Abstract

Road safety practitioners have traditionally relied on current road standards and past experiences to manage road safety elements in road design. A generation of new and existing software applications can be utilised to effectively identify and assess potential road safety risks. The NSW Roads and Traffic Authority Southern Region, has used a combination of simulation and three-dimensional software to identify a range of road safety considerations including sight distance, traffic weaving and merge lengths.

This paper will present case studies of the application of Paramics, VISSIM and Dynamite software packages. Paramics and VISSIM are micro simulation transport models that are commonly used to evaluate and develop road traffic management systems. Dynamite is a software package specifically tailored to visualise road design projects into three dimensional animations. Using these approaches, road safety problems can be resolved early in the project planning and innovative solutions can be developed.

Keywords

Simulation, Road safety risk, Road design

Introduction

There are numerous computer applications used in the development of road infrastructure projects ranging from visual to traffic modelling. New uses of these software packages have been developed to identify and assess road safety issues. This paper will present case studies of the application of Paramics, VISSIM and Dynamite software packages in road infrastructure development projects. Using these approaches, road safety problems can be identified early in the project planning and allowing innovative solutions to be developed.

The application of computer modelling to identify road safety risks will be illustrated by the following case studies from the New South Wales Roads and Traffic Authority Southern Region.

Case Study 1 – Princes Highway and Lawrence Hargrave Drive

Safety and traffic issues at the Princes Highway and Lawrence Hargrave Drive intersection at the foot of Bulli Pass approximately 12km north of Wollongong resulted in a decision to reconfigure the intersection. Bulli Pass is a major road corridor connecting Wollongong with Sydney. The 3.7km mountain pass 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. This intersection was found to exceed capacity in the afternoon peak and was approaching capacity in the morning peak. The site has a history of crashes and is considered to be one of the worst intersections in the Illawarra.

A preferred option was selected for the redesign of the intersection which involved the construction of a single northbound lane that spanned Woodland Creek and the Princes Highway (Bulli Pass) (Figure 1). The construction of the overpass allows for uninterrupted northbound traffic flow thus removing the queuing that currently occurs during the PM peak period. This configuration would also remove a major conflict point of the right turn movement from the Princes Highway to Lawrence Hargrave Drive with the through traffic travelling south down Bulli Pass which has been identified as the cause of many crashes.
Potential weaving movement

As part of the project’s pre-feasibility studies, manual intersection turning count data and queue length observations were collected for the AM, PM and Sunday peak periods. This information was used to calibrate the base year traffic model. The day time and night time off peak periods were estimated using classified mid block tube counts and the recorded proportions for each approach.

Due to the complexity of the intersection and its influence to the adjoining local road network, and community concerns regarding the operation of the final arrangements it was determined that modelling of the network be undertaken to clarify traffic patterns that would eventuate. Paramics, a micro simulation transport model that is commonly used to evaluate and develop road traffic management systems, was assessed as the most appropriate package for this purpose.

Traffic volume projections for AM and PM peak periods for 2016 and 2026 were generated using the Paramics model. From this level of service, vehicle travel times and vehicle operating costs were derived. This information was used to quantify the lane configuration required, and the benefits the proposed intersection would provide.

It was also identified that the lane configuration immediately south of the proposed works would change for northbound traffic (Figure 1). Currently traffic wishing to access Lawrence Hargrave Drive use the right (fast) lane whilst traffic travelling north on Bulli Pass use the left (slow) lane. The proposed intersection will change travel paths with motorists wishing to travel north onto Lawrence Hargrave Drive requiring them to use the left (slow) lane whilst motorists wishing to travel onto Bulli Pass would have to use the right (fast) lane. Approximately 650 metres south of the proposed overpass are located a set of traffic lights. It has been observed that heavier vehicles have used the slow lane as there is a 10% uphill and downhill grade to negotiate before arriving to the Princes Highway and Lawrence Hargrave Drive intersection. Many of the heavier vehicles remain in the left (slow) lane to travel onto Bulli Pass and through to Sydney. The changes to the lane configuration are expected to introduce a weave movement that currently does not exist.

