Speed Variation Analysis - A Case Study for Thailand’s Streets and Roads

July 2019

Photo: Capture from Google Street Maps of Hathai Rat Road in Min Buri district, Bangkok, Thailand (July 2019)
Executive Summary

Research shows that vehicle speed affects the severity of all road crashes. It is well known that higher speed crashes involve more kinetic energy and the more energy that is dispersed in a crash, the more severe it will be. Speed also affects the likelihood of a crash occurring. The likelihood of being involved in a fatal or serious crash increases significantly with even small increases in vehicle speed. Studies in the field show that a 1% increase in mean average speeds results in approximately a 2% increase in injury crash frequency, a 3% increase in severe crash frequency and a 4% increase in fatal crash frequency.

The safety of infrastructure is heavily influenced by traffic speed and without a detailed understanding of speed limits and vehicle operating speeds, it is difficult to assess the safety performance of infrastructure at a given location.

This report aims at highlighting how Speed Management is an important part of the Safe System Approach and how a simple speed variation can impact the safety of all types of road users. At the core of this report lays the experience from the iRAP assessments undertaken under the Bloomberg Philanthropies’ Initiative on Road Safety (BIGRS) on 867km of national roads in Thailand and 258km of streets in Bangkok, between 2015 and 2019, together with capacity building activities with local partner, Chulalongkorn University, which led to almost 700 specialists trained on road safety engineering during this period.

The importance of speed in influencing road user risk is highlighted in two case studies on different road types in Thailand, Outer Bangkok Ring Road and Hathai Rat Road in Bangkok, to demonstrate the effects of different speeds on the iRAP Star Ratings. Amongst a series of simulations and results, this study shows how enforcing speed limits reduced by 10km/h will save (prevent) one out of three fatal and serious injuries on both pilot roads.

On the 170km section of the Outer Bangkok Ring Road, at the current speed limit of 90km/h, the iRAP Star Rating results for vehicle occupants show 11% of the road length to be 4-star, 66% 3-star, 21% 2-star and 2% 1-star. With only a 10km increase in the speed limit, at 100km/h, the speed analysis testing shows that none of the road length scores 4-stars and 42% of the road length is in the high-risk (1- and 2-star) category. A reduction on an (enforced) speed limit from 90 to 80 km/h would lead to an estimated 30% reduction in FSIs on the road section, which translates into 36 fatal or serious injuries prevented (saved) each year. At the same time, the lack of enforcement of the current speed limit and adoption of a 120km/h speed, it is estimated to be leading to serious increases in FSIs, approximately three times more than an operating speed of 80km/h – 287 FSIs.
On the 2.3km section of Hathai Rat Road, in Min Buri district, Bangkok, at 80km/h, the raw iRAP Star Rating results for pedestrians show that the entire length is rated 1-star. At 50km/h, 33% is 3-star, 58% 2-star and 8% 1-star. At 40km/h, the results show that 33% of the road length is 4-stars, 58% is 3-stars and 8% is 1-star. For motorcyclists, at 80km/h, the raw iRAP Star Rating results show 4% of the road length to be 3-star, 88% 2-star and 8% 1-star. At 40km/h, the results show that 92% of the road length is 5-stars, 4% at 4-stars and 4% at 1-star. More results are presented through graphics in the report. A reduction in the (enforced) speed limit from 80 km/h to 70 km/h would lead to a 31% reduction in FSIs on the road section, which translates into an average of 3 fatal or serious injuries prevented (saved) each year. At the same time, halving the speed limit to 40km/h would lead to serious decreases in FSIs, approximately 90%, saving approximately 10 lives from fatal or serious injuries.

Both case studies have shown that road function, traffic mix and adjacent land use/development are important considerations in determining appropriate speed limits. These results raise awareness on the high impact of speed on the safety of all road users and should help Road Administration agencies in Thailand to adjust their enforced speed limits to the Safe System Approach.
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1. Introduction

Road safety is a critical consideration for the World Bank in its transport investment projects. Through its Global Road Safety Facility (GRSF), a partnership under the Bloomberg Philanthropies’ leadership was joined together with another 9 international institutions – Bloomberg Philanthropies’ Initiative for Global Road Safety (BiGRS).

