Relationship between Star Ratings and crash cost per kilometre travelled: the Bruce Highway, Australia

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Introduction

In 2013, RACQ, Transport and Main Roads Queensland and ARRB Group produced AusRAP Star Ratings for national highways in Queensland, Australia. These assessments were part of broader assessments of national roads undertaken around Australia, totaling more than 20,000km in length.¹ The Star Ratings were based on the newly updated iRAP model and involved an inspection of road infrastructure attributes that are known to have an impact on the likelihood of a crash and its severity. Between 1 and 5-stars were awarded depending on the level of safety which is ‘built-in’ to the road. The safest roads (4- and 5-star) have road safety attributes that are appropriate for the prevailing traffic speeds. The least safe roads (1- and 2-star) do not have the safety features required to ensure safety at the prevailing traffic speeds.

In this study a sample of the Star Ratings for vehicle occupants on one national highway – the Bruce Highway in Queensland – was compared with fatal and serious crash cost per vehicle kilometre travelled (VKT). Knowledge of the relationship between Star Ratings and crash rates is important for two reasons:

1. As a form of model validation, it is expected that on average the crash costs per VKT will increase on roads with a lower Star Rating. For example, we would expect that (after adjusting for traffic volume) a road with a 1- or 2-star rating would have more crashes than a road with a 3- or 4-star rating.

2. To provide knowledge of the crash cost savings that can be achieved through improvements in road infrastructure. This allows road users and authorities to understand the economic benefits to be achieved from improving the Star Rating of roads.

This study follows from similar comparisons that have been conducted in the past which are summarised by Lawson (2011).²

Methodology

This study involved the calculation of average vehicle occupant fatal and serious injury crash costs per VKT for each vehicle occupant Star Rating category.

Star Ratings

Vehicle occupant Star Ratings for 1,674km of the Bruce Highway, which connects Brisbane in the south with Cairns in the north, were compiled.³ The results of the assessment are shown below in Figure 1.

¹ At time of writing this paper, national network results had not yet been published.
³ Rural is defined as roads with a speed limit of 80km/h and above.
The Star Ratings used in this assessment were calculated using version 3 of the iRAP methodology. In this process, Star Ratings were calculated for each 100 metre segment of road and then ‘smoothed’ across consecutive 100 metre segments to determine an average Star Rating for homogenous lengths of road. The ‘smoothed’ Star Rating for each 100 metre segment was used in this study. The 100 metre segments were also labeled according to Transport and Main Roads Queensland’s link number, carriageway code and chainage, enabling them to be matched with crash and traffic volume data.

The Star Ratings shown in Figure 1 are for rural sections of highway, which are of particular interest to AusRAP. Rural roads are defined as those with a speed limit of 80km/h or more. Earlier comparison results for rural and urban roads are presented in the Appendix to this paper.

Although Star Ratings for motorcyclists, bicyclists and pedestrians had also been calculated for the Bruce Highway, these ratings were not used in this study because the crash data sample size for these road users was small.

The Star Ratings were based on video images of the Bruce Highway that were collected in 2011. Infrastructure changes to the Bruce Highway might have occurred throughout the crash data sample period (2007-2011, see below). The Star Ratings cannot account for those changes as they relate to a snap-shot at a point in time. It is expected that those sections where changes have occurred are relatively small in length compared with the overall length of the network, and so are expected to have a minimal impact on the comparison results.

**Fatal and serious crash costs per vehicle kilometre travelled**

In principle Star Ratings are independent of traffic volume (though volumes are used indirectly in the calculations, such as to determine the relative proportions of run-off and head-on crashes). This reflects the primary focus of Star Ratings on the risk of death or serious injury associated with infrastructure attributes and the impact of the road on

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4 In previous assessments, an earlier version of the AusRAP methodology was used.
5 For more information about the iRAP methodology, see *Star Rating Roads for Safety: The iRAP Methodology.*
an individual road user. Since Star Ratings relate to risk for an individual road user, the primary relationship of interest is the star ratings with crash costs per VKT, thus accounting for both the number and severity outcome of crashes.

