Wire Rope Safety Barriers and the Pacific Highway Program: RTA Research and Investigations

Karin Nilsson
Planager Pty Ltd, Sydney, Australia
Tel (02) 9985 1056; Fax (02) 9552 2252;email: planager@ozemail.com.au

Neville Prior
Roads and Traffic Authority NSW, Sydney, Australia
*Tel (02) 8814 2076; Fax 8814 2556; email:*neville_prior@rta.nsw.gov.au

Abstract: This paper discusses the decision process used by the Roads and Traffic Authority NSW to determine the type of median safety barrier that is most appropriate for reducing the risk of accident trauma on two-lane sections of the Pacific Highway. It shows the method used to quantify the predicted risk reduction after implementation of the proposed upgrade program, and compares the predicted results with those of 5-years' experience with median wire rope safety barriers in Sweden. It also shows the process used to determine the minimum median width for installation of median wire rope safety barriers.

1. Introduction and background

The Pacific Highway is the major coastal highway for north-south travel between Sydney and Queensland. It was established in the early days of Australian settlement, and is managed by the Roads and Traffic Authority NSW (RTA). Increasing accident frequency has accompanied increasing usage. Centreline crossover accidents have been identified as a significant cause of road accident trauma on the highway.

A large-scale reconstruction program is converting the highway to dual-carriageway standard. RTA identified a need to facilitate an immediate reduction in median crossover accidents on two-lane sections of the Pacific Highway until the long-term conversion to dual-carriageway can be implemented. Installing median safety barriers on narrow sections of the Pacific Highway was perceived to be an effective immediate solution to reducing road accident trauma.

This perception is in line with the conclusion reached in 2001 by the State Coroner Victoria after inquests into nine freeway crossover related deaths. The Coroner called for *'… a review of the current median barrier guidelines with a view to installing appropriate median barriers on all Freeways or State Highways where necessary to prevent errant vehicles traveling onto carriageways in the opposite direction of travel*'.[i]

2. Questions to be answered

Median safety barriers have been used with success on medians of dual-carriageway roads. An assessment was needed to determine if safety barriers could be used on narrow sections of road where median width was limited. In particular, the following four questions were asked:

1. To what extent will the installation of median safety barriers reduce accident trauma on the Pacific Highway?
2. What is the most appropriate type of median safety barrier?
3. What minimum median widths can be / should be adopted for the installation?
4. What issues need to be resolved to enable implementation of safety barriers in a narrow median?

This paper deals with questions 1, 2 and 3. The implementation issues are the subject of ongoing research that will be reported separately.

3. Risk reduction to be achieved through installation of median safety barrier
The assessment of potential risk reduction was carried out in two stages:

Stage 1: The first stage was to assess the risk reduction that could be achieved through the installation of median safety barriers by reviewing actual accident data for six sections of the Pacific Highway covering a five-year period (July 1998 to June 2003). The aim was to determine how the accident-severity would have been reduced with a median safety barrier in place. Five sections of road were chosen for their high-risk status (i.e. they are targeted by RTA as high priority areas for risk reduction). One section was chosen as representing an average-risk part of the highway. In all, 247 km of the highway were studied (representing 30% of its total length). The roads targeted carry 8,000-12,000 vehicles per day (AADT) with between 12-16% heavy vehicles. The sections of road studied are shown in Table 1; a representative photo of the highway is shown in Figure 1.

