to reduce speed below those of passenger cars.

Due to the small sample size the roads, which were classified as having either undulating or rolling terrain, were grouped together.
Undulating and Rolling Terrain

The following roads were classified as having either an undulating or rolling terrain:

- Plymouth Road;
- Blackburn Road;
- King Street;
- Andersons Creek Road;
- Burke Road (between Riverdale Rd and Toorak Rd);
- George Street;
- Park Road;
- Croydon Road;
- Jumping Creek Road; and
- Warrandyte Road

The proportion of run-off-the-road crashes within this category varies between 0% (along George Street) and approximately 50% (along Park Road).

The dominant run-off-the-road crash type for the undulating and rolling terrain roads, included within the study was left-carriageway-curve, with 38% of all crashes falling in this category. 32% of the run-off-the-road crashes classified left-carriageway-straight, while the remaining 31% were crashes to the right of the carriageway.

Poles were the most common hazard struck, with 36%, followed by trees and embankments with 23% and 16% respectively.

Figure 23 displays the offset to a roadside hazard and the number of run-off-the-road crashes per kilometre for undulating and rolling roads. A linear regression has been fitted to the data points; from this it would indicate that there is a negative linear relationship between the offset to roadside hazards and the number of the run-off-the-road crashes per kilometre. The regression model has an $R^2$ value of 0.152 indicating that there is a weak negative linear relationship.

The two-way traffic volume and the number of run-off-the-road crashes per kilometre for undulating and rolling terrain roads are shown in Figure 24. A negative linear regression line has been fitted to the data set; an $R^2$ value of 0.1012 was obtained from the regression model.
Hazard Offset and Run-Off-Road Crashes - Undulating/Rolling Roads

\[ y = -0.4342x + 3.412 \]

\[ R^2 = 0.152 \]

Figure 23: Hazard Offset and Run-off-the-road Crashes for Undulating/Rolling Terrain

Traffic Volume and Run-Off-Road Crashes - Undulating/Rolling Roads

\[ y = -7E-05x + 2.8338 \]

\[ R^2 = 0.1012 \]

Figure 24: Traffic Volume and Run-off-the-road Crashes for Undulating and Rolling Terrain
Level Terrain
The following roads have been classified as having a level terrain:

- Whitehorse Road (Elgar Rd and Dorkign Rd);
- Burke Road (between Riverdale Rd and Canterbury Rd);
- Lonsdale Street;
- High Street;
- Barkers Road;
- Buckley Street (between Waverley Street and Hoffmans Road);
- Whitehorse Road (between Union Road and Balwyn Road);
- Balwyn Road;
- Canterbury Road;
- Ascot Vale Road;
- Hoddle Street;
- Mount Alexander Road;
- Burwood Highway;
- Buckley Street (between the railway line and Waverley Street);
- Springvale Road; and

The proportion of run-off-the-road crashes within this category is below 20% for all of the assessed roads.

Poles were the most common hazard struck, with 44%, followed by trees and traffic signals with 13% and 11% respectively, while no embankments were hit.

The dominant run-off-the-road crash type for level terrain roads, included within the study, was left-carriageway-straight, with 60% of all crashes falling in this category. There were 39% of the run-off-the-road crashes classified right-carriageway-straight, and 1% of the crashes were classified as left-carriageway-curve.

Figure 25 displays the offset to a roadside hazard and the number of run-off-the-road crashes per kilometre for roads with level terrain. A linear regression has been fitted to the data points; however it would indicate that there is no particular trend for this data as the $R^2$ value given from the regression is 0.0088.

The two-way traffic volume and the number of run-off-the-road crashes per kilometre for level terrain roads are shown in Figure 26, the data points would indicate that there is a positive relationship between these two factors. A linear regression line has been fitted to the data; this regression provided an $R^2$ value of 0.3803, indicating that the fitted regression line slightly approximates the data.
Figure 25: Hazard Offset and Run-off-the-road Crashes for Level Terrain

Figure 26: Traffic Volume and Run-off-the-road Crashes for Level Terrain
4.4.3 Speed Zone

Within the analysis the 25 selected roads were classified by the designated speed zone for the section of road included within the study. The road lengths assessed were found to be within either a 60km/hr, 70km/hr or 80km/hr speed zone (excluding any school zone sections).

Due to the small sample size the roads, which were classified as having either a 70km/hr or an 80km/hr speed zone, were grouped together. It is further noted that 85th-percentile speeds were not recorded for the sites selected in this study. It is possible that the 85th-percentile speeds may not be representative of the speed limits in some locations.

60km/hr Speed Zone

There were 20 of the 25 roads being classified as having a 60km/hr speed zone. The proportion of run-off-the-road crashes varies between 0% (along George Street) and 70% along (Warrandyte Road), however majority of the assessed roads are below 30%.

The dominant run-off-the-road crash type for 60km/hr roads, included within the study, was left-carriageway-straight, with 46% of all crashes falling in this category. 26% of vehicles that left the carriageway left to the right on a straight section of road while 19% were to the left of the carriageway and on a curve and the remaining 9% were to the right of the carriageway on a curve.

