Brunei iRAP – Speed Management and Infrastructure Improvements

Shane Turner[a], Mike Smith[b], Marc Robson[a]

[a] MWH Global (now part of Stantec) New Zealand; [b] MWH Global (now part of Stantec) Brunei

Abstract

Brunei have made considerable investment in improving the design and safety of their road transport infrastructure over the last 20 years. Like almost all countries, Brunei (on the island of Borneo) are still not happy with the level of road trauma (fatal and serious injury crashes) on their roads and the impact this has on families and communities. In 2014 they decided to undertake an iRAP assessment of their strategic routes (just over 500km of their network) to determine what else could be done to reduce road trauma. The findings of the iRAP assessment did indicate that Brunei has a relatively safe network, compared with other ASEAN and developed countries. Around 45% of all roads (urban and rural) and 63% of highways (rural/high speed) had a three star rating or better (the rating varies from one star which is poor to five star which is excellent). Two safety road investment program (SRIP) scenarios were developed using the VIDA (iRAP) analysis tool.

Scenario One includes infrastructure upgrades with a cost of at least BND$42M. Scenario One, when fully implemented, is expected to increase the number of 3 star plus roads to 85%. Scenario Two includes both speed management (reducing operating speeds by typically 5 to 10km/h on all highways and main roads) and infrastructure upgrades. The infrastructure upgrades will be at least BND$36M. Scenario Two, when fully implemented, is expected to increase the number of 3 star plus roads to over 95%. Brunei is one country where a minimum three star rating for all highways and strategic main roads is within reach.

Introduction

Deaths and injuries from road vehicle crashes are a major and growing public health epidemic. Each year 1.3 million people die and a further 50 million are injured or permanently disabled in road crashes. Road crashes are now the leading cause of death for children and young people aged between 10 and 24. The burden of road crashes is comparable with malaria and tuberculosis and costs 1-3% of the world's GDP (Geneva, WHO, 2009).

While the number of fatal and serious injury crashes in Brunei (at around 100 per year) are relatively low compared with the global figures, the grief and suffering caused by road crashes still has a major impact on families and communities within this small country of around 400,000 residents. Hence the strong desire by the Government to continue to drive down the number of fatalities and serious injuries (hospitalisations). A key element of this commitment has been the major investment in highway infrastructure over the last twenty years. The other key areas of focus being safer road users and safer vehicles. With a relatively young vehicle fleet Brunei does benefit from improvements in vehicle safety. Driver behaviour still needs further attention, particularly around speeding and seatbelt wearing.

Given the high investment in infrastructure over the last twenty years it is important to understand the level of safety the current highway network provides and what further work could be done to reduce crash rates further. The iRAP road assessment approach is an excellent way of understanding the crash risks along the strategic road network and targeting improvements that address these risks. Of particular interest in Brunei is the high operating speeds on urban roads, given the relatively high speed limits, and many drivers travelling above these speed limits.

The iRAP package of tools includes the development of safer roads investment programme (SRIPs) to lower crash risks further. This normally focuses on infrastructure improvements. In the case of Brunei the investment program also included speed management. Initially it is suggested that a speed management program focuses on getting drivers to travel within the current speed limits, before considering whether the speed limits themselves need to be lowered.

This paper first outlines the iRAP process before presenting details on the 2014 safety performance of just over 500km of both urban and rural single and dual carriageway highways and main roads in Brunei. It then presents two safety improvement upgrade scenarios that are expected to reduce serious and fatal crashes significantly across this strategic road network.

International Road Assessment Programme (iRAP)

The International Road Assessment Programme (iRAP - www.irap.org) has drawn upon the extensive knowledge base of the developed world's Road Assessment Programmes (EuroRAP, AusRAP and usRAP), to develop a road survey methodology for all countries. This Star Rating methodology does not require detailed crash data and works directly from road surveys. The iRAP approach has been applied in over 70 countries.

