ASSESSING THE SAFETY OF VIETNAM'S NATIONAL ROADS

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ABSTRACT

More than 30 people are killed in road crashes in Vietnam every day. For each person killed, many more are seriously injured requiring admission to hospital. Nationally, road crashes are estimated to cost the equivalent of 1-3% of the nation's Gross National Product (GNP) [1]. 6 out of 10 patients in the Viet Duc University Hospital trauma centre with injuries are victims of road crashes [2].

In 2009, the Ministry of Transport (MOT), Vietnam Road Directorate (VRD), Transport Development and Strategy Institute (TDSI) and Institute of Transport Science and Technology (ITST) undertook an infrastructure-based risk assessment of 3,500km of national highways and developed a high-level plan of economically viable countermeasures. The project was assisted by numerous other organisations, including ARRB Group and the Global Road Safety Partnership (GRSP). The safety assessment approach used builds on decades of research and experience into the factors which influence the likelihood of crashes occurring and their severity. This paper presents the approach taken in the assessment of Vietnam national roads, results and outcomes.

1. INTRODUCTION

The International Road Assessment Programme (iRAP) was invited by the Vietnam Government to undertake an assessment of road infrastructure risk on national roads and develop a high-level plan of economically viable road safety countermeasures. The Vietnam Government's focus on road safety, through the National Traffic Safety Committee and associated agencies, provided a strong foundation for undertaking an iRAP project in Vietnam.

The project was established with financial support from the World Bank Global Road Safety Facility and the leadership and participation of the Ministry of Transport (MOT), Vietnam Road Directorate (VRD), Transport Development and Strategy Institute (TDSI) and Institute of Transport Science and Technology (ITST). This paper represents the culmination of a highly successful partnership between the organisations that participated in the project. The paper provides an overview of the approach taken in the project and key findings.

2. ROAD SAFETY IN VIETNAM

Road crashes are one of the top three causes of death for people aged between 5 and 44 years of age worldwide. The World Health Organisation estimates that 1.3 million people are killed each year in road crashes and unless preventative measures are put in place, this figure will almost double by 2030 [1]. In Vietnam, around 13,000 people are killed each year in road crashes – more than 30 deaths every day. For each person killed, many more are seriously injured requiring admission to hospital [3]. In the Viet Duc University Hospital trauma centre, the major trauma referral centre for Northern Vietnam, 6 out of 10 patients with injuries are victims of road crashes [2].

Such a high level of trauma puts enormous strain on Vietnamese society and the economy. Road crashes are often the factor responsible for tipping a household into financial distress. The loss of an income earner due to death or disability can be disastrous, leading to lower living standards and poverty. Nationally, road crashes are estimated to cost the equivalent of 2-3% of the nation's Gross National Product (GNP) through lost productivity, emergency services costs, property damage and, perhaps most significantly, health care [2]. It is reported that road crash injuries absorb more than 75% of some urban hospital budgets [4].

Road death statistics for Vietnam are characterised by the very high number of motorcyclist deaths, which account for up to 90% of road deaths in some cities [5]. This situation has evolved after a rapid increase in the number of motorbikes on the streets of Vietnam – registered vehicles jumped more than 300% from 2001 to 2008, putting Vietnam among the world's most rapidly motorising nations [6]. This corresponds with Vietnam's status as one of the fastest growing economies in the world. The development of roads and other transport infrastructure has not been able to keep pace with this rapid growth [7].

Another feature of road deaths in Vietnam is the distinct differences in crash type by age group. As children get older, their level of mobility increases, and consequently their risk of death or serious injury do too. Children aged 0-9 years are most commonly killed as pedestrians; children aged 10-14 most commonly die while riding a bicycle; and adolescents aged 15-19 are mostly killed on a motorcycle [8].

Vietnam's experience in achieving universal helmet use was a critical response to the growing crisis of motorbike-related fatalities in the country and represents an important step towards developing a safe system. In 2007 fewer than 3% of people wore helmets and traffic crashes were the leading cause of death for people aged 18-45. Resolution 32/2007/ND-CP required universal helmet use from December 15, 2007, increasing helmet-use rates to 99%. The impact has been dramatic. Deaths from traffic accidents dropped 12% relative to the previous year and injuries were down 24% [6].

iRAP's role is to focus on the 'safe roads' element of the safety equation, in the context of safer road users, safer vehicles and safe roads. iRAP builds on the experience of developed countries that have a proven track record in infrastructure safety and, with the support of local engineers and researchers, applies knowledge and technical processes that are applicable for low and middle-income countries.

An important principle for iRAP is the application of countermeasures on a large scale. Experience from the health sector has taught us that large-scale application of proven treatments is essential in eradicating wide-spread epidemics. Operation Smallpox Zero for example, was responsible for eradicating this deadly disease in just ten years. The programme of Smallpox vaccinations was described as a triumph of World Health Organisation management, not of medicine.

3. ROAD INSPECTIONS

In total, 3,500km of national highway were inspected. These include highways: 1, 3, 5, 9, 10, 18, 19, 20 and 51. They were selected by the local partners because of their higher traffic volumes and higher crash rates; they carry 2% of the nation's road network but are estimated to account for 12% of the nation's road deaths. The locations of the roads are illustrated in maps shown later in this paper.