Poles were the most common hazard struck, with 38%, followed by trees with 19% and fences with 13%.

The offset to a roadside hazard and the number of run-off-the-road crashes per kilometre for roads with a 60km/hr speed limit are shown in Figure 27. A linear regression has been fitted to the data points; however it would indicate that there is no particular trend for this data as the $R^2$ value given from the regression is 0.0649.

Figure 28 displays the two-way traffic volume and the number of run-off-the-road crashes per kilometre for roads with a 60km/hr speed limit. A linear regression has been fitted to the data points; however it would indicate that there is no particular trend for this data as the $R^2$ value given from the regression is 0.002.

In a 60km/hr speed zone, when a vehicle leaves the carriageway it has a greater opportunity to reduce its speed to 40km/hr or below before it collides with a roadside hazard. Accordingly, there is a higher likelihood that run-off-the-road crashes in a 60km/hr speed zone will result in property damage crashes only and will not appear in CrashStats. Therefore the proportion of run-off-the-road type crashes in a 60km/hr speed zone may be under represented.
Hazard Offset and Run-Off-Road Crashes - 60km/hr Roads

\[ y = -0.3155x + 2.8596 \]

\[ R^2 = 0.0649 \]

Figure 27: Hazard Offset and Run-off-the-road Crashes for Roads with a 60km/hr Speed Zone

Traffic Volume and Run-Off-Road Crashes - 60km/hr Roads

\[ y = -9E-06x + 2.3347 \]

\[ R^2 = 0.002 \]

Figure 28: Traffic Volume and Run-off-the-road Crashes for Roads with a 60km/hr Speed Zone
70km/hr and 80km/hr Speed Zone

Of the selected road lengths, only 5 road sections had speed limits of 70km/hr or 80km/hr. These roads are as follows:

- Andersons Creek Road (70km/hr);
- Blackburn Road (70km/hr);
- Hoddle Street (70km/hr);
- Springvale Road (80km/hr); and
- Burwood Highway (80km/hr)

Along these five roads, between January 2001 and December 2005, there were a total of 489 crashes and 40 of these were run-off the road crashes; this resulted in all roads having less than 15% of the crashes being classified as run-off-the-road crashes. Within the 40 run-off-the-road crashes 60% were classified as being left-carriageway-straight while the other 40% were classified as being right-carriageway-straight.

Poles were the most common hazard struck, with 47%, followed by trees and traffic signals both with 17%.

The offset to a roadside hazard and the number of run-off-the-road crashes per kilometre for roads with a 60km/hr speed limit are shown in Figure 29. A linear regression has been fitted to the data points; where the $R^2$ value from this regression is 0.4055. There is a negative line relationship, which indicates that as the offset to the roadside hazard increases the number of crashes decreases.

Figure 30 displays the two-way traffic volume and the number of run-off-the-road crashes per kilometre for roads with a 60km/hr speed limit. A linear regression has been fitted to the data points; an $R^2$ value of 0.7108 is given for this regression. This would suggest that the linear regression is a relatively good fit for the data and that there is a strong positive relationship between the two variables. Thus as the volume increases along a section of road, the number of crashes increases.
Roads with higher operating speeds tend to result in greater energy transfer on impact when the vehicle strikes a roadside hazard and are therefore more likely to result in a serious or fatal injury. This basic premise tends to suggest that roads with higher speed limits should have a provision for a greater clear zone width to allow an errant vehicle more time to reduce speed before colliding with any roadside hazard, however it is recognised in most guidelines that there are practical and economical constraints that may prevent a recommended clear zone from being provided.
5. Outcome-based Clear Zone Options

5.1 Clear Zone Widths and Run Off Road Crash Rate

From the limited research undertaken in this study, it appears that there is some relationship between clear zone width and risk of run-off-the-road collision for a given functional road classification.

In order to determine an Outcome Based Clear Zone, a set of charts, tables and equations can be produced that define the risk of run-off-the-road collision for a given functional road classification (with variables of road type, speed limit or design speed, terrain etc).

Either the clear zone can be selected to obtain an understanding of the likely risk of run-off-the-road collision, or the desired risk of run-off-the-road collision can be selected to determine the corresponding clear zone. This approach provides a good appreciation of the crash risk corresponding to clear zone decisions.

It should be noted that substantial further analysis of crash data should be undertaken before preparing such diagrams. It is further noted that any such diagrams should be reviewed as road and vehicle design practices improve over time.

Further, as demonstrated by the analysis in Section 4.3.2, an equation of the relationship between the run-off-the-road crash risk and different road types and crash factors can be determined provided that a statistically reliable sample size is adopted.

5.2 Further Research

Overall, the approach adopted as part of this investigation has the potential to be very insightful and can be used to develop Outcome-based Clear Zone Guidelines. However, as discussed in Section 4.1.1, there have been a number of limitations in the adopted approach for this investigation, particularly given the time, resources and scope constraints.