Paramics was used to model the effects of this new lane configuration and assess the associated impacts. Paramics graphical capability allowed observation of the expected traffic behaviour and the potential for

Figure 1: Artists impression of the proposed intersection at the Princes Highway and Lawrence Hargrave Drive
weaving. This analysis included completing a sensitivity analysis using Paramics to determine the degree of influence additional vehicles would have on traffic efficiency on the Princes Highway. The northbound traffic in the PM peak direction using future 2026 traffic volumes was identified as the worst case scenario. The sensitivity analysis involved adding 20% of the roads capacity to the 2026 traffic volumes to identify the pivotal point of when weaving would have an impact on traffic efficiency. The analysis found that the traffic volumes estimated would have to be doubled (approximately 60% of the roads capacity) before weaving would have an effect on traffic efficiency and associated safety.

A second modelling exercise was undertaken on the Urban Design aspects, an important element of project development. The proposed work was identified as having a significant impact on the existing landscape. To reduce the visual impact a curved bridge was designed. As the proposed overpass was a single lane carriageway there were sections on the bridge that had insufficient stopping sight distance. This was not evident at first on two dimensional drawings, as the height of the parapets on the bridge could not be appropriately accounted for.

The development of a three dimensional graphical representation produced using Dynamite\(^1\) enabled a number of aspects to be examined further. The stopping sight distance on sections of the bridge were clearly identified including the effects of the bridge parapets and similarly, the sight distance for vehicles entering Lawrence Hargrave Drive from Bulli Pass via a newly constructed off ramp could be appropriately considered. The impacts of the bridge parapets, railing and screens could be clearly viewed using Dynamite images thereby assisting road designers to appropriately configure the intersection.

Dynamite was also effectively used during the community consultation phase of the preferred option. The public concerns regarding sight distance being compromised for drivers wishing to turn right out of Lawrence Hargrave Drive and onto the Princes Highway (Bulli Pass) due to the position of the northern abutment of the overpass could be addressed. A Dynamite image was produced from the driver’s perspective clearly showing the available sight distance (Figure 2). This information greatly assisted in changing the public’s perception and gaining community support for the preferred option.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{sight_distance_image.png}
\caption{Dynamite image showing sight distance looking up Bulli Pass from Lawrence Hargrave Drive}
\end{figure}

\(^1\) Dynamite is a software package specifically tailored to visualise road design projects into three dimensional animations. It is commonly used as a tool for community consultation displays and presentations.

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Case Study 2 - Princes Highway Conjola Mountain Realignment

The Princes Highway is a key north-south route connecting Sydney and South Coast in New South Wales. Conjola Mountain is located approximately 46km south of the town centre, Nowra, in New South Wales. The project involved realigning approximately 3.5km of a steep and winding section of the Princes Highway. Through the data input including the digital terrain model, ground survey information and aerial photo of the project study area, a three-dimensional model of the proposed alignment was generated by Dynamite (Figure 3).

Due to the road’s alignment and terrain, the crash history in this section of the Highway is poor with a total of 35 reported crashes in the period between October 2001 and September 2006. 34 of the 35 reported crashes were out of control and off road on curves related crashes. With the main objective to improve road safety by reducing road safety risks and potential crash severity, a median wire rope safety barrier was proposed as part of the realignment project. The design of median wire rope safety barrier on a steep vertical alignment (5-7%) raised concerns relating to sight distance as well as the visual impact on motorists of the median safety barrier in the road environment.

Using the Dynamite model, the designer was able to specify a location at where sight distance could be checked rather than using the traditional method on a two-dimensional plan. For example, Dynamite assisted in the selection of the type of verge barrier to be used by checking safe intersection sight distance (SISD) from a side access road to the highway traffic (Figure 4). The designer was able to specify the angle of sight from the access road to the highway, and check the visibility of the highway traffic by comparing a concrete barrier with that of a wire rope safety barrier. Based on the Dynamite analysis, wire rope safety barrier was identified as providing a better safety outcome for the verge installation for this specific location due to its ‘see through’ characteristics.
The stopping sight distance on a horizontal curve was also checked by specifying the location of a stationary object at 200mm height on the road at nominated 1.15m driver’s height (Figure 5). These checks enabled the early identification of potential road safety risks during the preliminary concept stage.

The drive-through visualisation provided added benefits for the urban designer, and helped confirm the urban design and visual themes that could be practically achieved for this proposal. The three-dimensional representations assisted in the assessment of visual impacts for both motorists’ and the adjoining properties’ perspective. These images also assisted in the community consultation process of the project. Adjacent property owners were better able to understand the scope of the proposed project in the three-dimensional concept images, rather than the traditional two dimensional road design plans that have been previously used.

