Methods to Identify and Manage Runaway Heavy Vehicle Issues on Steep Descents

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Abstract

Mount Ousley Road and the Bulli Pass are two key freight routes entering the Southern Region of NSW from Sydney. Both roads are challenged geometrically with steep vertical grades and tight horizontal radius curves with a history of out of control crashes. Past attempts in managing the risk of runaway vehicles on steep descents have involved the construction of gravel arrester beds. The effectiveness of such treatments has been contested on recent projects. Questions regarding the feasibility and functionality of vehicle arrester beds have been raised leading to a search for alternative road safety technologies and ways of dealing with potential problems.

This paper presents case studies in analysing risk and the selection of appropriate treatments to manage these risks for runaway heavy vehicles on steep descents. It reviews the treatments available for each project and outlines the risk based methodologies applied to determine the most appropriate solution. This has resulted in selecting unique and tailored applications with a strong focus on road safety outcomes.

Keywords

Heavy Vehicle Safety, Risk Assessment, Arrester Bed

Introduction

Mount Ousley Road and Bulli Pass are two main north-south routes connecting Sydney to the Illawarra Region in New South Wales. Both routes traverse through the Illawarra escarpment, surrounded by a steep mountainous terrain and are constrained by the horizontal and vertical alignments (Figure 1).

Figure 1: Sydney-Wollongong corridor and major regional transport links [1]
Heavy vehicle traffic is anticipated to increase in the Illawarra region in association with the Port Kembla expansion and continual growth of the coal industry. It was predicted that growth would increase by at least 10% (in each direction) on the current heavy vehicle movements on key freight routes in the Illawarra region [2].

With the increase in heavy vehicle volumes and a higher focus on heavy vehicle safety in road infrastructure projects, the New South Wales Roads and Traffic Authority Southern Region completed a number of studies to identify and manage runaway vehicles on steep descents. This paper presents the methodologies and techniques used through two case studies.

**Case Study One – Bulli Pass**

Bulli Pass is a major road corridor connecting Wollongong with Sydney. The 3.7km mountain pass that connects the Illawarra escarpment with the Coastal Plain has a downward grade of up to 12%. It descends to an unsignalised at grade junction with priority to northbound (uphill) and southbound (downhill) movements on the Princes Highway (Bulli Pass). Lawrence Hargrave Drive is a main arterial and currently the only major road available to link the northern suburbs with Wollongong (Figure 2). It is expected that there will be an increase in pressure to the local transport network with the construction of adjoining arterial roads (Northern distributor) and further development in the northern suburbs. The improvement to the intersection at the Princes Highway and Lawrence Hargrave Drive will ease congestion and improve traffic flow. The intersection currently exceeds capacity in the afternoon peak and is approaching capacity in the morning peak. Due to the poor crash history, it is proposed to reconstruct the intersection of the Princes Highway (Bulli Pass) and Lawrence Hargrave Drive, Bulli.

**Figure 2: Location map showing intersection of the Princes Highway and Lawrence Hargrave Drive**

A single northbound lane that spans the nearby Woodlands Creek and the Princes Highway (Bulli Pass) was determined as the most cost effective solution to manage the traffic management and road safety issues at this site. The proposed bridge removes the right turn movement from the Princes Highway to Lawrence Hargrave Drive which has been identified as having significant conflict movement and the main cause of many accidents (Figure 3). As part of the proposal, the issue of managing runaway
vehicles on the Princes Highway (Bulli Pass) was an integral component of the project development as there was an existing facility that had to be upgraded and/or replaced.

![Figure 3: Artists impression of the proposed intersection at the Princes Highway and Lawrence Hargrave Drive](image)

**Issue**

The steep topography on Bulli Pass has led to the loss of brakes of heavy vehicles causing them to lose control. A safety ramp currently exists in the vicinity of the proposed work at the bottom of Bulli Pass as a means to manage run away vehicles. Those that need to access the facility have to cross the path of southbound vehicles from Lawrence Hargrave Drive to access the safety ramp, a movement with an hourly volume of 1000 vehicles in peak times. Anecdotal evidence from RTA maintenance crews and local business owners, suggest that it had been over 10 years since the safety ramp had been used for such an event. A review of the existing facility found that it was too short for the anticipated entry speeds and would require a significant upgrade. The safety ramp also crossed Woodlands Creek which restricted flows during a flood event.

The provision of a suitable vehicle arrester system is further compounded by the site constraints. The intersection is located at the bottom of a steep decent, in an urban environment. There is limited space available to provide a facility that is capable of managing a heavy vehicle that has lost control.