The iRAP Protocol used internationally has four stages:

1. **Risk Maps**; where detailed crash data is available maps can illustrate the actual number of deaths and injuries on a road network (good quality data is not readily available in Brunei).
2. **Star Ratings** provide a simple and objective measure of the level of safety provided by a road's design.
3. **Safer Roads Investment Plans** draw on approximately 90 proven road improvement options to generate affordable and economically sound infrastructure options for saving lives. Multiple investment plans should be created with different scenarios and goals to highlight the beneficial aspects of each and drive a forwards work programme to improveroad safety.
4. **Performance Tracking** enables the use of Star Ratings and Risk Maps to track road safety performance and establish policy positions.

Star Ratings provide a simple and objective measure of the relative level of risk associated with road infrastructure for an individual road user. 5-star (green) roads are the safest, while 1-star (black) roads are the least safe. Figure 1 shows photo examples of the various star rating levels. Notice that the location and type of road-side hazards and presence of shoulder is important in the 'vehicle' star rating. For the higher standard roads both shoulder and median barriers are provided from extra protection of drivers. Importantly, Star Ratings can be produced without reference to detailed crash data.

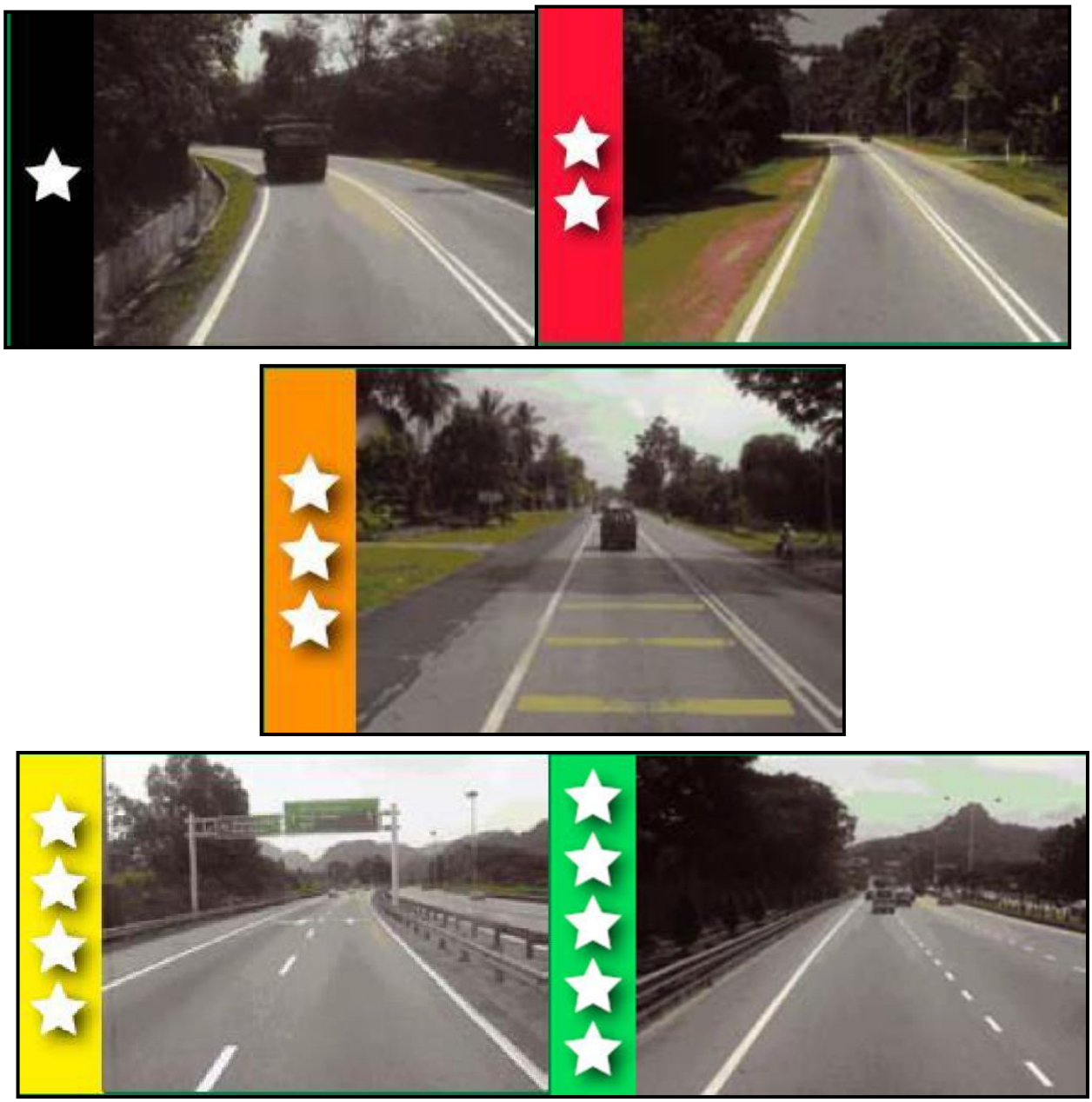