The Bloomberg Philanthropies’ BiGRS (2015-2019) is the second phase of a $125 million partnership program focused on reduction of road deaths and serious injuries in 10 selected cities and five countries in the developing world. The cities were selected through a competitive process and these are: Mumbai, Fortaleza, Sao Paulo, Bogota, Addis, Accra, Shanghai, Bandung, Ho Chi Minh City and Bangkok. Under the program cities are receiving funding support for full staff embedded in the city agencies, comprehensive technical assistance from the collaborating organizations, training and capacity building for enforcement agency, media and social awareness campaigns.

In addition, five countries were selected (India, China, Thailand, Philippines, and Tanzania) to receive support for national-level activities including legislative and policy implementation activities. Bloomberg has also requested the World Bank to carry out financial costing studies and assessment of high-risk roads in the selected five countries.

Figure 1. BiGRS (2015-2019) cities and countries
A World Bank study under BIGRS in 2017 shows that, over time, sharply reducing the number of road traffic injuries and deaths would enable these five countries to attain substantial increases in economic growth and national income, while leading simultaneously to clear welfare gains. Reducing road traffic mortality and morbidity by 50 percent and sustaining it over a period of 24 years could, for example, generate an additional flow of income equivalent to 22.2 percent of 2014 GDP in Thailand. This puts into perspective the magnitude of economic benefits that the countries may realize with sustained action if they were to achieve the UN targets on road safety.

**Thailand has one of the highest road traffic death rates in the world**, with motorcyclists accounting for 74% of these deaths. Bangkok, Thailand’s capital and largest city, has a population of 5.7 million and its number of registered vehicles in the city continues to grow at a rapid rate, including motorcycles, which make up 36% of all vehicles. In 2016, more than 850 people died on Bangkok’s roads.

Under BIGRS, the objective for the World Bank engagement is to:

- build road safety management capacity;
- improve road infrastructure safety; and
- leverage related road safety investment in countries where significant impact on lives saved can be achieved.

Working together with other BIGRS Safer Streets and Safer Mobility partners, EMBARQ - the World Resources Institute (WRI) Ross Center for Sustainable Cities and the National Association of City Transportation Official’s Global Designing Cities Initiative (NACTO-GDCI), the World Bank complements their efforts in improving road infrastructure and mobility safety for the selected cities.

**The World Bank has partnered with the International Road Assessment Programme (iRAP)** for the survey and assessment of high-risk road infrastructure in each of the cities and countries, but also to provide additional support activities related to design implementation, audit and related training.

This report aims at highlighting how Speed Management is an important part of the Safe System Approach and how a simple speed variation can impact the safety of road users. At the core of this report lays the experience from the iRAP assessments undertaken on **867km of national roads in Thailand** and **258km of streets in Bangkok**, between 2015 and 2019, together with capacity building activities with local partner, Chulalongkorn University, which led to **almost 700 specialists** trained on road safety engineering during this period.

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2. Road Safety strategies

2.1. Safe system approach

The “Safe System” approach advocates for a safe road system, better adapted to the physical tolerance of its users. The core principles of this approach are in line with the well-known mid-1990s national strategies such as Sweden’s Vision Zero and the Netherlands’ Sustainable Safety approach. It was officially endorsed by the Australian Transport Council in 2004 and adopted by all Australian state and territory road authorities. The history of how the Safe System Approach was adopted and some of the rationale behind it is presented by Grzebieta et al.

The main highlight of the Safe System Approach is that while it recognizes the need for responsible road user behavior, it also accepts that human error is inevitable. It therefore aims to create a road transport system that makes allowance for errors and minimizes the consequences - in particular, the risk of death or serious injury. The statement in the Australian National Road Safety Strategy makes this very clear that: “Australians should not regard death and serious injury as an inevitable cost of road travel. Crashes will continue to occur on our roads because humans will always make mistakes no matter how informed and compliant they are. But we do not have to accept a transport system that allows people to be killed or severely injured as a consequence.”