The Dynamite drive-through scenarios in both southbound and northbound directions were also used by road safety auditors at the preliminary design stage.
Case Study 3 - Mount Ousley Road Heavy Vehicle Enforcement Facility

Mount Ousley Road is a key freight route connecting Sydney and the Illawarra southern region of New South Wales. Based on a strategic heavy vehicle compliance and enforcement analysis study, a location for a northbound heavy vehicle enforcement facility on Mount Ousley Road has been identified.

The operation of a heavy vehicle enforcement facility typically involves a heavy vehicle entering an off-road paved area via a deceleration lane for weight and/or mechanical vehicle inspection. Upon completion of the inspection, the vehicle would leave the facility on a dedicated acceleration lane prior to merging with northbound traffic. At the proposed Mount Ousley Road heavy vehicle enforcement facility, the length of the acceleration lane was designed based on road design standard with the aim to enable heavy vehicles to safely merge on Mount Ousley Road at signposted speed of 100km/h. The merge from the acceleration lane was found to be 190m away from a highly trafficked left turning lane at the Picton Road junction (Figure 6). This prompted consideration of the feasibility of the continuation of the acceleration lane to connect to the left turning lane at Picton Road as an alternative to a merge/diverge situation. Although traffic efficiency with a combined acceleration and deceleration left turning lane was considered to be a more practical arrangement, the road safety risk associated with the merging and weaving movements between vehicles over this road length needed to be considered as part of the feasibility assessment (Figure 6).

Figure 6: Option 1 with acceleration lane only (left); Option 2 with extension of acceleration lane to Picton Road (right)
A traffic micro-simulation modelling application called VISSIM\(^2\) was used to model the potential merging and weaving movements on Mount Ousley Road. Using VISSIM, simulated traffic modelling scenarios were generated, with model calibration and validation against the collected traffic data. Each simulated scenario generated could be viewed as a continuous movie clip of the traffic stream, with the ability to identify traffic delay or queuing on the computer screen.

The option of the acceleration lane by itself (option 1) and an alternative option of the extension of acceleration lane to connect to the left turning lane (option 2) were modelled using VISSIM. The VISSIM simulated scenarios enabled road safety practitioners to identify potential safety risk with weaving and merging movements on computer screen. Visual observation of the simulation did not show delays or queues caused by merging or weaving movements. Further, potential delay related to difficulty in merging and weaving would be indicated by a higher vehicle average delay (seconds/vehicle), average network delay, number of stops and average queue length results generated by VISSIM. Based on the minimal differences in average network delay results between the two options, merging and weaving safety risks were considered low. Figure 7 shows a stationary shot of the simulation captured from VISSIM.

Merging and weaving length requirements have been traditionally limited to mathematical approximation using methods outlined in road design standard and the Highway Capacity Manual [2]. In this particular case study project, VISSIM analysis results provided road safety practitioners the level of confidence in assessing road safety risks associated with merging and weaving movements through computer visualisation.

**Case Study 4 - Princes Highway upgrade at South Nowra**

South Nowra is located 160km south of Sydney. It is proposed to upgrade a rural section of the Princes Highway in South Nowra from two to four lanes two-way. This section of the Princes Highway is has signposted speed of 100km/h, with two rural local road junctions adjoining either side of the highway. The scope of work includes two channelised seagull treatment at both junctions (Figure 8). A channelised seagull treatment features a dedicated deceleration lane for the right turning movement from the highway to the local road, and an acceleration lane for the right turning movement from the local road to the highway. Turning movements to and from the highway would require lane change or merging in the proposed upgraded highway.

\(^2\) The VISSIM traffic simulation model requires data input including the horizontal and vertical road alignment, the design of the option to be analysed, traffic volume data, percentage of light and heavy vehicles in the traffic, and lane usage data [1].
The two local road intersections are currently separated by 500m. Based on road design standard, a separation length of 735m (a combination of weaving, acceleration and deceleration lengths for design speed of 100km/h) between the two junctions would be required for safe merge and weaving between vehicles. As a result, the concept design was modified to allow for 800m separation between the two junctions by relocating a side road (BTU Road).