Figure 1 - Examples of different Vehicle Star Rating roads (Malaysia, source iRAP website)

iRAP Star Ratings are based on the engineering features of the road and the degree to which they impact on the likelihood and severity of crashes (see Figure 2). Data on engineering features are coded at 100m intervals along the surveyed roads. The focus is on the features that influence the most common and severe types of road crash for motor vehicles, motorcyclists, pedestrians and bicyclists. The volume and speed of vehicles is also a key factor in crash occurrence.

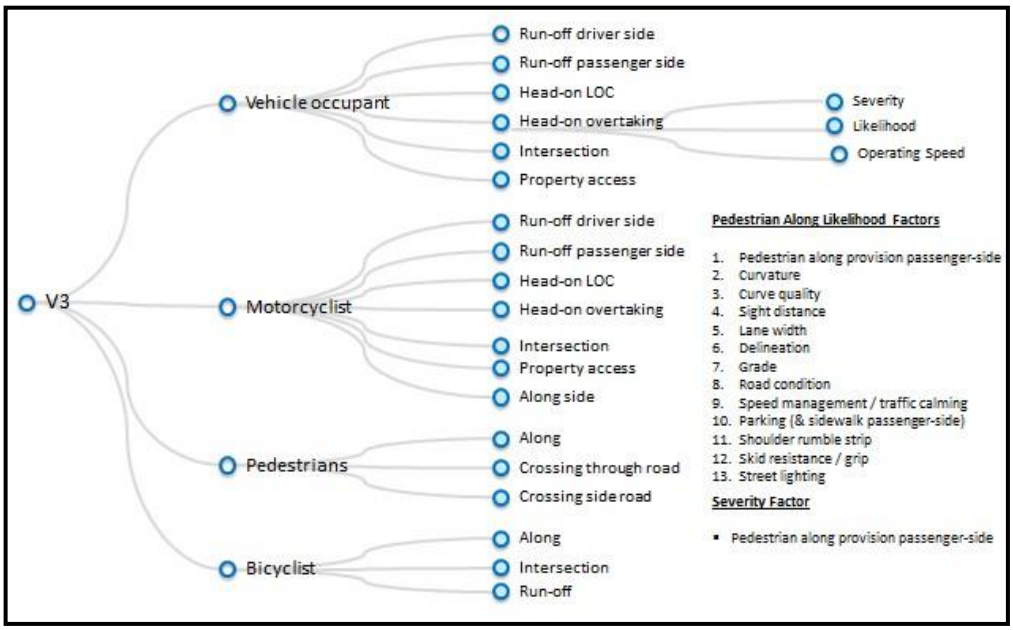

Figure 2 – Main crash types considered for each mode and example of crash variables examined - in this case for pedestrians walking alongside road (source iRAP website)

Brunei iRAP Data Collection

The surveyed network consisted of 535 km of strategic routes and main arterials (single and dual carriageway). These roads were selected by the Brunei Department of Roads and were surveyed between 3rd and 16th of December 2014. The location of roads surveyed in Brunei (which is a small country in the northern part of the island of Borneo) are shown in Figure 4. The main highway /motorway travels along the coast (the bottom left of the diagram to the top right). The separate section of black and red highways is in the Tempurong (popular for eco-tourism) region which is separated from the other regions of Brunei (Muara, Tutong and Belait) by part of the Malaysia state of Sarawak. Access to this area is by boat or car through Sarawak.