Transport and Main Roads Queensland report that during the five year period from 2007 to 2011, 1,770 fatal and serious injury crashes were reported on the section of the Bruce Highway. For this study, a number of crashes were removed from the dataset, as follows:

- 78 crashes were removed from the dataset because they had carriageway labels that did not match the Star Rating dataset. This included crashes that occurred on off-ramps, over-passes and under-passes.
- A further 213 crashes were removed because they did not involve a vehicle occupant. A vehicle occupant crash is one involving a car, station wagon, utility, panel van, truck, articulated truck, omnibus, special purpose vehicle (tractor etc), road train, b-double or b-triple.
- A further 442 crashes were removed because they were on sections of road where Star Ratings had not been calculated, such as in major urban areas (this issue is discussed further in the Appendix).

This left a crash sample of 1,037 fatal and serious injury vehicle occupant crashes. Each crash was then matched with its corresponding 100 metre Star Rating road segment based on link number, carriageway code and chainage.

The cost of crashes on each 100 metre segment of road was estimated using values provided by Transport and Main Roads Queensland, as summarised below in Table 1. These costs were calculated using the ‘Willingness to Pay’ approach.

<table>
<thead>
<tr>
<th>Crash severity</th>
<th>Rural (&gt;= 80 km/h)</th>
<th>Urban (&lt; 80 km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>$7,787,700</td>
<td>$6,464,600</td>
</tr>
<tr>
<td>Serious (admitted to hospital)</td>
<td>$802,900</td>
<td>$539,100</td>
</tr>
</tbody>
</table>

According to Transport and Main Roads Queensland, in 2011, sections of the Bruce Highway carried between 2,500 vehicles per day (vpd) and 50,200 vpd. These traffic volumes were matched with their corresponding 100 metre Star Rating road segments based on link number, carriageway code and chainage. The estimated total distance traveled (VKT) in each segment over a five year period was then calculated.

Using these data, the vehicle occupant fatal and serious injury crash cost per vehicle kilometer traveled was calculated for each 100 metre Star Rating road segment.

**Comparison**

Utilising the full data-set, the average vehicle occupant fatal and serious injury crash costs per VKT for each Star Rating category was then calculated.

**Results**

The results of the comparison are shown below in Table 2 and Figure 2. The results show that there is a very clear relationship between vehicle occupant Star Ratings and fatal and serious injury crash costs per vehicle kilometre travelled (VKT), such that:

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6 A serious injury crash is one in which at least one person was admitted to hospital.

7 A vehicle occupant crash is one involving a car, station wagon, utility, panel van, truck, articulated truck, omnibus, special purpose vehicle (tractor etc), road train, b-double or b-triple.
• crash costs on 2-star roads are 40% lower than on 1-star roads
• crash costs on 3-star roads are 61% lower than on 2-star roads
• crash costs on 4-star roads are 44% lower than on 3-star roads (and 86% lower than on 1-star roads)

Table 2 Comparison results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46</td>
<td>567,667,345</td>
<td>$84,240,100</td>
<td>$0.148</td>
</tr>
<tr>
<td>2</td>
<td>616</td>
<td>12,522,941,585</td>
<td>$1,120,844,200</td>
<td>$0.090</td>
</tr>
<tr>
<td>3</td>
<td>305</td>
<td>11,983,984,593</td>
<td>$423,319,600</td>
<td>$0.035</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>4,582,386,295</td>
<td>$9,086,320</td>
<td>$0.020</td>
</tr>
<tr>
<td>5*</td>
<td>0</td>
<td>4,854,500</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Total</td>
<td>1037</td>
<td>29,661,834,318</td>
<td>$1,719,267,100</td>
<td>$0.059</td>
</tr>
</tbody>
</table>

* The sample of 5-star roads is too small to enable a comparison.