VISSIM traffic modelling simulation program was used to assess potential merging and weaving issues related to the turning movements in and out of the two local roads. Simulated peak hour traffic scenarios were checked on computer screen. Potential safety risks related to merging and weaving issues could be identified by network delay or through visual clusters of simulated vehicles on the computer screen. The VISSIM modelling conducted a sensitivity analysis for a range of scenarios, including the testing of increased volumes on one of the side road, as well the testing of a range of gap acceptance behaviours between five seconds and seven seconds. Under all scenarios, visual reviews of the modelling did not identify any appreciable merging or weaving issues. The modelling indicated that the separation distance between the two rural seagull layouts is sufficient to enable safe merging and weaving manoeuvres.

**Case Study 5 - Mount Ousley Road Climbing Lanes**

Mount Ousley Road between the Southern Freeway (F6) and Picton Road is defined by frequent steep grades and tight horizontal radius curves, at a signposted speed of 100km/h. Mount Ousley Road is a key freight route connecting Sydney to the southern Illawarra region. Due to the steep grades and tight horizontal radius curves, heavy vehicles travel at very slow speeds on the steep ascents. The road has two lanes in each direction with a median concrete barrier, with slow heavy vehicles usually travelling on the left lane. However, slow travelling heavy vehicles may occasionally introduce temporary queuing issues termed as traffic shockwaves. Traffic shockwaves are caused by a significant decrease in operating speed by high speed vehicles due to a shock introduced by travelling behind a slow heavy vehicle, causing a temporary queue situation. The shockwave will pass to vehicles behind the slow heavy vehicle, until the heavy vehicle gathers speed and discharges the queue.

In the aim to improve traffic efficiency on Mount Ousley Road, climbing lanes are considered to have benefits in some steep ascent sections of the road to allow slow heavy vehicles to gather speed prior to merging to high speed traffic. The posted speed on Mount Ousley Road is 100km/h. Using current road design guidelines [3] and adopting the most conservative scenario, the starting point of the climbing lane would be where slow vehicles (heavy vehicles assumed) reduce their speed by 10km/h (i.e. 90km/hr), and where slow vehicles gather speed to the operating speed minus 15km/h (i.e. 85km/h). The end point of the climbing lane also needs to provide adequate sight distance for a slow vehicle to safely merge into the through carriageway. In addition to the design criteria based on operating speeds, there is also a general recommended length of 1.2km for climbing lanes. If road design guidelines are to be strictly applied based on the operation speed and sight distance requirements for merges, climbing lanes required on Mount Ousley Road would be in excess of 1.5km to 2km in length. This raised concerns regarding cost and constructability of the proposal.
In order to understand the complexity of traffic shockwaves caused by slow vehicles and the potential weaving movements by the introduction of climbing lanes, Paramics was used to further investigate opportunities to modify the lengths of the climbing lanes. The aim of the study is to define lengths of climbing lanes such that traffic efficiency would still be improved while minimising road safety risks due to the merging of slow vehicles.

The use of Paramics simulation modelling will assist road safety practitioners in identifying potential road safety risks through the observation of simulated merging and/or weaving behaviours of slow vehicles associated with the provision of climbing lanes. By modifying the climbing lane lengths in each simulated scenario, a road designer could assess any potential safety issues with weaving and merging traffic. This assists in the concept design of the climbing lanes, and minimises the need to retrofit a potential road safety problem in the future.

The Paramics simulation study is in progress at the time of writing. This paper aims to provide road safety practitioners technologies, methodology and approach used in the consideration of road safety risks in the design of climbing lanes.

Conclusion

Road designers and road safety practitioners have previously relied on their previous experience and knowledge to recognise road safety issues. With the introduction of a suite of traffic simulation and three dimensional graphic computer applications, their use has introduced a new technique to identify and assess road safety issues. This paper has presented a number of case studies where such computer applications have been utilised effectively.

The use of traffic simulation software packages such as Paramics and VISSIM has been found to be beneficial in the assessment of weaving movements. With their graphical capabilities, simulations can be run to determine which of a number of different scenarios will achieve the best road safety outcome. Similarly Dynamite, a three dimensional graphic software can be used to assess sight distance issues. It effectively targets road safety issues during the development of a concept design and is a valuable tool in community consultation.

The potential to apply this software in other areas of road safety including road safety audits is in its early stages. Opportunities exist to make better use of this technology in the future which will contribute towards creating a safer road environment.

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References

Biography

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.

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