**Data Collection and Analysis**

An analysis using a detailed computer simulation (SIMON) was undertaken to determine the maximum speeds a runaway vehicle could achieve at the bottom of Bulli Pass and the maximum speed it could travel before rollover should it attempt to negotiate the bend. Simulation Model Non-linear (SIMON) is one of a suite of analysis models designed to simulate vehicle handling and impact dynamics within the HVE-3D computer simulation environment [3].

The vehicle speeds were calculated assuming a worst case scenario where the onset of a runaway vehicle causes the vehicle to travel in neutral with no braking. The vehicle speeds for both 19 metre B-double...
vehicles and passenger cars were calculated. It was determined that vehicles were unable to descend the entire length of Bulli Pass without losing control at many of its smaller radius curves.

The analysis found that the maximum speed a B-double vehicle could achieve at the entry of the existing safety ramp was between 105 and 110 km/h. This was assuming that the B-double vehicle lost control approximately 640 metres from the safety ramp and was traveling at the prevailing 20km/h speed limit currently imposed on heavy vehicles. A passenger car was assessed at entering the safety ramp between 115 and 120km/h assuming it lost control 770 metres from the safety ramp at a speed of 60km/h [4].

The findings of this analysis were later used as inputs in a risk workshop which identified a preferred option to manage runaway vehicles.

Other studies completed during the project scoping phase included a traffic analysis of the proposed intersection upgrade. The traffic modelling identified that the intersection is characterised predominantly (up to two thirds) by local traffic travelling in a north-south direction between Wollongong and the northern suburbs. The remainder of the traffic is linked to the F6 freeway for inter city trips to and from Sydney. The study also modelled the operation of the proposed intersection compared to the existing conditions at 2006, 2016 and 2026. The model outputs showed that the proposed intersection would significantly improve operation and reduce delays, with spare capacity available during all peak periods at 2026.

Options Considered

As part of the project scoping to find suitable treatments to manage runaway vehicles, a literature review was undertaken of both Australian and international papers investigating the use of crash barriers or other alternatives to the traditional gravel arrester bed. The search of the available literature found that there were no suitable treatments available that would automatically lend themselves to be used to the type of application considered at the bottom of Bulli Pass. Much of the literature reviewed discussed the performance of traditional treatments including the inadequacies of gravel arrester beds and the potential for heavy vehicles rolling over concrete barriers. Unfortunately none of the studies had discussed methods to contain heavy vehicles at the speeds expected on Bulli Pass [5].

Among the possible solutions identified in the literature search was a US treatment to provide a heavily reinforced retaining facility to contain runaway heavy vehicles. This was located on the outside of a curve to protect a school where heavy vehicle speeds were in the order of 100km/h. A similar barrier had also been used in New Zealand to protect a power generation site. With the high forces and energies involved in such an impact, the US Federal Highway Administration has developed a test level 6 (TL6) criteria to assess such structures that are based on a 36 tonne truck and trailer unit travelling at 80km/h at an impact angle of 15 degrees. Using this as a basis for further analysis, a concept design was developed.

Due to the limited space available at the site, an alternative vehicle arrester bed was assessed that had been used overseas. The Dragnet vehicle arresting system uses a series of chain link fences to slow vehicles down and bring them to a stop. The fences have continuous cables running at the top and bottom that are connected to a proprietary energy absorber system. Each of the energy absorber units contain an alloy tape that is wound through a series of offset pins. When the fence is hit by a vehicle, the steel tape is pulled through the pins creating sufficient resistance to safely bring a vehicle to a stop. The system can be accommodated for all site conditions and multiple traffic mixes simply by adding or removing the number of fences.

As a result of the investigations undertaken and giving consideration to the site constraints, the following options were considered in further detail and formed the cornerstone of a risk assessment exercise:

- Containment wall
- Dragnet
- Arrester bed
- Removal of the existing facility
- Guardrail/wire rope (this was later discarded as it was not structurally effective)
**Risk Assessment**

A risk management workshop was undertaken to obtain an understanding of the site conditions and recommend a preferred option for the management of runaway vehicles travelling down the lower section of Bulli Pass.

The workshop formulated a decision statement and developed objectives to be used as part of the ultimate decision-making process. These objectives were formulated as part of a Kepner Tregoe decision-making process and are shown in Table 1 [6].