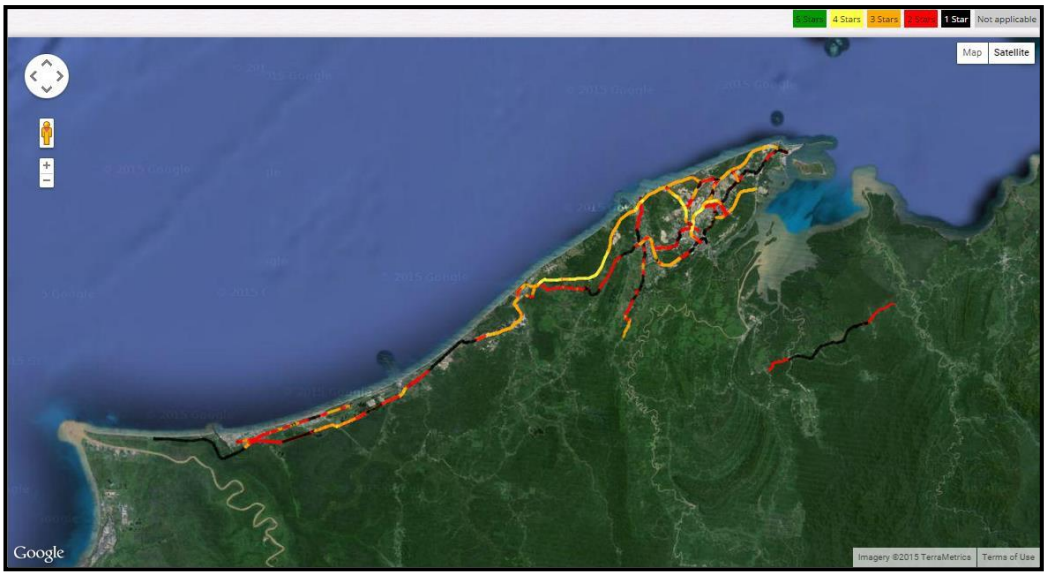

Figure 4 - Strategic Brunei Road Network (surveyed)

Dual carriageway roads have been surveyed in both directions. The surveyed network includes approximately 10% of all roads in Brunei, and the majority of the strategic and high volume urban and high speed routes. All the countries motorways and highways are included.

To calculate the Star Rating of each section of route the entire survey network was videoed, and from this feature data has been coded at 100m intervals. In excess of 60 speed and traffic volume counts were collected (for a representative sample of routes), as this data was not readily available. Countermeasure costs were estimated using Malaysia unit construction costs. The crash saving benefits for each serious and fatal crash were collated (based on willingness to pay for fatalities). Aggregated crash data was also provided for the last two years to calibrate the iRAP model to Brunei conditions.

The predicted distribution of fatal and serious crashes across the Brunei network is expected to decreases by around 60-65% for each improvement in Star Rating band (e.g. upgrading a road from the middle of the 2 star band to the middle of the 3 star band will reduce fatal and serious injury crashes by around 60 to 65%). A four star road is predicted to have between 80% and 90% less fatal and serious injury crashes (per user) than a two star road (full 2 band shift). So an improvement in star ratings of one and two star roads can lead to a major difference in the number of serious injury and fatal crashes.

While motor vehicle occupants are the primary mode of transportation in Brunei, pedestrians, bicyclists, and motorcyclists star ratings were developed so that this can be considered in the design of new roads and safety improvements. The weight being placed on a safer design for each mode should reflect the likely future use of each corridor. Hence routes that may be promoted for bicycle use need a better star rating for bicycles compared with those where cycling is less likely.