Road inspection data for the highways was collected by ARRB Group from March to April 2009, using a vehicle specially equipped with digital cameras to record panoramic images of the road and roadsides and location data as it travelled at highway speed (see Figure 1). The images were calibrated to enable on-screen measurements of the road features and the system enabled automated measurement of horizontal curvature and vertical grades.

Figure 1 - The iRAP Vietnam inspection vehicle

In addition to inspecting the highways, the iRAP and ARRB team used various opportunities to help build knowledge and capacity of local engineers. These included:

- equipment demonstrations and information sessions for over 15 local stakeholder staff members in Ha Noi
- four project briefings and demonstrations in the VRD Regional Road Maintenance Units (RRMU) across Vietnam. Approximately 50 stakeholder staff participated
- on-the-job training for VRD staff directly involved in the inspection.

After the inspections were complete, detailed coding of the road began. This involved desktop coding of 50 road attributes at 100 metre intervals. The elements inspected include provision for vulnerable road users (such as footpaths), lane widths, roadside conditions and intersection layouts. In total, some 1.75 million data points were recorded. Table 1 below provides an example of how lane widths (one of the 50 road attributes) are categorised.

Table 1 - Road attributes recorded by iRAP

Road Attribute	Road User Types Effected			
	Car occupants	Motorcyclists	Pedestrians	Bicyclists
Bicycle facilities				✓
Delineation	✓	✓		✓
Intersection road volume level	✓	✓		✓
Intersection type [a]	✓	✓		✓
Lane width	✓	✓		✓
Median type [b]	✓	✓	✓	✓
Minor access point density	✓	✓		✓
Number of lanes	✓	✓	✓	✓
Passing demand	✓	✓		
Paved shoulder width	✓	✓		✓
Pedestrian crossing facilities [c]			✓	✓
Quality of crossing [d]			✓	✓
Quality of curve [d]	✓	✓		✓
Quality of intersection [d]	✓	✓		✓
Radius of curvature	✓	✓		✓
Pavement condition	✓	✓		✓
Roadside design/obstacles [e]	✓	✓		✓
Shoulder rumble strips	✓	✓		
Side friction/roadside activities			✓	✓
Sidewalk provision			✓	
Speed [f]	✓	✓	✓	✓

[a] Intersection types includes 3-leg, 4-leg, roundabout, grade separation, railway, median crossing, provision of turning lanes and signalisation.
[b] Median type includes centerlines (no median), centerline rumble strips, two-way left-turn lanes, and various width of raised, depressed, or flush medians with and without barriers.
[C] Pedestrian facilities include unsignalised and signalised crossings, median refuges and grade separation.
[d] The quality of crossing, curve, and intersection includes consideration of pavement markings, advance signing, advisory speed limits, and sight distance.
[e] Roadside design/obstacles includes non-frangible objects such as trees and poles, drains, embankments, cuts, cliffs and the distance of objects from the side of the road.
[f] Speed is currently based on speed limit; consideration of measured operating speeds is a planned enhancement.

The coding process began with a 5-day intensive training course at the Vietnam Road Directorate (VRD) head office during May 2009 (pictured below in Figure 2). Participants from Vietnam roads and research agencies developed their understanding of iRAP, built their expertise in safe road design and learned how to assess the digital inspection images using specialised ARRB 'Hawkeye' software.

Figure 2 - Road rating training at the Vietnam Road Directorate, Ha Noi

At the completion of the training, the team began formal coding of the network. This process took the team approximately two months to complete. Throughout that time, the team was supervised by an experienced rater from ARRB Group. The coding was subject to quality assurance procedures, which included peer, supervisor and iRAP core team cross-checks of data. The coding was also guided by the iRAP Inspection Manual, which had been adapted specifically for Vietnam (including translation), and provides detailed instructions on how road attributes are to be coded.

4. RISK ASSESSMENT

Following the inspections and coding of the road infrastructure attributes, a Road Protection Score (RPS) was calculated for each 100 metre section using the iRAP's online software (which is made freely available to project partners). A separate RPS is calculated for car occupants, motorcyclists, pedestrians and bicyclists. The RPS forms the basis for generating the Star Ratings (and, in turn, Safer Roads Investment Plans).

The approach taken was consistent with the methodology described in *Safer Roads Investment Plans: The iRAP Methodology* (which is available at http://irap.org/media/9573/irap504.04_star_rating_roads_for_safety.pdf) [9].

The RPS is based on a series of risk factors that relate road infrastructure with the relative likelihood of crashes and their severity. An example of such research is shown below in Figure 3, which plots crash rates versus horizontal curvature [10]. It shows that the relative risk between a road segment with a very sharp curve (radius less than 100 metres) and one with a very mild, or no curve, is approximately 5.5. At the radius range of 100-200 metres, where the greatest number of crashes was observed, the risk ratio is 3.5. This finding is supported by published literature (see for example, [11]). Notably, the RPS is independent of traffic volumes and actual crash rates on the road being assessed. These factors are taken into account later, in the Safer Roads Investment Plan stage.