Figure 2 Smoothed vehicle occupant Star Ratings and fatal and serious injury crash costs per vehicle kilometre traveled

It is acknowledged that the sample sizes for the 1-star and 4-star categories are relatively small (and no analysis for 5-star category was possible), and so these results should be treated with a degree of caution. Nevertheless, the large differences between crash costs in each Star Rating category suggest a trend.

Conclusion

Between 2007 and 2011, a total of 1,037 vehicle occupant fatal and serious injury crashes occurred on the sections of Bruce Highway assessed, at an estimated cost of more than $1.7 billion to the Queensland economy. The AusRAP assessment helps to explain this high-level of trauma, with a significant length of the Bruce Highway infrastructure...
rated in the relatively high-risk categories of 1- or 2-stars for vehicle occupants. Nearly half (44%) of all travel on the Bruce Highway occurs on these roads.

The results of this study provide a means of quantifying the social and economic benefits that would be realised by improving Star Ratings of the Bruce Highway. The results show that there is a relationship between vehicle occupant Star Ratings and fatal and serious injury crash costs per vehicle kilometre travelled (VKT), such that:

- crash costs on 2-star roads are 40% lower than on 1-star roads
- crash costs on 3-star roads are 61% lower than on 2-star roads
- crash costs on 4-star roads are 43% lower than on 3-star roads (and 86% lower than on 1-star roads)

The implication of this study is clear: by improving the Star Ratings of the Bruce Highway, large reductions in fatal and serious injury crash costs would be achieved.

**Acknowledgments**

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Appendix: Earlier Research

During the development of what is known as ‘version 3’ of the iRAP model, which is now used by AusRAP, regular validation testing was conducted in order to refine the model’s parameters. This analysis followed the same methodology described in the main body of this paper, but a slightly different data set was used which, in particular, included a sample of urban roads. Although AusRAP’s focus is on rural roads, the iRAP model is applied to urban roads around the world. As such, validation testing using data for both rural and urban roads was important.

Furthermore, because this comparison was undertaken during the model’s development, slightly different model parameters were used than in the comparison discussed in the main body of this paper. This included different Star Rating threshold levels (for example, between 1-star and 2-stars), which helps to explain the relatively small percentage of roads in the 1-star category compared to the corresponding table in the main report.

Overall, the pattern of the relationship between Star Ratings and crash costs is the same: as Star Ratings improve, crash cost decline. The sample sizes for the 1-star, 4-star and 5-star categories are relatively small so these results should be treated with a degree of caution.

Table A1  Comparison results (during model development)

<table>
<thead>
<tr>
<th>Vehicle Occupant Star Rating</th>
<th>Vehicle kilometers traveled (VKT), 2007-2011</th>
<th>Total KSI crash cost, $ 2011 terms</th>
<th>Average fatal and serious injury crash cost per VKT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Star</td>
<td>8,523,845</td>
<td>$1,605,800</td>
<td>$0.19</td>
</tr>
<tr>
<td>2 Star</td>
<td>10,096,474,145</td>
<td>$949,389,600</td>
<td>$0.09</td>
</tr>
<tr>
<td>3 Star</td>
<td>16,825,515,778</td>
<td>$589,095,000</td>
<td>$0.04</td>
</tr>
<tr>
<td>4 Star</td>
<td>7,243,061,643</td>
<td>$130,109,400</td>
<td>$0.02</td>
</tr>
<tr>
<td>5 Star</td>
<td>4,121,684,573</td>
<td>$27,057,300</td>
<td>$0.01</td>
</tr>
<tr>
<td></td>
<td>38,295,259,984</td>
<td>$1,697,257,100</td>
<td>$0.04</td>
</tr>
</tbody>
</table>

Figure A1  Smoothed vehicle occupant Star Ratings and fatal and serious injury crash costs per vehicle kilometre traveled for urban and rural road sections combined (during model development)