<table>
<thead>
<tr>
<th>Must Objectives</th>
<th>Want Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Must be buildable without closing Lawrence Hargrave Drive</td>
<td>• Safety</td>
</tr>
<tr>
<td>• Must support current intersection design</td>
<td>o Minimise conflicts with other people (Motorists, pedestrians, cyclists)</td>
</tr>
<tr>
<td></td>
<td>o Maximise safety of driver of runaway vehicles</td>
</tr>
<tr>
<td></td>
<td>o Maximise perception of safety to motorists using intersection</td>
</tr>
<tr>
<td></td>
<td>• Technical</td>
</tr>
<tr>
<td></td>
<td>o Maximise technical effectiveness of the solution</td>
</tr>
<tr>
<td></td>
<td>o Minimise traffic disruption/flow post incident</td>
</tr>
<tr>
<td></td>
<td>o Minimise closure of Bulli Pass during construction</td>
</tr>
<tr>
<td></td>
<td>• Cost</td>
</tr>
<tr>
<td></td>
<td>o Minimise overall solution cost</td>
</tr>
<tr>
<td></td>
<td>• Community</td>
</tr>
<tr>
<td></td>
<td>o Minimise impact to local residents</td>
</tr>
<tr>
<td></td>
<td>o Minimise environmental impact</td>
</tr>
</tbody>
</table>

Once determined, the objectives were audited against the decision statement to ensure that they supported the statement and ensure that they collectively provided a balanced perspective.

Four options were nominated for consideration at the workshop which included;

1. Do nothing
2. Replace the existing safety ramp with a Dragnet System
3. Realign the intersection and place the Dragnet system on the shoulder of Bulli Pass
4. Construct a containment wall

At the workshop an additional two alternatives were suggested for further consideration including;

- Construct a dragnet arrester bed on the left side of the off ramp
- Construct a dragnet arrester bed on the right side of the off ramp

All of the alternatives were then assessed against the objectives. Any option that did not meet the ‘must’ objective was no longer considered in the risk analysis. The alternatives were then assessed against the ‘want’ criteria, the best performing alternative received the highest score and the remainder were scored relatively.

The assessment highlighted one important issue that had a significant influence on the selection of the preferred option. When each option was assessed against the criteria of “Maximise technical effectiveness of the solution”, the containment wall was the only treatment that could be guaranteed being used when required. It removed the decision from the driver of the runaway vehicle as to whether to utilise the facility or not. The other alternatives that had been considered had a potential risk of not being utilised by the driver or being unable to be accessed. The containment wall not only removed the risk utilisation but also guaranteed the protection of the southbound motorists from Lawrence Hargrave Drive, of which no other alternative could provide.
The risk assessment also highlighted that one of the objectives was not required. The objective of “Minimise closure of Bulli Pass during construction”, scored equally amongst all options, thereby not influencing the final outcome of the assessment.

The alternative with the highest weighted score was determined as the preferred option. With the selection of the preferred option to manage runaway vehicles, a preliminary risk analysis was completed to identify the issues associated with the containment wall that would require further attention during the next stage of the project development.

Case Study Two – Mount Ousley Road

Mount Ousley Road is a key north-south freight route connecting Sydney and the Southern Illawarra region of New South Wales. Based on the Sydney Wollongong Corridor Strategy [1], heavy vehicles account for approximately 16 percent of road traffic to the immediate north of Wollongong along Mount Ousley Road (due in large part to coal traffic heading to and from Port Kembla). The Annual Average Daily Traffic (AADT) on this road in 2007 was recorded at 40,169 vehicles.

The southbound section of Mount Ousley Road between the Picton Road interchange and the Wollongong exit has a 4.4km section of steep vertical alignment (steep vertical grade in the range of 8-10%). Due to the steep descent and tight horizontal curves in the southbound direction, crash history on this section of road is very poor. Based on crash record in the five years period between October 2002 and September 2007, there were 121 recorded crashes, of which 44% (54 crashes) were out of carriageway on curves or straights crashes. 17% (21 crashes) of the total number of crashes involved heavy vehicles.

Existing measures to manage heavy vehicle safety on this section of Mount Ousley Road include a signposted speed of 40km/h for trucks and buses, an informal stopping bay at the top of the descent, a concrete barrier in the median and guardrail safety barrier on the verge, signs to require trucks to use low gears, two gravel vehicle arrester beds for emergency use, and a heavy vehicle inspection area to improve vehicle compliance and safety on road.

There are three southbound lanes on Mount Ousley Road with the left and middle lanes marked as trucks and bus lanes. The steep descent starts at the Picton Road interchange. Half way down the descent there is a relatively flat area prior to the second descent towards the Wollongong exit. On the relatively flat section of the descent, RTA inspectors use this area for heavy vehicle inspection activities as the flat and straight alignment of entry enables accurate vehicle inspections to be carried out. In this flat area a gravel vehicle arrester bed is also located. This means the entrances to the arrester bed and the heavy vehicle inspection area are closely located. This has caused concerns related road safety and Occupational Health & Safety (OHS) risks for vehicle inspectors working in the area. In 2007, an OHS risk assessment completed for the operation of vehicle inspection area resulted in the closure of the site. The closure of the heavy vehicle enforcement site initiated a review of the management of heavy vehicle safety risks on Mount Ousley Road in the southbound direction through a number of studies as described below.