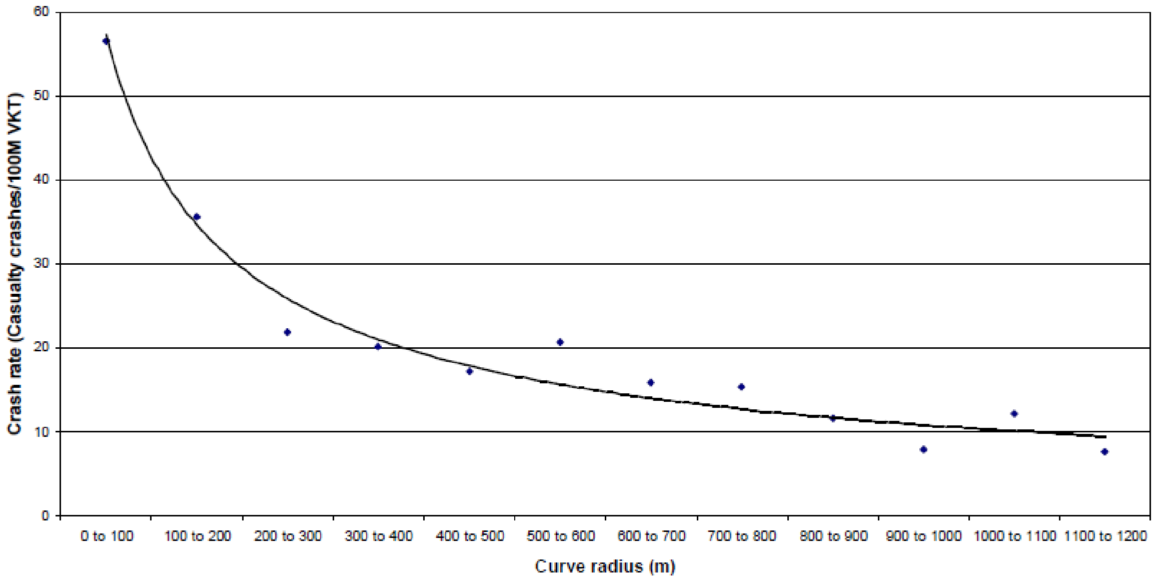

Figure 3 - Casualty crash rates and curve radius [8]

Figure 4 shows the underlying level of risk (RPS) for motorcyclists for each 100 metre section of the eastbound carriageway of Highway 51 (the higher the score, the greater the risk). It also illustrates the Star Ratings along the road, whereby 5-star (green) roads are the safest while 1-star (black) roads are the least safe. It illustrates the variation in risk as the vehicle travels along the road. The spike in the chart represents a dramatically increased level of risk at an intersection.

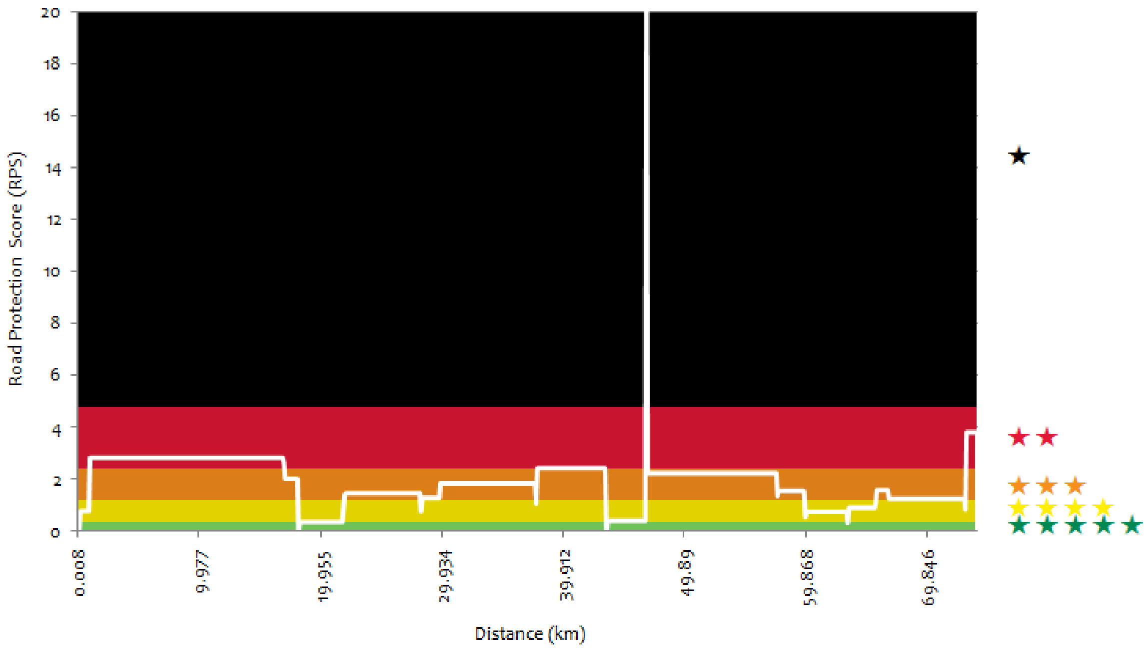

Figure 4 - Road Protection Scores and Star Ratings for motorcyclists on Highway 51

Figure 5 below shows the length of the network (%) by Star Rating and road user category. Overall, a significant percentage of the network is rated 1- or 2-stars for each road user, indicating a high level of risk.