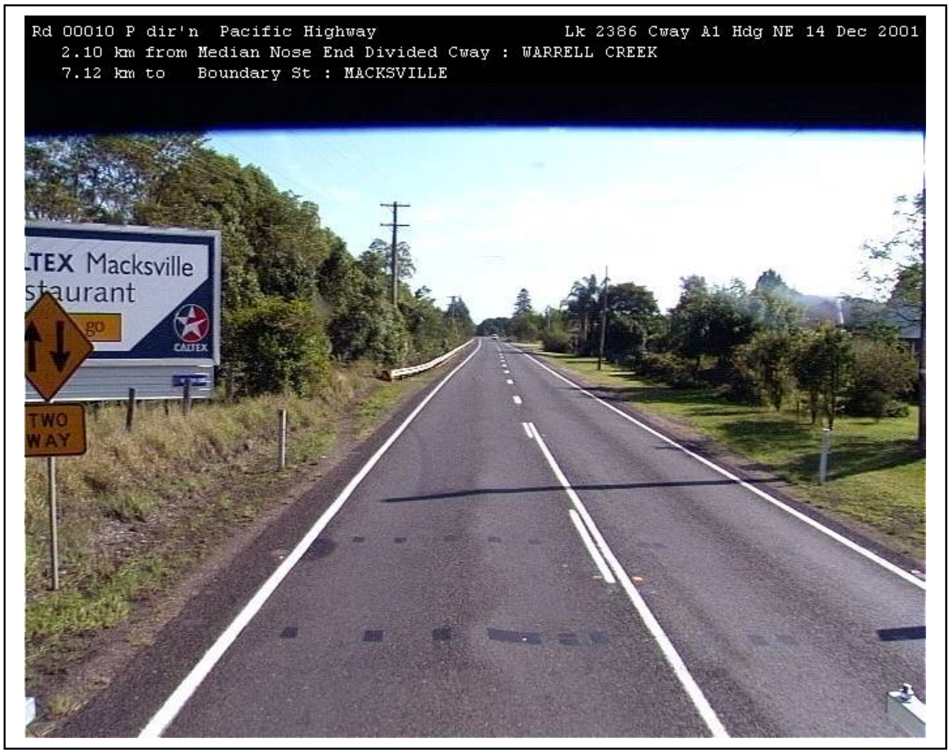
Table 1 – Road Segments Analysed

Section	Length (km)	AADT	% Heavy Vehicles
1. Kempsey to Eungai Rail	30	11204	13
2. Macksville to Urunga	28	11023	13
3. Woolgoolga to South Grafton	53	8430	15.5
4. Ulmarra to Woodburn	77	10418	16
5. Ballina to Bangalow	27	9410	12
6. Woodburn to Bruxner Highway	32	9206	13

Notes: AADT = Annual Average Daily Traffic

Sections 1 to 5 are sections of the Pacific Highway that have a high accident history. Section 6, Woodburn to Bruxner Highway, was adopted as a control section that was not in a high-risk category.

Figure 1 - Representative photograph of road sections analysed



Stage 2: The second stage of the risk analysis was to compare and contrast the risk reduction calculated for the Pacific Highway with actual experience.

Australia has only limited experience with safety barriers in medians of regional (not motorway) roads. In Sweden, however, 950 km of wire rope median safety barriers have been installed since 1998, and the Swedish Road and Transport Institution (vti)[1] is an excellent source of information. The study used data from Sweden's '13-metre roads' that were upgraded to 'MLV'[2] roads. Data was taken from 12 sections of road (covering a total of 165 km) where road conditions and other factors that influence the risk situation most closely resembled the situation of the Pacific Highway.

Findings: Accidents involving overtaking (head-on collisions and off-carriageway to the right), represent about 50% of all accidents involving fatalities on high-risk sections of the Pacific Highway. These overtaking accidents also represent about 40% of all accidents involving injuries on high-risk sections of the highway. The accident statistics are slightly lower for the average-risk section that was used as a reference. It had the same 50% for fatalities but a lower 30% for injuries. The expected result of installing an appropriately chosen median safety barrier is a reduction in the severity of accidents.

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1 'Vag och transport-forsknings institutionen' (Sweden)

2 'Motesfri Lands Vag', or literally, Meetingfree Rural Road (i.e., a 2+1 configuration on rural roads), with two lanes in one direction of travel and one lane in the opposite direction, separated by a median safety barrier.