Obviously, the Safe System Approach does not absolve road users from complying with the road laws. On the contrary, the Safe System Approach works at its optimum when road users comply with road laws. In other words, the Safe System Approach should be considered as a holistic graded safety system. For fully compliant road users, the Safe System Approach should guarantee maximum protection against death and serious injury. Road users should not expect to die or be seriously injured if, through no fault of their own, they find themselves involved in a crash or collision. However, the system should also assist

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with reducing the risk of a fatality or serious injury for a non-compliant road user who is involved in a crash.

So, in a nutshell, by taking a total view of the combined factors involved in road safety, the Safe System approach encourages a better understanding of the interaction between the key elements of the road system: road users, roads and roadsides, vehicles and travel speeds, and has three core components:

- **Safe roads and roadsides** - a transport system designed to make a collision survivable through a combination of design and maintenance of roads and roadsides.

- **Safe vehicles** - the design of vehicles and their safety equipment to include protective systems including electronic stability control, air cushions, etc.

- **Safe speeds** – the speed limit should reflect the road safety risk to the road users.

*Figure 2. Conceptualization of the Safe System Approach*  

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It is essential that vehicles travel at speeds that suit the function and the level of safety of the road to ensure that crash forces are kept below the limits that cause death or serious injury. This requires the setting of appropriate speed limits supplemented by effective enforcement and education.

2.2. Evidence-based measures

Evidence based-measures involve looking at a crash, casualty and any other available data to be sure that the road safety issue needs to be addressed, and research and evaluation reports to check whether the type of intervention being considered is likely to be effective. Evidence based practice originated in medicine, but it has been translated to a number of policy areas, including road safety.

Evidence based practice can help to ensure that new and existing interventions are successful, as they have been proven to work in a similar context, but also maximize efficiency in times of budget cuts.

The main evidence-based intervention in road safety can be divided into 4 main groups:

- **Safer Road Users** – informing and educating users about safe use of the road, and taking action against those who do not comply with the rules;
- **Safer Roads** – designing, constructing and maintaining roads and roadsides to reduce the risk of crashes, and minimise the severity of injury if a crash occurs;
- **Safer Vehicles** – designing and maintaining vehicles to minimise the risk of crashes, and the severity of injury to motor vehicle occupants, pedestrians, and cyclists if a crash occurs;
- **Safer Speeds** – setting speed limits that take into account the level of risk on the road network and the benefits of lower speeds in minimising the incidence and severity of injury in the event of a crash, together with the corresponding self-explaining infrastructure and enforcement.

According to Wegman et al.⁸, three subjects are key in this new approach of evidence-based and data-driven road safety management: ex-post and ex-ante evaluation of both individual interventions and intervention packages in road safety strategies, and transferability (external validity) of the research results.

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2.3. Speed Management

Vehicle speed affects the severity of all road crashes. Higher speed crashes involve more kinetic energy and the more energy that is dispersed in a crash, the more severe it will be. Speed also affects the likelihood of a crash occurring. The likelihood of being involved in a fatal or serious crash increases significantly with even small increases in vehicle speed. Research shows that a 1% increase in mean average speeds results in approximately a 2% increase in injury crash frequency, a 3% increase in severe crash frequency and a 4% increase in fatal crash frequency\(^9\).

Cars are now designed so that a person can survive without serious permanent injury a head-on crash between similar vehicles, with a 10% fatality risk, for collision speeds of up of 70 km/h. At higher impact speeds, survivability reduces rapidly. An image that is commonly used in Europe is to display the risk of crashing at a higher speed and associate that risk with a falling object, as shown in Figure 3.

![Diagram showing the building floor level and height that a vehicle, driving off the roof floor, would be equivalent to when compared to impact crash speed](image)

**Figure 3.** Diagram showing the building floor level and height that a vehicle, driving off the roof floor, would be equivalent to when compared to impact crash speed \(^{10}\)

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\(^{10}\) Murray N.W., *When it Comes to the Crunch, The mechanics of Car Collisions*, World Scientific, Singapore, 1994
2.4. Setting local speed limits

In many countries there can be a marked difference between the posted speed limit and the actual speed of vehicles using the road. This is a function of local behavior, traffic flows, local enforcement practice and whether the engineering features of the road are designed in accordance with the speed limit, for example the use of traffic calming measures to help manage speeds.