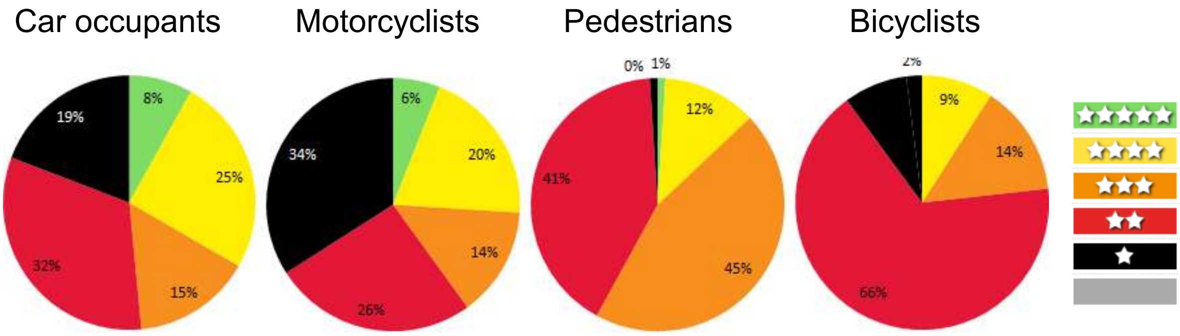

Figure 5 - Road network by Star Rating and road user type

Some of the factors driving the relatively poor Star Ratings are:

- medium to high pedestrian flows along and across many of the roads and poor provision of footpaths and crossings mean the risk of serious pedestrian crashes occurring is high. 85% of the network does not have footpaths in place, and the average distance between crossing facilities is Xkm

- on a majority of the network more than 20% of vehicles are motorcycles and more than a third of the network more than 60% of vehicles are motorcycles. Yet only 3% of the network has dedicated motorcycle lanes in place

- high overtaking demand and a majority of the network has no median separation (66% of the network is undivided) contributes to a high risk of serious head-on crashes

- 65% of roadsides has hazards (such as fixed objects or steep embankments) within 10 metres of the pavement. This, combined with the fact that 41% of the network has moderate to very sharp curves, increases the risk that a run-off road crash will result in severe injuries

- 2,796 significant at-grade intersections, many of which are poor quality. This increases the likelihood of severe intersection crashes occurring.

Notably, most of the network (86%) has sealed shoulders that are greater than 1 metre wide in place (23% has shoulders greater than 2.4 metres). Apart from helping to reduce risk of run-off and head-on crashes, this provides a degree of access and safety for bicyclists, who use almost all the network.

Overarching these factors, however, is the speed limit. 71% of the network is set at 80km/h. Based on research reported by the OECD, the risk of death and serious injury in most crashes is very high at this speed [12].

Figure 6 shows the motorcyclist Star Rating map for the network and Figures 7 and 8 show screenshots of the digital inspection images for Highway 18. Figure 7 shows a relatively new section of road, with a relatively good level of infrastructure safety. Figure 8 shows an equally new section but with relatively poor safety features (green boxes indicate relatively good provision, red boxes indicate relatively poor provision).