The goal being to increase the proportion of trips by each mode that occur on higher star rated roads.

Current Performance of Network

Table 1 shows the star rating table for all four road user types, vehicle occupants, pedestrians, bicyclists, and motorcyclists. Figure 6 and 7 show the star rating maps for vehicle occupants and pedestrians (showing facility ratings only in areas pedestrians were observed). The star rating of the road, both urban and rural, in Brunei compares well with those of other developed countries and generally above that of other ASEAN countries. It shows that 45% of strategic roads have a star rating of three or better for vehicle occupants. Further investigation indicates that 63% of motorways have three star or better.

A review of the star rating scores indicate that the proportion of roads that have three stars for vehicle occupants, and particularly urban roads, would increase markedly if the high operating speeds on Brunei roads could be reduced. The infrastructure for walking, cycling and motor-cycling is fairly poor. Fortunately there are few serious and fatal crashes involving these modes. But some routes are used by these modes, and should have better infrastructure provided.

Pedestrians can be protected through the provision of safe crossing places such as at signalised crossings and overpasses, and protected at mid-point locations through wider and increased separation of footpaths and pedestrian fencing.

Smoothed Star Ratings - Before countermeasure implementation								
	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
Star Ratings	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent
5 Stars	0.00	0%	0.00	0%	0.10	0%	0.00	0%
4 Stars	38.30	7%	0.00	0%	3.30	1%	0.00	0%
3 Stars	205.60	38%	16.70	3%	7.70	1%	3.40	1%
2 Stars	170.00	32%	177.20	33%	40.10	7%	77.60	15%
1 Star	118.10	22%	338.10	63%	187.80	35%	353.20	66%
Not applicable	2.70	1%	2.70	1%	295.70	55%	100.50	19%
Totals	534.70	100%	534.70	100%	534.70	100%	534.70	100%

Table 1 – 2014 Star Ratings Table

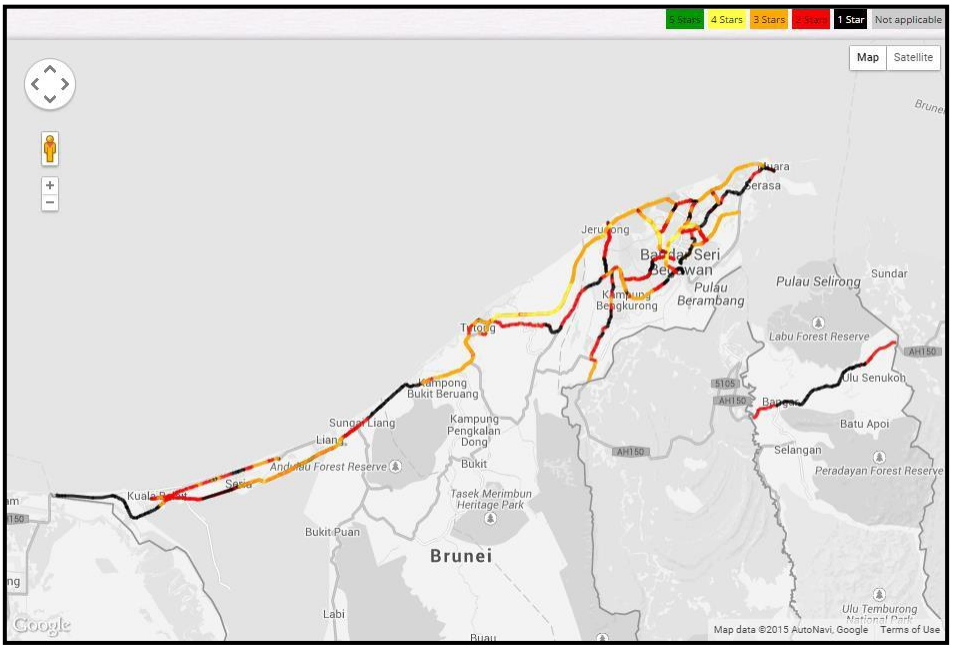

Figure 5 - Vehicle Occupant Star Rating Map (smoothed)