That is, a percentage of accidents would be less severe - a fatality may be converted into a severe injury, a severe injury into a less severe injury.

This aligns with the findings in the latest half-yearly report of the Swedish Road and Transport Institution, which states that on the Swedish 13-metre roads upgraded to MLV *'… accidents with severe outcome are prevented by the barrier but instead are turned into barrier collisions with limited injuries'.* [ii] The Swedish report shows the number of fatalities is reduced by 45-55% and the number of fatalities and severely injured is reduced by 35-50% after the upgrade, which includes installation of median safety barriers. The report further shows that the number of mild injuries remains much the same and that the number of non-injury accident increases after the upgrade.

To determine how best to extrapolate the Swedish experience, a review was carried out of the similarities and differences between the Swedish roads and the proposed upgrades to the Pacific Highway in NSW, with the following aspects taken into account:

- Speed limits: Ranging from 80-100 km/h on the Pacific Hwy and from 90-110 km/h on Swedish roads.
- Traffic volumes: Slightly higher in Australia with an AADT of 8,000-12,000 on the sections of road analysed, compared with AADT of 5,000-10,000 in Sweden. Similar percentages of heavy vehicles in the two countries.
- Standard of road maintenance: Considered to be approximately similar.
- Width of the lanes: Mainly 3.5 metre lanes on the Pacific Highway sections analysed, compared with 3.75 metre single lanes and 3.25 metre lanes for two lanes in the same direction on the Swedish roads.
- Width of shoulders: The width of the shoulder next to the 2+1 roads in Sweden is very narrow (0.75m) compared with the 2.0 – 3.0 metre wide shoulders proposed for the Pacific Highway.
- Seasonal conditions: Roads in Sweden are subject to snow and ice in winter. It was initially thought that safety barriers would substantially reduce risk during these months. There are more impacts on the safety barrier during the Swedish winter months and it follows that the safety barrier reduces risk more in winter than for the rest of the time. However, injury levels in Sweden tend to decrease during the winter months because people drive at lower speeds, thus this difference between the Swedish and the Australian situation may not be as important as was initially thought.
- Wildlife: While different, wildlife on NSW roads (kangaroo, wombat etc) and wildlife on Swedish roads (moose, deer etc) pose similar dangers to vehicle passengers.
- Police presence and checks: Considered to be approximately similar.
- Other road upgrades with risk reduction impacts: The road upgrades carried out on the 13-metre roads in Sweden consist of installing median barriers, delineating the road into 2+1 lanes (alternating approximately every kilometre), installing shoulder barriers and upgrading road condition. The option assessed for the Pacific Highway is for 1+1[3] roads with some overtaking lanes (2+1 sections),

[3] 1+1 = One lane in each direction.

generally at a greater spacing than in the Swedish case. The safety barrier will be installed as part of pavement widening works.

Installing wire rope safety barriers on 1+1 lanes instead of 2+1 lanes may increase the risk of accidents caused by driver impatience when queuing behind slow vehicles for longer periods of time. However, confining vehicles in a single lane will reduce lane change accidents. The two effects are opposing (one increasing and one decreasing the risk of an accident).

Installation of shoulder safety barriers would further reduce the risk of serious accident trauma. Communication with the Swedish Road and Transport Institution indicates that shoulder barriers and other side area upgrades are responsible for about 5% of the 50% reduction in the number killed. Median safety barriers and the 2+1 upgrade are considered to be responsible for about 45% of the reduction in the number of fatalities.

Analysing all these factors leads to the conclusion that 80-90% of the Swedish risk reduction could be applied to median safety barrier upgrade work on the Pacific Highway. The following effect is therefore expected for the Pacific Highway where median safety barriers are installed:

- 35-50% reduction in the number of fatalities
- 30-45% reduction in the number of fatalities and severely injured[4]
- No increase or slight increase in the number of mild injuries
- 30% increase in the number of vehicle damage / non-injury accidents

The increase in the number of vehicle damage only accidents occurs because previously harmless incidents where vehicles strayed over the centerline, when there were no opposing vehicles, would now become impacts with the median safety barrier.