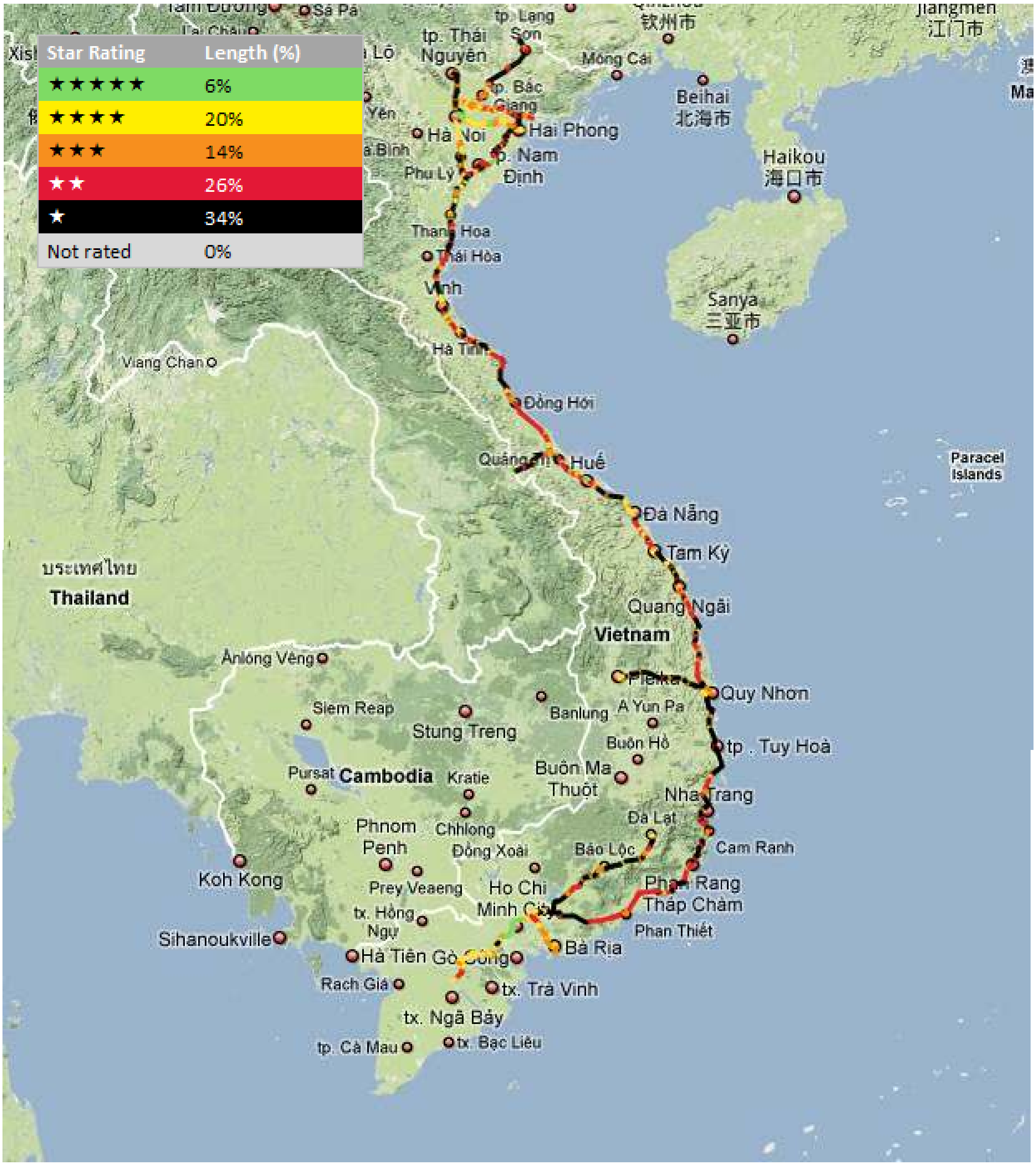

Figure 6 - Road network by Star Rating for Motorcyclists

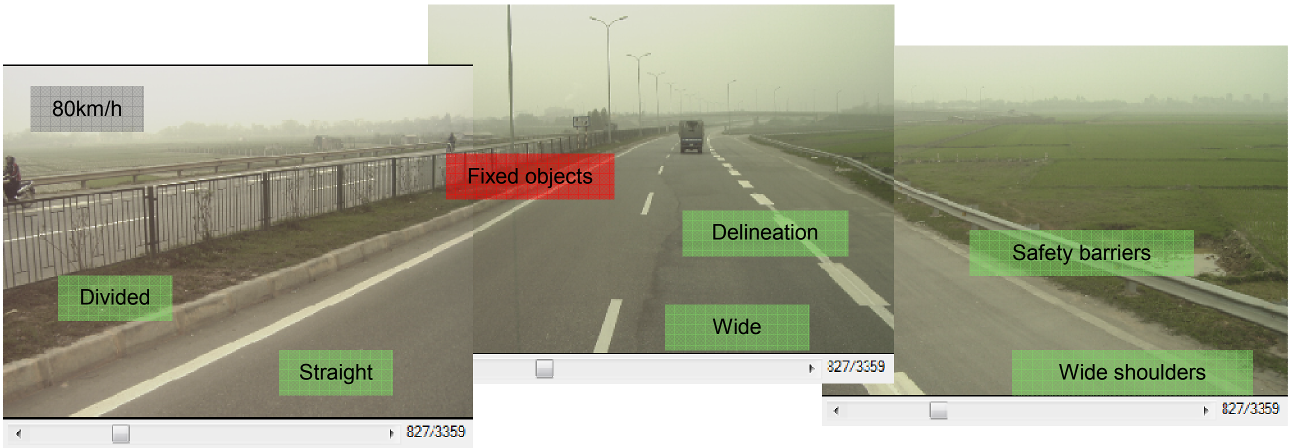

Figure 7 - National Highway 18 (24km west of Bac Ninh)

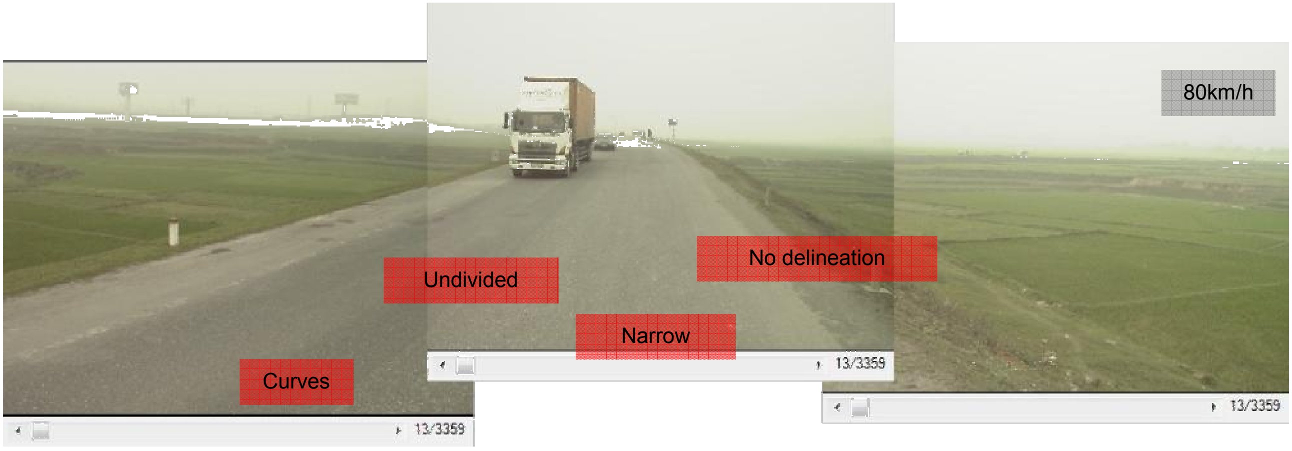

Figure 8 - An undivided section of road that leads into the divided carriageway shown in Figure 6