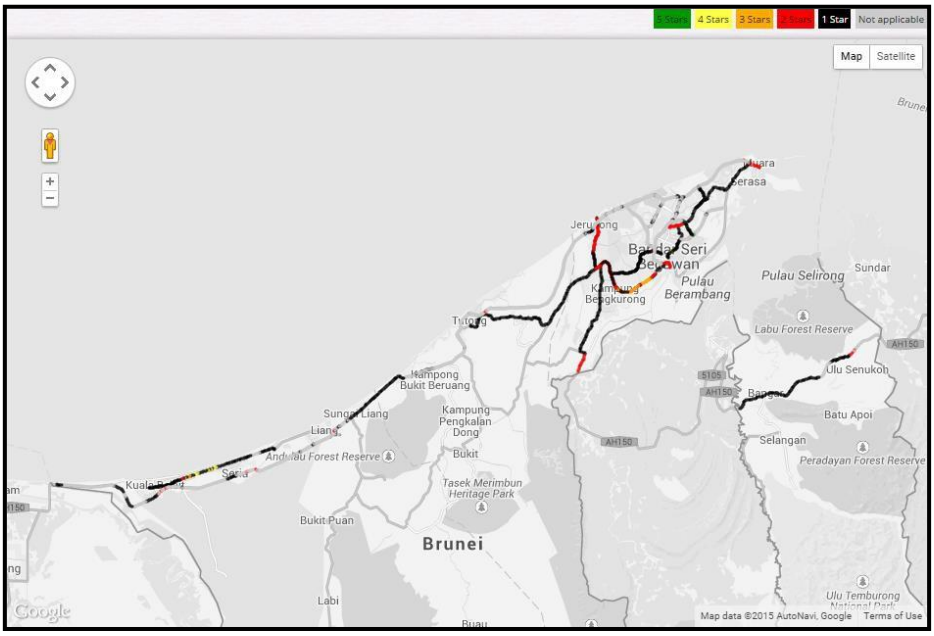

Figure 6 - Pedestrian Star Rating Map (smoothed)

Safer Road Investment Programmes (SRIPs)

A Safer Roads Investment Plan (SRIP) shows a list of affordable and economically sound road safety treatments (or countermeasures), specifically tailored to reduce risk on the surveyed network (see Figure 7 for examples). Each countermeasure proposed in the SRIP is supported by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way, i.e. it is suggested that the countermeasures listed will save more in crash costs prevented than it costs to construct and maintain the feature. Nevertheless, each countermeasure should be regarded as a recommendation only for further investigation and must be subject to additional prioritisation, concept planning and detailed design before implementation. Although the results shown here were generated using a cost-benefit ratio (BCR) threshold of 3 (only treatments that return benefits three times their implementation cost or better); this cut-off can be increased in order to produce a smaller and less costly programme of works, or decreased in order to produce a larger and more costly programme of works, to suit the available budget. The countermeasure unit costs are currently based on Malaysian construction costs.

Figure 7 – Examples of proven road safety treatments/countermeasures

Two scenarios have been run to produce two different SRIP, with different costs and outcomes. A scenario involves the application of a series of countermeasures to the surveyed (or baseline) road network. For each scenario the reduction in fatal and serious crashes (for a given cost) is predicted. The crash reduction is the sum of crash reduction benefits of a large number of upgrade treatments.

The unit treatment costs are currently based on Malaysian unit costs for each treatment type converted into Brunei dollars.

Scenario 1 - Infrastructure Improvements Only

The first scenario includes a number of road safety treatments that have at least an initial cost-benefit ratio of 3 or higher and no change in operating speed for each speed limit and road type. The treatments are generated by algorithms in the VIDA tool, which is the platform that the iRAP organisation has produced for storing and analysing iRAP data for each country that has collected this information. The treatment analysis tool (in VIDA) looks at each road deficiency (that leads to a lower star rating) and look at the range of improvement options that could be implemented to address that deficiency. For example shoulder barriers can be implemented to prevent drivers going into hazardous road-sides. It selects those treatments that have a cost-benefit ratio (crash saving benefits divided by treatment costs) that is at or above the cut-off. In this case the BCR cut-off is 3 or more.