As well as being the legal limit, speed limits are a key source of information to road users, particularly as an indicator of the nature and risks posed by the road both to themselves and to all other road users. Speed limits should therefore be evidence-led and self-explaining and seek to reinforce the road user’s assessment of what is a safe speed to travel. They should encourage self-compliance and be regarded as a maximum permitted speed rather than a target speed. It is important that traffic authorities and police forces work closely together in determining, or considering, any changes to speed limits. Speed limits should be clearly signed in both directions wherever a change occurs, and they should also meet the needs of all road users and vehicle technologies. Repeater signs may also be required.

2.5. Traffic Speed and Mobility

The Safe System challenges the fatalistic view (Bliss, 2013)\(^{11}\) that road traffic injury is the price to be paid for achieving mobility. It sets a goal of eliminating road crash fatalities and serious injuries in the long term with interim step-wise targets to be set in the years towards elimination.

Tingvall (2005)\(^{12}\) comments that traditionally, mobility has been regarded as a function of the road transport system for which safety is traded off. However, Vision Zero turns this concept around and resets mobility as being a function of safety. No more mobility should be generated than that which is inherently safe for the system. This ethical dimension reflects the principles accepted for work-place safety, where the effectiveness of the working process cannot be traded off for health risks. Vision Zero contends that it is the legitimate right of the citizen to be able to use the road transport system in a safe way and that is the main driving force.

In addition, in particular on short journeys, the perceived gain of time is much larger than the objective gain of time, which is in fact only marginal\(^{13}\):


\(^{13}\) European Commission. *Mobility and Transport. Road Safety.*
Table 1. Extra time taken for a 10 km journey when speed is reduced by 5 km/h (Source: ETSC, 1995)

<table>
<thead>
<tr>
<th>Original speed</th>
<th>50 km/h</th>
<th>70 km/h</th>
<th>90 km/h</th>
<th>110 km/h</th>
<th>130 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra time taken (minutes)</td>
<td>1.33</td>
<td>0.66</td>
<td>0.39</td>
<td>0.26</td>
<td>0.18</td>
</tr>
</tbody>
</table>

2.6. Speed in the iRAP Star Rating model

The safety of infrastructure is heavily influenced by the speed of traffic and without a detailed understanding of the speed limits and vehicle operating speeds it is difficult to assess the safety performance of infrastructure at a given location. All iRAP star rating assessments are based on the higher of the speed limit and vehicle operating speeds. For further details on the iRAP specifications in relation to vehicle speeds see *Vehicle Speeds and the iRAP Protocols*, which can be found on the iRAP website [http://irap.org/about-irap-3/research-and-technical-papers](http://irap.org/about-irap-3/research-and-technical-papers).

Speed management is of paramount importance in road safety and traffic speeds have a significant bearing on the iRAP Star Ratings.

According to the Speed Management Manual\(^\text{14}\), the risk of death or serious injury is minimized in any crash, where:

- vulnerable road users (e.g. motorcyclists, bicyclists and pedestrians) are physically separated from cars and heavier vehicles, or where traffic speeds are 40km/h or less; research indicates that while a pedestrian hit by a car traveling with 30km/h has high chances of survival, at 50km/h these chances are highly reduced, to less than 20%;
- opposing traffic is physically separated and roadside hazards such as trees and other fixed objects are well managed;
- traffic speeds are restricted to 70km/h or less on roads where opposing traffic flows are not physically separated, or where roadside hazards exist.

The iRAP analysis provides valuable source data to inform systematic speed management actions associated with the revision and enforcement of speed limits on urban and rural road sections. The implementation of speed management changes requires the cooperation of multiple agencies and enforcement levels must deliver sustained outcomes to be effective. Any speed management initiative should be accompanied by the relevant changes to the engineering environment to support the desired speeds (e.g. traffic calming, road diets, speed platforms). For further details refer to the WHO Save LIVES package and the Speed Management Manual:


This report seeks to explore the importance of speed in influencing road user risk and uses two case studies on different road types in Bangkok, Thailand to demonstrate the effects of different speeds on the iRAP Star Ratings.
3. Case Study 1: Outer Bangkok Ring Road

3.1. General overview and baseline

The iRAP model can be used to show how speed influences risk. Using a 170km section of the Outer Bangkok Ring Road, Thailand as a case study, various speed limit options have been tested to measure the change in risk (Star Ratings) for vehicle occupants as speeds are modified.