5. SAFER ROADS INVESTMENT PLAN METHODOLOGY

The purpose of a Safer Roads Investment Plan is to provide an appreciation of the types of countermeasures that could affordably and economically reduce risk – and therefore prevent deaths and serious injuries. To do this, iRAP considers the suitability of various countermeasures from a list of 70 countermeasures, ranging from low-cost road markings and pedestrian refuges to higher-cost intersection upgrades and full highway duplication (more information on the countermeasures in the iRAP list is available in the Road Safety Toolkit (http://toolkit.irap.org) [13]).

The process used to generate Safer Roads Investment Plans in the Bangladesh project was consistent with the approach described in the paper titled *Safer Roads Investment Plans: The iRAP Methodology* (available for download at: http://irap.org/media/10503/irap504.05_safer_roads_investment_plans.pdf [14]).

In general terms three steps were taken, as summarised below.

Estimating the number of deaths and serious injuries on road sections

To enable economic evaluation of various countermeasure options, an estimate of the number of deaths and serious injuries under existing conditions on each 100 metre section of road was made.

There is limited information available about the actual numbers of deaths that occur on the network. Data from JICA and NTSC, and World Bank reports were cited to determine estimated numbers of deaths on Highways 1 (part), 3, 5, 9, 10, 18 and 51 [3 and 15]. This data was then extrapolated on a deaths per vehicle kilometre travelled basis for the remainder of the network. In total, it was estimated that 1,518 deaths occur on the network annually.

However, previous studies have pointed out there is likely to be a significant level of under reporting of road crashes in Vietnam. For example, in its study of three demonstration corridors (two sections of national highway 1 and national highway 51), the World Bank reported that there was 1.6 crashes for every fatality, and 1.5 injuries for every fatality [15]. This was compared to New Zealand, which has a good reporting regime, where the ratio of reported crashes to fatalities is nearly 100; the ratio of serious injuries to fatalities is about 5, and the ratio of serious plus minor injuries to fatalities of about 25. The World Bank concluded that in effect, the Vietnam Traffic Police report only fatal accidents and a very small proportion of serious injury accidents. However, their report also noted that there is even some indication that all fatal accidents are not reported. It is therefore likely that the estimated number of deaths for the iRAP network is conservative. As a result, the estimated benefits discussed later in the paper are also likely to be conservative.

Since the number of deaths was available only in aggregate form (that is, for the entire length of each road), the deaths needed to be distributed among the 100 metre sections of road. The number distributed to each section was a function of the product of each section's Road Protection Score (RPS) and exposure (in the case of car occupants, exposure is measured as the annual average daily traffic). Hence, it is feasible that a road with a 1-star rating (indicating high risk) can still experience very few deaths if its traffic volume is low, and the reverse is also true.

An estimate of the number of serious injuries on each section was then made by assuming that for each death, 10 serious injuries occur. This approach is based on research by McMahon and Dahdah (2008) [16].

Selecting countermeasures

For each 100 metre section of road, a series of countermeasures that feasibly could be implemented were identified. This was achieved by considering each countermeasure's ability to reduce risk (as measured by the RPS) and 'application' and 'hierarchy' rules. For example, a section of road that has a poor pedestrian RPS and high pedestrian activity was likely to benefit from the installation of a pedestrian refuge, pedestrian crossing or signalised pedestrian crossing. Similarly, a section of road with poor delineation and a high car occupant RPS was likely to benefit from better delineation.

'Application' rules were used to help ensure that the countermeasures identified align with reasonable engineering practice. For example:

- grade-separated pedestrian crossings should be at least one kilometre apart. Hence, a grade separated crossing was not be considered feasible if one has already been identified for the previous 100 metre section

- new signalised pedestrian crossings (non-intersection facilities) should be at least 600 metres apart

- additional lanes (such as overtaking lanes or 2+1 cross section) should be required for a minimum length of one kilometre.

'Hierarchy' rules were used to ensure that more comprehensive countermeasures took precedent over less effective countermeasures. For example:

- if a grade separated pedestrian facility was feasible then it took precedent over other pedestrian measures (such as a pedestrian refuge or signalised crossing)

- if a horizontal realignment was feasible then redundant countermeasures were not considered (for example, curve delineation and shoulder widening)

- if a segregated motorcycle lane was feasible then other motorcycle lanes (such as an on-road motorcycle lane) were removed from the plan.

Economic analysis

Each countermeasure option identified was then subject to a benefit cost ratio (BCR) analysis. Countermeasures that failed to achieve a BCR of at least 1 were excluded from the analysis. However, higher BCR thresholds were also used to develop less expensive plans.

The benefit of a countermeasure was determined by calculating the net present value of deaths and serious injuries that would be avoided over twenty years if the countermeasure were installed (a discount rate of 7% was used). The reduction is deaths and serious injuries was determined by replacing the RPS used in the original estimate (made in the process of distributing deaths among 100 metre sections of road) with a new, lower RPS.