The Safer Roads Investment Plan (SRIP) for Scenario One includes various works, the most effective and prolific are:

- 25 km of road duplication and central median barrier mostly on the Rasau Bypass – this cost appears low but has a programme BCR provisionally of six
- 128 km of roadside barrier and 151 km of roadside hazard removal – roadside hazards contribute significantly to crash severity, hazard protection through semi-rigid barrier systems is often more effective than clear-zone work through hazard removal
- 73 km of high fiction surfacing – road surfacing quality was based on a brief visual inspection rather than a measured process and so surfacing condition within iRAP is not necessary representative of actual skid resistance available
- 314 km of shoulder rumble strips – rumble strips provide audio and tactile awareness to vehicle drivers that they are straying from the traffic lanes. Centreline rumble strips are effective low cost short term treatments prior to duplication or a central median barrier
- 73 km of route and curve delineation

Table 2 shows the star rating that are expected when Scenario One is fully implemented. This proposed scenario is estimated to reduce deaths and hospitalisations by 20 annually including approximately 7 fatalities. A total of approximately BND$250M in safety benefits over 20 years for a capital expenditure in excess of BND$43M and an overall cost-benefit ratio of 6.

Under this scenario the length of road with a (vehicle occupant) star rating of three or more improves from 45% to 85% of the surveyed network. This includes 20% of the road length being rated at four or five stars. Approximately 90% of vehicle kilometres travelled would be on three or higher star roads and 25% of vehicle kilometres would be on four and five star roads. The length of roads with one star is very low and two star is less than 20%.

Smoothed Star Ratings - After countermeasure implementation

	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
Star Ratings	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent
5 Stars	18.60	3%	0.00	0%	0.10	0%	6.80	1%
4 Stars	98.50	18%	1.00	0%	6.40	1%	1.00	0%
3 Stars	346.00	65%	113.60	21%	20.50	4%	10.90	2%
2 Stars	61.10	11%	340.50	64%	121.80	23%	189.40	35%
1 Star	7.80	1%	76.90	14%	90.20	17%	226.10	42%
Not applicable	2.70	1%	2.70	1%	295.70	55%	100.50	19%
Totals	534.70	100%	534.70	100%	534.70	100%	534.70	100%

Table 2 - Scenario One Star Ratings Table

Scenario 2 – Speed Management and Infrastructure Improvements

In Scenario 2 both speed management and infrastructure treatments have been considered. Like many countries in South East Asia speeding is a major issue in Brunei and it does have a big bearing on the number of serious and fatal crashes. Table 3 shows the improvement in operating speed (85th percentile and mean speeds) by speed limit that have been assumed for this scenario. This reduction in operating speeds seems reasonable in the short to medium term. Ideally speeds

could be reduced further, especially in urban areas. Further refinement of this scenario (and the assumed speed changes) would be undertaken once a speed management strategy has been developed for Brunei. A speed management strategy needs to consider the level of investment in education and enforcement that might be required to achieve particular operating speed targets.

Table 3. Maximum 85th percentile and mean speeds for various posted speed limits

Posted Speed Limit	**Reported Speed Range**		**Scenario 2 Maximum**		**Scenario 2 Maximum 85th**
	Mean	**85th**	**Mean**	**85th**	**Speed Reduction**
50 km/h	80 km/h – 65 km/h	95 km/h – 75 km/h	55 km/h	65 km/h	30 km/h
65 (70) km/h	70 km/h – 50 km/h	80 km/h – 60 km/h	65 km/h	75 km/h	5 km/h
80 km/h	85 km/h – 80 km/h	95 km/h	80 km/h	90 km/h	5 km/h
100 km/h	95 km/h – 85 km/h	105 km/h – 95 km/h	90 km/h	95 km/h	10 km/h

Once the operating speeds were adjusted, the iRAP tools (in VIDA) have been used to develop the SRIP for the lower speed network based on a cost-benefit cut-off for each treatment of 3.