Traffic Analysis

A traffic analysis was undertaken to understand the amount of heavy vehicles travelling southbound on Mount Ousley Road. A permanent traffic counter called the ‘The Infra Red Traffic Logger’ (TIRTL) was installed on Mount Ousley Road which collected traffic volume data for both northbound and southbound traffic.

The TIRTL consists of transmitter and receiver units. The transmitter is the source of infra-red beams used to detect traffic. The receiver detects disturbances in the infra-red beams caused by passing tyres. By placing the TIRTL transmitter and receiver units on opposite sides of a carriageway, the system precisely measures the number of axles, axle separation, wheel width and the front to back wheel width ratio to classify vehicles [7].
Based on traffic data collected between November 2007 and August 2008, average weekday southbound traffic volume is approximately 20,000 vehicles, with heavy vehicles representing approximately 12% of total traffic. Percentage lane usage on Mount Ousley Road southbound is 12%; 57%; 32% for the corresponding left, middle and right lanes (Table 2).

<table>
<thead>
<tr>
<th>Lane 1 - Left</th>
<th>Lane 2 - Middle</th>
<th>Lane 3 - Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Heavy</td>
<td>Light</td>
</tr>
<tr>
<td>Average weekday traffic (vehicles/day) and % split</td>
<td>282</td>
<td>2037</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>12%</td>
<td>88%</td>
<td>96%</td>
</tr>
<tr>
<td>Total volume</td>
<td>2319</td>
<td>11319</td>
</tr>
<tr>
<td>Lane usage %</td>
<td>12%</td>
<td>57%</td>
</tr>
</tbody>
</table>

Mount Ousley Road southbound has a signposted speed limit of 40km/h for trucks and buses. Based on TIRTL data collected, average heavy vehicle travelling speeds are summarised in Table 3.

<table>
<thead>
<tr>
<th>Travelling speed ranges (km/h)</th>
<th>Percentage of heavy vehicles travelling speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10</td>
<td>0%</td>
</tr>
<tr>
<td>10-20</td>
<td>1%</td>
</tr>
<tr>
<td>20-30</td>
<td>3%</td>
</tr>
<tr>
<td>30-40</td>
<td>16%</td>
</tr>
<tr>
<td>40-50</td>
<td>40%</td>
</tr>
<tr>
<td>50-60</td>
<td>19%</td>
</tr>
<tr>
<td>60-70</td>
<td>6%</td>
</tr>
<tr>
<td>70-80</td>
<td>7%</td>
</tr>
<tr>
<td>80-90</td>
<td>7%</td>
</tr>
<tr>
<td>90-100</td>
<td>2%</td>
</tr>
<tr>
<td>100+</td>
<td>0%</td>
</tr>
</tbody>
</table>

Heavy Vehicle Speed Simulation Study

ARRB Pty Ltd was engaged by the RTA to investigate the likely speed profile of a runaway vehicle on Mount Ousley Road. This speed simulation study investigated the capacity for out of control heavy vehicle to traverse the various horizontal curves and the maximum speed at which a vehicle is likely to reach at the entrance of the vehicle arrester bed. Speed profiles of modelled heavy vehicles in a 15 tonne rigid truck and a fully laden 25 metre 62.5 tonne B-double configuration were assessed in the study.

SIMON was used to examine simulated vehicle’s approach paths. A three-dimensional road environment model was generated for the southbound direction of Mount Ousley Road for the speed simulation study.
SIMON considered a worst case scenario, where an initial speed of 80 km/h was used for the B-double and rigid truck. The model vehicle was also simulated to have complete brake failure and neutral gear so there was no capacity for any form of engine or exhaust braking.

The simulations were achieved through an extensive iterative process. The process involved changing the steer input applied to the vehicle as it progressed down the Mount Ousley Road alignment until a combination of steer input and vehicle path could be obtained that allowed negotiation of each progressive curve along the road. Simulation of vehicle paths utilised all of the available road space, including sealed shoulders, to maximise the turning radius through each of the horizontal curves to keep the vehicle upright. In practice, this may not be achievable in the presence of other vehicles.

Based on a combination of steer and vehicle path input, a number of simulated vehicle paths resulted in heavy vehicle rollovers or failures on the road and were subsequently saved for visual presentation (Figure 5). Most of these rollover simulated scenarios were caused by excessive heavy vehicle speed built up due to the steep descent, and the failure to negotiate the tight curves or vehicle paths constrained by the concrete median barrier causing a rollover.