The section of road used in this study covers the western portion of the Outer Bangkok Ring Road (also known as Kanchanaphisek Road), a multi-lane divided road under the Department of Highways (DOH), Ministry of Transport. The section starts from the Prapradaeng area (Route 9, km 0+000) and ends at Bangpa-in interchange (Route 9, km 84+127). This priority corridor was first assessed using the iRAP methodology in 2017. The smoothed Star Rating results from that survey for vehicle occupants and based on vehicle operating speeds are shown in the figure below.

Figure 4. Vehicle Occupant Star Ratings (smoothed) - Western portion of the Outer Bangkok Ring Road, Bangkok, Thailand
This road section is currently subject to a speed limit of 90km/h. However, the speed data collection surveys conducted at the time of the original baseline assessment shows operating speeds in excess of the 90km/h speed limit for 24% of the length of the corridor. Therefore, the original assessment was based on speeds of 90km/h for 76% of the length and 100km/h for 24% of the length.

Table 2. Operating speeds on the Outer Bangkok Ring Road based on 2017 speed data collection for baseline survey

<table>
<thead>
<tr>
<th>Operating Speed (85th percentile)</th>
<th>km</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30km/h</td>
<td>0.10</td>
<td>6</td>
</tr>
<tr>
<td>85km/h</td>
<td>49.00</td>
<td>29</td>
</tr>
<tr>
<td>90km/h</td>
<td>80.00</td>
<td>47</td>
</tr>
<tr>
<td>100km/h</td>
<td>40.90</td>
<td>24</td>
</tr>
</tbody>
</table>

3.2. Speed variation results

At the current speed limit of 90km/h, the iRAP Star Rating results for vehicle occupants show 11% of the road length to be 4-star, 66% 3-star, 21% 2-star and 2% 1-star. With only a 10km increase in the speed limit, at 100km/h, the speed analysis testing shows that none of the road length scores 4-stars and 42% of the road length is in the high-risk (1- and 2-star) category. The chart below shows how the percentage of high-risk road increases with speed:

Figure 5. Increase in the percentage of high-risk road sections (1-2 stars) for vehicle occupants with speed variation
The full star rating performance for vehicle occupants with speed variations is detailed in the chart below:

**Figure 6. Speed analysis testing for vehicle occupants on the Outer Bangkok Ring Road**

Based on the crash data received, during 2014-2016 an average of 11 fatalities took place on the Outer Bangkok Ring Road. With no data available on serious injuries, the default ratio of 10 serious injury crashes to 1 fatal was used for the analysis. That is a total of 121 annual fatalities and serious injuries (FSIs) estimated on the baseline dataset i.e. 90km/h. The results based on the speed variation are shown in the chart and table below.

**Table 3. Data on FSIs on the Outer Bangkok Ring Road based on speed variation**

<table>
<thead>
<tr>
<th>Variation</th>
<th>Baseline</th>
<th>Variation</th>
<th>Variation</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed limit (km/h)</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Annual average fatalities</td>
<td>7.7</td>
<td>11</td>
<td>15.1</td>
<td>20.1</td>
</tr>
<tr>
<td>Annual average serious injuries (estimated)</td>
<td>77.4</td>
<td>110</td>
<td>150.7</td>
<td>200.6</td>
</tr>
<tr>
<td>Annual FSIs</td>
<td>85.2</td>
<td>121</td>
<td>165.8</td>
<td>220.7</td>
</tr>
<tr>
<td><strong>Change in FSIs Outcomes</strong></td>
<td><strong>-36</strong></td>
<td><strong>NA</strong></td>
<td><strong>45</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td><strong>% change from baseline</strong></td>
<td><strong>-30%</strong></td>
<td><strong>NA</strong></td>
<td><strong>37%</strong></td>
<td><strong>82%</strong></td>
</tr>
</tbody>
</table>