The SRIP for Scenario 2 includes various works, the most effective and prolific are:

- 25 km of road duplication and central median barrier mostly on the Rasau Bypass – this cost appears low but has a programme BCR provisionally of six
- 104 km of roadside barrier and 220 km of roadside hazard removal – roadside hazards contribute significantly to crash severity, hazard protection through semi-rigid barrier systems is often more effective than clear zone work through hazard removal
- 60 km of high fiction surfacing – road surfacing quality was based on a brief visual inspection rather than a measured process and so surfacing condition within iRAP is not necessary representative of actual skid resistance available
- 167 km of shoulder rumble strips – rumble strips provide audio and tactile awareness to vehicle drivers that they are straying from the traffic lanes. Centreline rumble strips are effective low cost short term treatments prior to duplication or a central median barrier
- 56 km of route and curve delineation

Table 4 shows the overall changes in star rating of this scenario.

Smoothed Star Ratings - After countermeasure implementation								
	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
Star Ratings	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent
5 Stars	27.50	5%	0.00	0%	0.10	0%	0.20	0%
4 Stars	119.80	22%	2.00	0%	6.40	1%	2.50	0%
3 Stars	349.00	65%	187.20	35%	18.10	3%	22.30	4%
2 Stars	33.90	6%	281.70	53%	130.40	24%	193.70	36%
1 Star	1.80	0%	61.10	11%	84.00	16%	215.50	40%
Not applicable	2.70	1%	2.70	1%	295.70	55%	100.50	19%
Totals	534.70	100%	534.70	100%	534.70	100%	534.70	100%

Table 4 - Speed Management with Physical Works Star Rating Table

This proposed SRIP is estimated to reduce deaths and hospitalisations by 22 annually including approximately eight fatalities on the surveyed network. It would have a benefit of approximately BND$190M over 20 years for a capital expenditure of BND$36M. For this scenario the vehicle occupant star rating of three stars or more increases from 45% to 95% by road length. In addition approximately 25% of the road length would be rated as four or five Stars.

Summary and Conclusions

The iRAP assessment of Brunei's strategic road network (in 2014) shows that approximately 45% of strategic roads (and 63% of motorways) have a star rating of three or better for vehicle occupants. The network is performing relatively well compared with other countries in the ASEAN region and many developing countries. However there is plenty that could be done to make the network safer for a relatively low cost (around BND$35M to $50M). Indeed Brunei is well placed to achieve a minimum three star rating on all strategic roads, especially if operating speeds can be reduced.

Two safer road improvement programme (SRIP) scenarios were developed to show how the risk of serious injury and fatal crashes could be reduced on Brunei strategic road network. Scenario One includes infrastructure upgrades with a cost of BND$42M. Scenario One, when fully implemented, is expected to reduce the number of fatal and serious crashes per year by 20 (a saving of 7 to 8 fatalities), and increase the number of 3 star plus roads to 85%.

Scenario Two includes both speed management (reducing operating speeds by typically 5 to 10km/h on all highways and main roads) and infrastructure upgrades. The infrastructure upgrades will be around BND$36M. The speed management costs, which will be ongoing, are yet to be priced. Scenario Two, when fully implemented, is expected to reduce the number of fatal and serious crashes per year by 22 (a saving of 8 to 9 fatalities), and increase the number of 3 star plus roads to 95%.

Further analysis could be undertaken to determine how this remaining 5% of roads could be upgraded to at least three stars. Such an achievement would make Brunei one of the first countries internationally to achieve this goal of all strategic roads being three stars or better.

References

Global status report on road safety: time for action. Geneva, World Health Organization, 2009 (www.who.int/violence_injury_prevention/road_safety_status/2009).