For the purposes of this project, the economic value of a death and a serious injury was determined by following guidance from McMahon and Dahdah (2008) [16]:

- economic cost of a death = 75 x Gross Domestic Product (GDP) per capita (current price) = VND 1,278,364,595 (US$71,327)
- economic cost of a serious injury = 0.25 x economic cost of a death = VND 319,591,149 (US$17,832).

The cost of a countermeasure was determined by estimating the net present cost of installing and maintaining each countermeasure over 20 years. These costs were estimated in consultation with the VRD.

6. PROPOSED COUNTERMEASURES

Three Safer Roads Investment Plan options were generated for the road network in Vietnam. Plan 1 is a US$195 million investment plan that would prevent 78,500 deaths and serious injuries over a 20 year period. For each dollar invested in this plan, there would be a saving of $6 in terms of crash costs avoided. Overall, this plan would result in a 24% reduction in road trauma on the network. Tables 2 provides a summary of Plan 1, as well as alternative, lower cost plans.

Table 2 - Safer Roads Investment Plan options ($US)

		Investment options		
		Plan 1	**Plan 2**	**Plan 3**
Investment (initial construction costs)		US$ 195 m	US$ 125 m	US$ 70 m
Number of deaths and serious injuries prevented	Annual average	3,930	3,400	2,750
	Over 20 years	78,500	68,100	55,100
Economic benefit	Annual average	US$ 60 m	US$ 52 m	$US40 m
	Over 20 years	US$ 1,210 m	US$ 1,050 m	US$ 850 m
Cost per death and serious injury prevented		US$ 2,500	US$ 1,800	US$ 1,270
Benefit cost ratio		6	8	12
Reduction in deaths and serious injuries on network		24%	20%	16%

Note: 1 USD = 17,857 VND.

Table 3 lists countermeasures types proposed in Plan 1. As can be deduced from Table 3, the countermeasures proposed in the plan focuses on:

- reducing the likelihood and severity of run-off road crashes through improved delineation, shoulder sealing, horizontal realignment, clearing roadside hazards and installing safety barriers
- reducing the likelihood and severity of head-on crashes by widening shoulders, duplication (adding a median) and adding additional lanes (to manage overtaking demand)
- reducing the likelihood of motorcycle crashes by installing motorcycle lanes
- reducing the likelihood and severity of pedestrian crashes by installing crossing facilities and footpaths
- reducing risk at intersections using traffic signals
- reducing bicycle risk by adding bicycle lanes.

Table 3 - Recommended countermeasures in Plan 1 ($US)

Countermeasure	Length / sites	Deaths and serious injuries prevented		Investment (USD million)	Cost per death and serious injury prevented (USD)	Benefit cost ratio
		Over 20 years	Annual			
Roadside safety - hazard Removal	940km	25,900	1,295	$75	$2,890	5
Motorcycle Lanes	900km	19,100	1,000	$37	$1,610	8
Realignment - horizontal	10km	7,400	370	$7	$890	17
Delineation	700km	5,500	275	$11	$640	8
Duplication	9km	4,000	200	$12	$2,900	5
Bicycle facilities	50km	3,300	165	$6	$1,750	9
Shoulder widening	80km	2,800	140	$7	$2,400	6
Intersection - signalise	60 sites	2,600	130	$11	$4,240	4
Additional lane	40km	2,500	125	$10	$4,130	4
Pedestrian crossing	360 sites	2,100	105	$10	$4,540	3
Roadside safety - barriers	40km	1,200	60	$5	$4,110	4
Road surface upgrade	20km	800	40	$0.5	$360	26
Lane widening	8km	800	40	$1	$820	11
Intersection - delineation	10 sites	100	5	$0.5	$1,090	5
Pedestrian footpath	7km	100	5	$1	$6,910	2
Median barrier	3km	100	5	$0.3	$1,500	6
Central hatching	10km	100	5	$0.4	$2,510	4
Rumble strip / flexi-post	4km	20	1	$0.03	$980	9
Traffic calming	1km	10	1	$0.04	$3,090	3
TOTAL		**78,500**	**3,930**	**$195**	**$2,500**	**6**

The map in Figure 9 details the locations where deaths and serious injuries could be prevented over the next 20 years if Plan 1 is implemented. Black and red sections of road are where the most deaths and serious injuries could be prevented. Green and yellow sections are where the fewest could be prevented. The initial priorities for investment should be targeted to those black and red sections of road where there is the potential to save the greatest number of deaths and serious injuries. This suggests an initial focus on implementing the recommended countermeasures on national highway 1 (from Phu Ly to Vinh and Quy Nhon to Ho Chi Minh City), 3, 10, 20 and 51 (upgrading underway) will provide the greatest impact.