Simulation results completed by SIMON demonstrated that for a 25 metre 62.5 tonne B-double at the top of the descent travelling at an initial speed of 80 km/h, with no brakes and freewheeling in neutral, that it was technically possible to find a combination of steer manoeuvres which would enable the vehicle to reach the gravel arrester bed at a speed in the order of 140km/h. However, this requires the driver to completely replicate the simulated sequence of events to enter the gravel arrester bed. Failure to replicate the same sequence of events or steering adjustments could result in rollover prior to the arrester bed. In other words, it is technically possible for a runaway heavy vehicle to enter the existing vehicle arrester bed, however, the frequency of such an event could be low as it relies on no vehicles on adjacent lanes on Mount Ousley Road. Further, the entrance to the vehicle arrester bed requires the heavy vehicle to be travelling on the left lane. Based on Table 2, this means heavy vehicles travelling on the middle lane and right lane (approximately 22% of all heavy vehicles) could potentially miss the arrester bed.
Feasibility study for alternative arrester bed locations

A second heavy vehicle simulation speed study was undertaken to assess other feasible locations on the steep descent suitable for arrester beds. The aim of the assessment was to find alternative locations to relocate the existing arrester bed so that the existing flat area could be solely used for heavy vehicle inspection area, minimising the OHS risks for inspectors. Two potential locations on the descent were assessed using SIMON to investigate the potential entry speed to the arrester beds. It was found that by placing an arrester bed approximately mid-distance between the top of the descent to the flat area, and another arrester bed prior to the flat area, the potential runaway heavy vehicle speed could potentially reduce from 140km/h to 110-120km/h [3].

A reduction in the potential entry speed of a runaway vehicle into an arrester bed means the design of any arrester bed could be shortened.
**Heavy vehicle risk assessment**

In addition to the understanding of speed profiles of potential runaway heavy vehicles on Mount Ousley Road, a risk assessment has been initiated to analyse other options to manage heavy vehicle safety risks other than the provision of vehicle arrester beds. Vehicle arrester beds are reactive measures designed to decelerate an out of control vehicle to a stop through energy absorption properties. Other proactive measure under consideration includes providing a number of stopping bays on the descent to encourage vehicles to decelerate and stop prior to resulting in out of control runaway incidents.

The risk assessment utilises information such as the exposure of heavy vehicles on the road, traffic volume and lane usage data, the frequency of vehicle defects based on heavy vehicle non-compliance reports, the attendance rate of heavy vehicle enforcement inspectors on-road, and heavy vehicle crash history on Mount Ousley Road. The study aims to assess the relative risk associated with various treatment options by the data collected. Together with the simulation study results, the relative risk assessment provides a decision making process for the selection of a preferred option for management of heavy vehicle safety risks.

The study is currently underway at the time of writing, and a preferred option has yet to be determined.

**Conclusion**

This paper presents the types of analysis methodologies, possible available technologies and decision making processes that could be used to improve heavy vehicle safety on steep descents.

In the Bulli Pass study, the research and analysis completed along with the subsequent risk management process, led the New South Wales Roads and Traffic Authority (RTA) to a treatment for runaway vehicles that had not been previously considered. This case study delivered an innovative, cost effective solution that met all of the projects objectives.

In the Mount Ousley Road study, a combination of traffic analysis, speed simulation and risk assessment methodologies were used to assist in the identification and management of heavy vehicle safety risks. The study outlined techniques that could be applied for similar scenarios for the management of heavy vehicle safety risks on steep descents.

**Acknowledgements**

Whilst the views and conclusions in the paper are those of the authors, the assistance and support of the Roads and Traffic Authority in using work examples is acknowledged and appreciated.

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7. CEOS Industrial, TIRTL Product Overview, unpublished.
Biography

Jennifer Mak has 10 years of experience in the road infrastructure planning and development projects. She is currently working as the NSW Roads and Traffic Authority Southern Region Project Development Manager. Prior to this role, she worked in the former RTA Road Safety Strategy Branch responsible for the development of road environment safety guidelines and policies. She holds a Bachelor degree in Environmental Engineering and a Master degree in Transport and Traffic.

Paul Vecovski has 18 years of experience in major civil engineering infrastructure planning and construction. He is currently with the NSW Roads and Traffic Authority as the Project Development Manager. He is involved in infrastructure planning and project management of major road infrastructure projects in the southern region of NSW. Paul holds a Bachelor Degree in Civil Engineering (Civil) and completed a Masters in Business and Technology.