It is recommended that future analysis into the development of Outcome-based Clear Zone Guidelines include the approach adopted as part of this assessment, with consideration to addressing the limitations identified in Section 4.1.1. Specifically:

- Collect crash history and site data from a statistically reliable sample size, including for each sub-category.
- Collect crash history and site data for a broad range of road types, areas, locations and environments. The required clear zone and crash risk for these categories can be graphically presented and an equation for the relationship identified.
- Include in the analysis consideration of a broader range of factors that may contribute to run-off-the-road type crashes (e.g. delineation, street lighting, pedestrian volumes, etc). The required clear zone and crash risk for these factors can be graphically presented and an equation for the relationship identified.
- There may be benefit in any future analysis incorporating more detailed and accurate site information (e.g. measure roadside hazards with GPS, measure lane widths, etc.)

In summary, any future assessment will be required to be considerably larger; it should follow a similar approach, as the preliminary assessment that GHD has completed however should be completed in
greater detail and with a larger selection of roads and road lengths for greater statistical conclusions to be drawn.

For a subsequent assessment to gain a greater understanding of aspects that affect the frequency and severity of single vehicular run-off-the-road crashes the following issues are recommended to investigated and included:

- Rural roads, particularly rural highways, should be included within any further investigation. Possible roads that could be included within this investigation include: Melba Highway; Maroondah Highway; South Gippsland Highway; Bass Highway; Princes Highway; Midland Highway; Hume Highway, etc.

- Further investigation of run-off-the-road crashes that occur on horizontal curves.
  - Determine if the type of curve (left curve as compared to right curve) has any effects the crashes that occur on curves;
  - Determine what affect the size and frequency of curves on a section of road has on the run-off-the-road crashes;

- Use GPS to map a small selection of roads with respect to clear zone distances;

- Map all run-off-the-road crashes for the roads included within the assessment, to determine if there are any trends for run-off-the-road crashes in particular regions of Victoria;

- Further statistical analysis of the crash data; and

- Weighting of the factors listed in Table 3 could also be completed. This would enable the factors that have been found to have a greater effect on the frequency and severity of run-off-the-road crashes to have a large effect on the clear zone width.
6. Key Findings and Conclusions

GHD defined “Outcome-based Clear Zone Guidelines” as defining a potential crash risk for a provided clear zone on a given road classification and speed limit. This varies from the traditional ‘chart based’ approach where a ‘recommended’ clear zone is defined by relevant guidelines that are not always achievable for various reasons. In this way, a more educated understanding of the type of clear zone that should be provided for a given set of parameters such as road classification, speed limit and terrain could be obtained that provides a defined crash risk rating.

GHD’s approach to the study involved the application of an evidence based approach to investigating the effect of clear zone widths on run off the road single vehicle crash rates, along with a review of current clear zone guidelines currently in practice in Australia and overseas.

Based on our review of the available literature, research and existing clear zone guidelines it would appear that the Austroads clear zone guidelines, which are adopted in Victoria, is the most conservative approach (i.e. produces the highest clear zone requirement).

Also based on our review of the available literature, the following objectives were identified as appropriate for Outcome-based Clear Zone Guidelines:

1. That the guidelines are easy to understand and apply;
2. That they eliminate or reduce impacts with objects for impact speeds above 40 km/h, and accordingly the lateral distance of the safety zone must accommodate the motions of the vehicles until this speed is reached;
3. The clear zone provided will determine a level of run-off-road risk associated with a road for a given set of parameters such as design speed, terrain and functional road classification.
4. The clear zone is to be kept free from all non-frangible hazards, where it is economically viable; and
5. Whenever a hazardous terrain feature or fixed object cannot be eliminated through redesign or made to yield on impact, shielding with an appropriate traffic barrier should be considered.

In order to have an evidence based approach to the application of clear zone widths for a range of road types, GHD investigated a number of road lengths with varying clear zone widths, road classifications, speed limits and other various factors to determine how these may relate to single vehicle run off the road crash rates.

The key findings of this report were as follows:

- Overview of clear zone guidelines literature review;
- Run-off-road crash risk increases with increasing traffic volume (exposure measure);
- Run-off-road crash risk increases with decreasing clear zone width (except for Activity Centres); and
- An outcome-based clear zone approach is possible, by categorising risk profiles for road types and speed limits. It may be possible to obtain an understanding of run-off-the-road crash risk by defining clear zone width. Then an assessment of the road design (or existing road profile) will determine the likelihood of a crash.
The investigation has indicated that there appears to be some relationship between clear zone width and risk of run-off-road collision for different factors such as the adjoining road environment, terrain and speed zone. These relationships can be plotted to determine their impact on run off the road crash rates and clear zones. In addition, equations of the relationships can be determined, provided that sufficient sample sizes are adopted.

Any future assessment will be required to be considerably larger; it should follow a similar approach, as the preliminary assessment that GHD has completed, however should be completed in greater detail and with a larger selection of roads and road lengths for greater statistical conclusions to be drawn.
7. Acknowledgements

The author would like to thank the following key people who were instrumental in the development of this study:

- Daniel Gregor, Nicole Guy, and Shaun Smedley from GHD. All were instrumental in the development of the report as part of the study team.
- Bruce Thompson, Ken Hall and Nick Szwed from VicRoads.