15 iRAP. *The true cost of road crashes. Valuing life and the cost of a serious injury.*

http://resources.irap.org/Research/iRAP%20report%20-%20the%20true%20cost%20of%20road%20crashes%20-%20ESP.pdf
Figure 7. Chart showing estimated annual FSIs with changes in speed limit on the western portion of the Outer Bangkok Ring Road

A reduction on an (enforced) speed limit from 90 to 80 km/h would lead to an estimated 30% reduction in FSIs on the road section, which translates into 36 fatal and serious injuries prevented (saved) each year. At the same time, the lack of enforcement of the current speed limit and adoption of a 120km/h speed, it is estimated to be leading to serious increases in FSIs, approximately three time more than an operating speed of 80km/h – 287 FSIs.
4. Case Study 2: Hathai Rat Road, Bangkok

4.1. General overview and baseline

The iRAP model can be used to show how speed influences risk for all major road user types including vehicle occupants, motorcycle riders, pedestrians and bicyclists. Using a 2.3km section of Hathai Rat Road, in Min Buri district, Bangkok, Thailand as a case study, various speed limit options have been tested to measure the change in risk (Star Ratings) for each of the major road user types present.

The section used in this study is a 4-lane (2-lanes in each direction) road starting at the junction with Suwinthawong Road and running north to the district boundary. The southern section is undivided for a length of 1.6km. The remaining length to the district boundary is a divided carriageway with a physical median. This urban road has a mix of commercial, industrial and educational land use with vulnerable road users present along the entire length. Several schools and colleges are located along the road including Sudjai Wittaya School, Phumsamit School, Priyakorn School and the Minburi Business Administration Vocational College. The road is currently subject to a speed limit of 80km/h. A sidewalk is present along the entire passenger-side and two unsignalized pedestrian crossings are present along the route. Although warning signs and flashing indicators are present, the condition of the road markings is poor as shown in the Street View image shown below.

![Image of unsignalized pedestrian crossing in poor condition](Figure 8. Unsignalized pedestrian crossing in poor condition outside Phumsamit School, Hathai Rat Road, Bangkok, Thailand (Image capture May 2018))
This road was first surveyed using the iRAP methodology in 2017 as part of the BMA high-risk districts 1-6 assessment project. A location map showing Hathai Road within Min Buri district and the location of the district with Bangkok is shown below.

![Location map showing Hathai Rat Road in Min Buri district, Bangkok, Thailand](image)

**Figure 9. Location map showing Hathai Rat Road in Min Buri district, Bangkok, Thailand**

### 4.2. Speed variation results

Speed sensitivity modelling has been conducted to investigate the change in risk for vehicle occupants, motorcyclists, pedestrians and bicyclists at different speed limits. Raw Star Rating results, that is the Star Ratings for each 100m segment in isolation, has been used in this case study due to the short length of road section being assessed. The results are shown in the charts below.
Figure 10. Speed analysis testing for vehicle occupants, Hathai Rat Road

At the current speed limit of 80km/h, the raw iRAP Star Rating results for vehicle occupants show 38% of the road length to be 3-star, 58% 2-star and 4% 1-star. The 1-star segment is located at the major intersection with Suwinthawong Road where risk of fatal and serious injury for vehicle occupants is highest. At 40km/h the speed analysis testing shows 92% of the road length to be 5-stars, 4% at 4-stars and 4% at 2-stars.

Figure 11. Speed analysis testing for motorcyclists, Hathai Rat Road
At 80km/h, the raw iRAP Star Rating results for motorcyclists show 4% of the road length to be 3-star, 88% 2-star and 8% 1-star. At 40km/h, the results show that 92% of the road length is 5-stars, 4% at 4-stars and 4% at 1-star.

**Figure 12. Speed analysis testing for pedestrians, Hathai Rat Road**

At 80km/h, the raw iRAP Star Rating results for pedestrians show that the entire length is rated 1-star. At 50km/h 33% is 3-star, 58% 2-star and 8% 1-star. At 40km/h the results show that 33% of the road length is 4-stars, 58% is 3-stars and 8% is 1-star.

**Figure 13. Speed analysis testing for bicyclists, Hathai Rat Road**
At 80km/h, the raw iRAP Star Rating results for bicyclists show 62% of the road length to be 2-star and 38% 1-star. At 40km/h the results show that 63% of the road length would be 5-stars, 33% 4-stars and 4% at 3-star.