4. The most appropriate type of median safety barrier

The following three types of safety barriers were assessed to determine the appropriate choice for a median safety barrier:

- Wire rope safety barriers
- Steel guardrail
- Concrete barrier

Parameters for the assessment of median safety barrier alternatives were:

- Impact severity: A severity index is used to describe the severity of the impact and the possible damage to vehicles and injury to occupants after hitting various types of barriers. Table 2 below shows the impact severity index for the safety barrier systems that were reviewed, as detailed in the *RTA Road Design Guide*.

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[4] Note that this assumes a similar distribution between mild and severe injuries in Australia as in Sweden (approximately 1:3 or 1:4).

- Generic costs per accident[5]: The generic costs per accident from the *RTA Economic Analysis Manual* were used to derive the comparison of safety barriers shown in Table 2.
- Hardware footprint: Only minimal road widening will be carried out to allow for the installation of a median safety barrier. Table 2 shows the widths required by the hardware of the safety barrier systems reviewed.
- Deflection[6]: When hit by a vehicle a safety barrier will deflect and allow the vehicle to travel past the original line of the barrier. Comparitive deflections from the *RTA Road Design Guide* are shown in Table 3. Containment of deflections within the median will influence the width of the median to be provided.
- Aesthetics: Both the steel W-beam barrier and the concrete barrier types positioned in the median of the Pacific Highway would restrict the view for motorists. While this would have some advantages at night (because it would partially block out the lights from oncoming traffic), it would also give the motorist a sense of driving in a tunnel. Wire rope barriers are in most circumstances see-through and do not block out the view for motorists.

Table 2 - Safety barrier comparison

Safety barrier system	**Impact severity index at 100km/h**	**Accident costs over 30 year period (100 km/hr impact)**	**Width required for system hardware footprint (not including shoulder widths beside barrier)**
Wire rope safety barrier	2.5	$89,500	120mm (400mm where anchors are required)
Steel guardrail	3.0	$174,000	625mm
Concrete barrier	3.5	$234,300	600mm

Typical installation costs of safety barriers are:

- Wire rope safety barrier $115/m
- Steel guardrail $85/m single sided, $125/m double sided
- Concrete barrier $102/m

The installation cost of different safety barriers was not included in the comparison because the costs were similar and the relativity of costs would vary with the size of the project, location, availability of materials and consideration of life cycle costs.

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[5] Generic costs per accident include human and incident costs. Human costs include medical and care expenses, insurance claims, quality of life support and earnings related costs. Incident costs includes vehicle repair, insurance administration, investigation, legal and alternative transport costs.

[6] Deflection is the transverse distance a road safety barrier moves off its original line during an impact.

Table 3– Safety barrier design deflections

Safety barrier type	Dynamic deflection (m) for straight line of barrier			
	80km/h	90km/h	100km/h	110km/h
Wire rope safety barrier	1.2	1.3	1.4	1.5
Steel guardrail	1.2	1.3	1.4	1.6
Concrete barrier	0	0	0	0

Findings: Of the barrier types reviewed, the wire rope safety barrier provides the optimum solution in most circumstances due to the following factors:

- Wire rope safety barriers have the lowest risk of injury and damage in case of a light vehicle crashing into the barrier[7] (it has the lowest impact severity index at 100 km/h)
- Wire rope safety barriers provide the lowest accident costs
- Wire rope safety barriers have the smallest hardware footprint
- The low deflection of concrete barrier is an advantage that is offset by the higher impact severity that results from impact with an immoveable barrier
- Wire rope safety barriers are the best aesthetic solution because in most circumstances it allows motorists to see through the barrier and does not block the view of the landscape