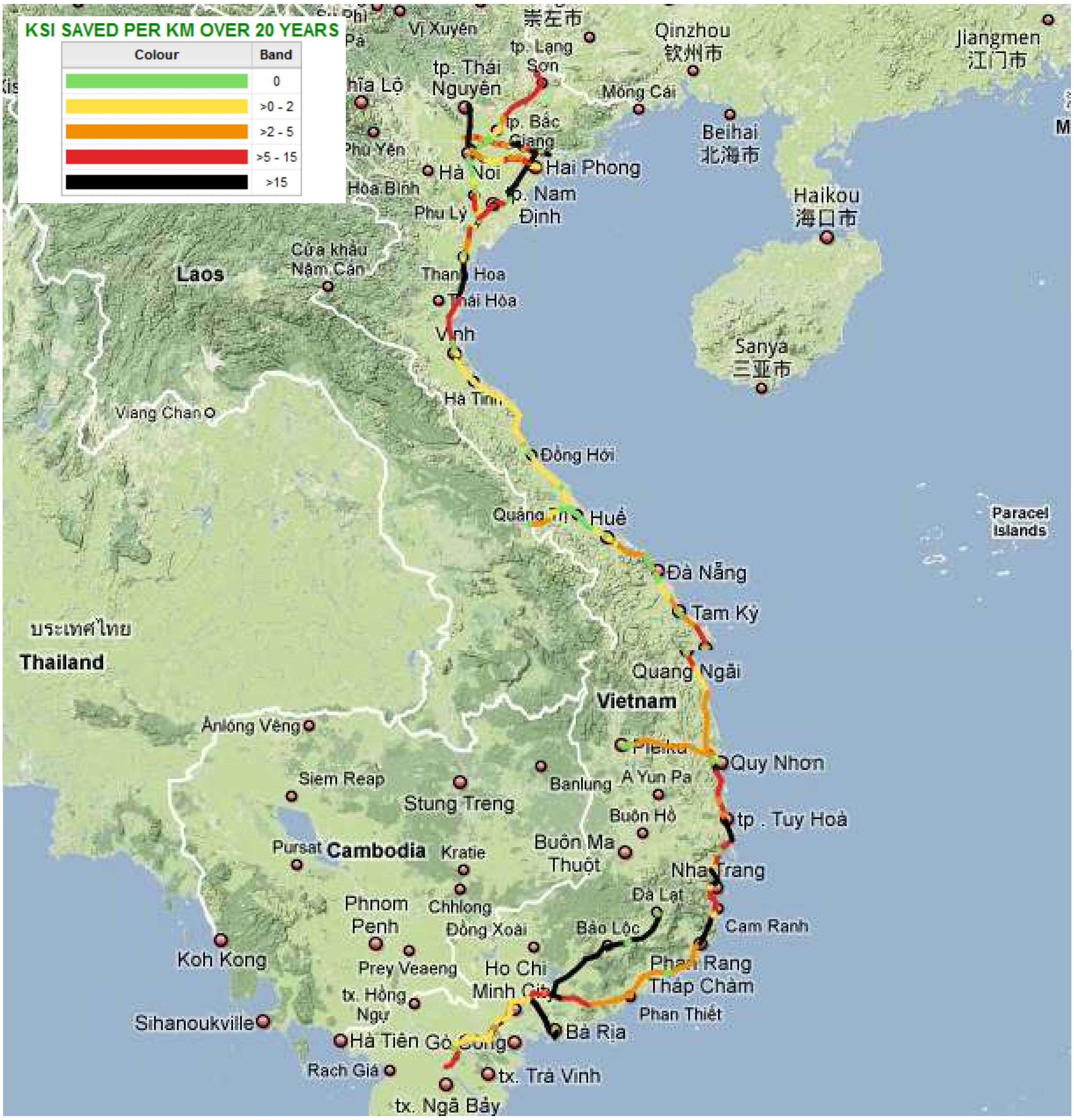

Figure 9 - Numbers of deaths and serious injuries that can be prevented (per km) over 20 years

Because the Safer Road Investment Plan analyses are based on 100 metre sections of road, it is possible to provide local engineers with a detailed listing of the countermeasures for each section along the road. This aids in reviews of the appropriateness of the countermeasure and detailed design. The engineers are also able to make use of interactive maps within the iRAP software which plot the exact location of proposed countermeasures.

The iRAP plans are supplemented by the Road Safety Toolkit (http://toolkit.irap.org), which provides additional information on what is meant by each countermeasure, typical benefits and implementation issues.

CONCLUSIONS

The iRAP Vietnam Project provided the first comprehensive infrastructure risk assessment of national highways. The assessment showed that all road users face a high level of infrastructure related risk on a significant percentage of the network.

The project identified a range of economically viable countermeasures that have the potential to prevent thousands of deaths and serious injuries. These include wider shoulders and safety barriers to reduce run-off road and head-on risk, footpaths and pedestrian crossings to reduce risk of severe pedestrian crashes, and traffic signals to reduce the incidence of serious intersection crashes. The most comprehensive of the plans identified the potential to reduce deaths and serious injuries 24%, with a benefit cost ratio of 6:1.

The results of the project provide the Government of Vietnam with a means of planning infrastructure safety improvements and negotiating support from the development banks. The plans also provide a basis for setting infrastructure safety performance indicators and associated targets for the roads. For example, it is now possible to monitor and aim to decrease the percentage of travel on roads that have high risk of death or serious injury due to head-on crashes (car occupants and motorcycles).

Overall, the Project demonstrated that the iRAP approach to risk assessment is able to be applied in Vietnam, as it has been in numerous countries around the world. With the Government's demonstrated commitment to road safety, and with the support of local road safety organisations and the regional development banks, it hoped that significant gains can be made during the Decade of Action for Road Safety.

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