Based on the crash data received, during 2014-2016 an average of 1 fatality took place on Hathai Rat Road. With no data available on serious injuries, the default ratio of 10 serious injury crashes to 1 fatal was assumed. That is a total of 11 annual FSIs on the baseline dataset i.e. 80km/h. The results based on the speed variation are shown in the chart and table below.

### Table 4. Data on FSIs on the Hathai Rat Road based on speed variation

<table>
<thead>
<tr>
<th>Speed limit (km/h)</th>
<th>Baseline</th>
<th>Variation</th>
<th>Variation</th>
<th>Variation</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual average fatalities</td>
<td>1</td>
<td>0.7</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Annual average serious injuries (estimated)</td>
<td>10</td>
<td>6.9</td>
<td>4.2</td>
<td>2.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Annual FSIs</td>
<td>11</td>
<td>7.6</td>
<td>4.6</td>
<td>2.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Change in FSIs Outcomes</td>
<td>NA</td>
<td>-3.4</td>
<td>-6.4</td>
<td>-8.5</td>
<td>-9.8</td>
</tr>
<tr>
<td>% change from baseline</td>
<td>NA</td>
<td>-31%</td>
<td>-58%</td>
<td>-77%</td>
<td>-90%</td>
</tr>
</tbody>
</table>

![Figure 14. Chart showing estimated annual FSIs with changes in speed limit (and associated speeding behaviour) on Hathai Rat Road, Bangkok](image)

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A reduction in the (enforced) speed limit from 80 km/h to 70 km/h would lead to a 31% reduction in FSIs on the road section, which translates into an average of 3 fatal or serious injuries prevented (saved) each year. At the same time, halving the speed limit to 40km/h would lead to serious decreases in FSIs, approximately 90%, saving approximately 10 lives from fatal or serious injuries.
5. Conclusions and recommendations

It is recommended that appropriate mandatory speed limits be set, that are clearly supportive of the Safe System principles, and consistently marked and well understood by all road users, in order to maximize the length rated at 3-stars or better for all road users where present. In addition to appropriate and correct speed limits, complementary engineering measures for traffic calming need to be in place, jointly with improved enforcement and education for all road users.

Both case studies have shown that road function, traffic mix and adjacent land use/development are important considerations in determining appropriate speed limits. For example, undeveloped rural areas with adequate road design standards may be suitable for a limit of 100 or even 120km/h, whereas vehicle speeds in business districts, commercial centers and residential areas or rural towns and villages where pedestrians are likely to be present should be limited.
The results of the analysis on the Outer Bangkok Ring Road show that even at 120km/h roads can score 3-stars, particularly where head-on and run-off crash risk is reduced through adequate road design. At the current speed limit of 90km/h, 23% of the assessed length is high-risk. However, it is known that vehicle operating speeds exceed the speed limit, therefore a combination of enhanced speed limit enforcement plus engineering improvements along the current high-risk sections is recommended in order to bring the corridor up to a minimum 3-star standard.

The current speed limit of 80km/h on the Hathai Rat Road is shown to increase risk of death and serious injury for all road user types. A revised speed limit of 50km/h would improve over 95% of the road length to 3-stars or better for vehicle occupants, motorcyclists and bicyclists; for pedestrians, 33% would achieve 3-stars at this speed. To further reduce risk for pedestrians as they cross Hathai Rat Road engineering improvements such as upgrading existing pedestrian crossings and providing additional crossing facilities at key high-use locations is recommended. Consideration should also be given to reducing the number of lanes needed to be crossed at key locations and the benefits of pedestrian refuge islands and traffic calming measures reducing pedestrian-vehicle collisions.

85 fatalities & serious injuries can be prevented each year on the western portion of the Outer Bangkok Ring Road with a 10km/h speed reduction, from 90 to 80km/h

Halving the speed leads to 90% reduction on fatalities & serious injuries on Hathai Rat Road.
6. References

iRAP. The true cost of road crashes. Valuing life and the cost of a serious injury.
Murray N.W., When it Comes to the Crunch, The mechanics of Car Collisions, World Scientific, Singapore, 1994