5. Determining median width

A safety barrier located on both sides of the median has the advantage that it maximises the opportunity to contain deflections within the median. However a central location was assumed for the evaluation because it has the following advantages:

- Debris from damaged barriers is less likely to encroach into the carriageway
- Sight distance past the barrier on curves is maximised with a centre location
- A centrally located median barrier will sustain less nuisance impacts than a barrier on the side of the median
- Central location has less cost than a barrier on both sides of a median

A vehicle hitting a wire rope safety barrier may encroach beyond the line of the barrier, or it may cause barrier wires or posts to encroach beyond this line. On narrow medians, this may allow the vehicle or part of the barrier to encroach into the opposing carriageway. Such incidents have occurred in Sweden. While experience shows that the wire rope safety barrier reduces the consequences of a head-on collision by reducing the speed of the accident-causing vehicle, it is desirable to provide sufficiently wide medians to prevent encroachment into an opposing carriageway, as far as practicable.

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[7] Even though experience shows that the wire rope safety barrier may also restrain trucks, the analysis has conservatively assumed that trucks would not be restrained.

A crash test on a 200m radius curve at 80 km/h impact speed and 25° angle of impact, showed the 1.5 tonne vehicle was past the original line of the barrier for about 1.5 seconds, after which the vehicle will be back in the travel lane.[iii] The probability of a collision due to encroachment after impact is related to the probability of a vehicle being adjacent to the impact site during this short period of time.

The cables of a severely impacted wire rope safety barrier system form a chord across the inside of a curve as a result of being released from the supporting posts. Tests at 80 km/h and 25° angle of impact on a 200 metre-radius curve show that the cables will lie about 0.8 metres off the line of the barrier after impact and may become a hazard for oncoming traffic. It is likely this offset would be larger at higher impact speeds due to dislodgement of longer lengths of wire rope. Where wire rope safety barriers are installed in medians of less than 1.6 metres wide, the posts (which are generally 0.8 metre high) may lie on the road carriageway after an accident impact, and become a hazard.

The authors think that a median width of 1.6 metres might eventually be adopted as the minimum width for installation of wire rope safety barriers in narrow medians. This is however dependant on the half median width of 0.8 metres being shown to be sufficient to contain dislodged cables and bent posts from damaged installations, and assessment of the results of higher speed impacts. The first stage of the RTA trial installation will adopt a minimum median width of 2.0 metres as a conservative measure. The additional width will provide for containment of debris and provide additional sight distance past the barrier on curves.

A 1.25 metre wide median (corresponding to the width used in Sweden) could be considered in the future, however these narrow medians would need to be supported by very efficient incident clearance procedures. It is necessary to ensure that cables and posts from damaged wire rope safety barriers are quickly removed when they encroach into the carriageway.

Because of a lack of data, it is not possible at this stage to quantify the additional risk reduction that can be achieved by expanding the width of the median to beyond the minimum 1.25 meters used in Sweden. Advantage will be gained if the median is made as wide as is practicable without foregoing other road safety conditions (e.g. without narrowing the lanes). Sweden quotes a 65% reduction in the number of fatalities and severely injured if the road is upgraded to a dual-carriageway, which can be seen as the ultimate safety upgrade. Compare this figure with the 30-45% reduction achieved by installing the safety barrier in the 1.25 metre wide median and the risk reduction achieved by widening the median will lie somewhere in between. Based on the authors' knowledge of practice in Sweden, it is likely to be closer to the 30-45% figures than to the 65% figures.

6. Issues that need to be resolved to enable implementation of safety barriers in a narrow median

Many implementation issues are being resolved before initiating the work of installing wire rope safety barriers in the median of the Pacific Highway. For example, a number of design parameters need to be determined, such as requirements for cross section, median break configuration, sight distance, deceleration lanes, provision for bicycles, gap dimensions, delineation and the ability to move past incidents. Other issues to be taken into account are the impact on all road users (including motorcycle riders), and the requirements for maintenance, repair and worker safety.

This paper will not go into the details of these implementation aspects, but the layout of safety barriers on motorcycle users warrants comment. A summary of the issues for motorcyclists has been provided in a study with representatives from the Australian Transport Safety Bureau, the Australian and the NSW Motorcycle Councils, the Motorcycle Riders Association and the Ulysses Club.[iv] The study reports that: '*The function of conventional crash barriers in relation to motorcycle safety is problematic. On the one hand, they have potential to reduce the risk of rider collision with rigid roadside objects and oncoming vehicles. On the other hand, they can expose riders to significant risk of injury from contact with the barriers themselves.*'

In the *In-depth investigation of run-off-road motorcycle crashes* prepared for Austroads in 2003[v], it is noted that: *'… no evidence has yet been found (after an extensive search) to indicate that flexible barriers present a greater (or lesser) risk when struck by a rider compared to other commonly used barrier types, such as rigid concrete or semi-rigid, steel guardrails. Furthermore, no evidence has been found to indicate that the presence of any roadside barrier presents a greater (or lesser) risk to errant riders than does the absence of a barrier of any kind. Barriers are typically installed only where hazards exist within the roadside such as trees, poles, rock embankments, steep drops, concrete culverts or other hazards, or to prevent median crossover crashes. Rider impacts with these types of hazard also present a serious risk of injury to errant riders.'*

The Ulysses Motorcycle Club web-site quotes the Vice President's view on wire rope safety barriers as: *'In many cases it is better for us than no barrier at all, e.g. medians, where it will protect us from head on crashes, and on steeper roads where a drop off the edge is not desirable.'*[vi]

7. Conclusion

Comparitive studies with Swedish experience of median wire rope safety barriers suggests that installation of safety barriers in the median of the Pacific Highway is likely to substantially reduce the number of road users killed and seriously injured. The expected reductions in accident rates are:

- 35-50% reduction in the number of fatalities
- 30-45% reduction in the number of fatalities and severely injured[8]
- No increase or slight increase in the number of mild injuries
- 30% increase in the number of non-injury accidents

[8] Note that this assumes a similar distribution between mild and severe injuries in Australia as in Sweden (approximately 1:3 or 1:4).

The Swedish National Road Administration analysis of the effectiveness of median wire rope safety barriers noted that: *'….. accidents with severe outcome are prevented by the barrier but instead are turned into barrier collisions with limited injuries.';* and further: *'.…. head on accidents have been eliminated and the number of single vehicle accidents with severe injuries have been significantly reduced.'*[vii]

Of the types of barriers assessed (wire rope safety barriers, steel guardrail and concrete barrier), the wire rope safety barrier was shown to provide the most appropriate safety improvement, considering the following aspects:

- Impact severity
- Accident costs
- Hardware footprint
- Deflection
- Aesthetics

From Australian and international experience, it is clear that the severity of the trauma experienced in accidents caused by centreline crossover accidents will be significantly reduced after the installation of wire rope safety barriers. The experience with accidents with severe outcomes, i.e. fatalities or severe injury, should be very similar to experience in Sweden.

Acknowledgement
The authors of this paper kindly acknowledge the support and technical input given by Arne Carlson from the Swedish Road and Transport Institution and Jan Moberg from the Swedish Road Administration, as well as by RTA's Graham Brisbane (former Manager Road Environment and Light Vehicle Standards), Steve Williamson (Road Safety Design and Management Program Manager), Wayne O'Mara (Road Environment Safety Project Officer), John Vickery (Manager Road Design Policy and Standards), Colin Jackson (Roadside Furniture Project Manager, Crashlab), Damien Chee (Road Environment Safety Project Manager), Steve Levett (Federal Blackspot Programming Officer) and Anthony Donohoe (Road Safety Analysis Northern).

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