Use of the Safe System Assessment Framework as a Safety Key Performance Indicator

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Key Findings

- Historical safety metrics in the tendering process are typically based on a minimum compliance model, which may encourage improving other performance areas to the detriment of safety.
- Use of Safe System Assessment Framework provides a quantified assessment of safety which can be used as a Key Performance Indicator to encourage prioritisation of safety outcomes in conjunction with other performance targets.
- The project data provided valuable insights into aspects of current road design that achieved greatest conformance with Safe System principles, and where gaps still lie. The greatest risks in the project suite related to large complex intersections in high speed environments (findings based on over 100 Safe System Assessments undertaken as part of this project).
- Breaking down project designs into homogeneous sections or stereotypes when undertaking a Safe System Assessment provides a greater level of understanding of road safety risk associated with different aspects of designs within and across projects.

Abstract

As part of the Northern and South-Eastern Suburban Roads Upgrade packages, Major Road Projects Victoria has sought to incorporate road safety metrics into the tender designs review process. The Australian Road Research Board adapted the Safe System Assessment Framework (Austroads 2016) to meet this need. Twelve road projects were assessed to provide baselines scores for the reference designs. The submitted tender designs will then be reassessed to provide an assessment of road safety in the designs. This work provided an extension in use of Safe System Assessment Framework as well as insight into current gaps in road safety design practice.

Keywords

Safe System, Key Performance Indicator, Safe System Infrastructure, Safe System Assessment Framework

Glossary

KPI – Key Performance Indicator

MRPV – Major Road Projects Victoria

SSA – Safe System Assessment

SSAF – Safe System Assessment Framework

Reference design – Baseline designs prepared by MRPV that formed the basis of the tenderer's design responses (see Tenderer's Design).

Tenderer's design – The tenderer's design response to the reference design.

Introduction

Major Road Projects Victoria (MRPV) are implementing a suite of outer suburban arterial road upgrade (SRU) projects transforming the arterial road network across Melbourne. The projects are to be undertaken via public private partnership (PPP) and involve an investment of over $2 billion by the state government.

As part of the PPP arrangement the projects are to be put out to competitive tender. To ensure that safety was not sacrificed to achieve other performance targets it was desirable to incorporate a safety Key Performance Indicator (KPI) — or KPIs — into the tender assessment criterion. MRPV engaged the Australian Road Research Board (ARRB). To that end, the Australian Road Research Board (ARRB) developed a method for scoring each of the tweleve road projects included in the SRU program using the Safe System Assessment Framework (SSAF).

The Suburban Roads Upgrade Program

The Suburban Road upgrades program is a suite of road infrastructure upgrade projects being undertaken across Melbourne. The program consisted of three works packages based on geographical location known as the 'western', 'northern' and 'south-eastern' packages. Each of the packages were advertised for competitive public tender to be designed, constructed and maintained under a PPP arrangement.

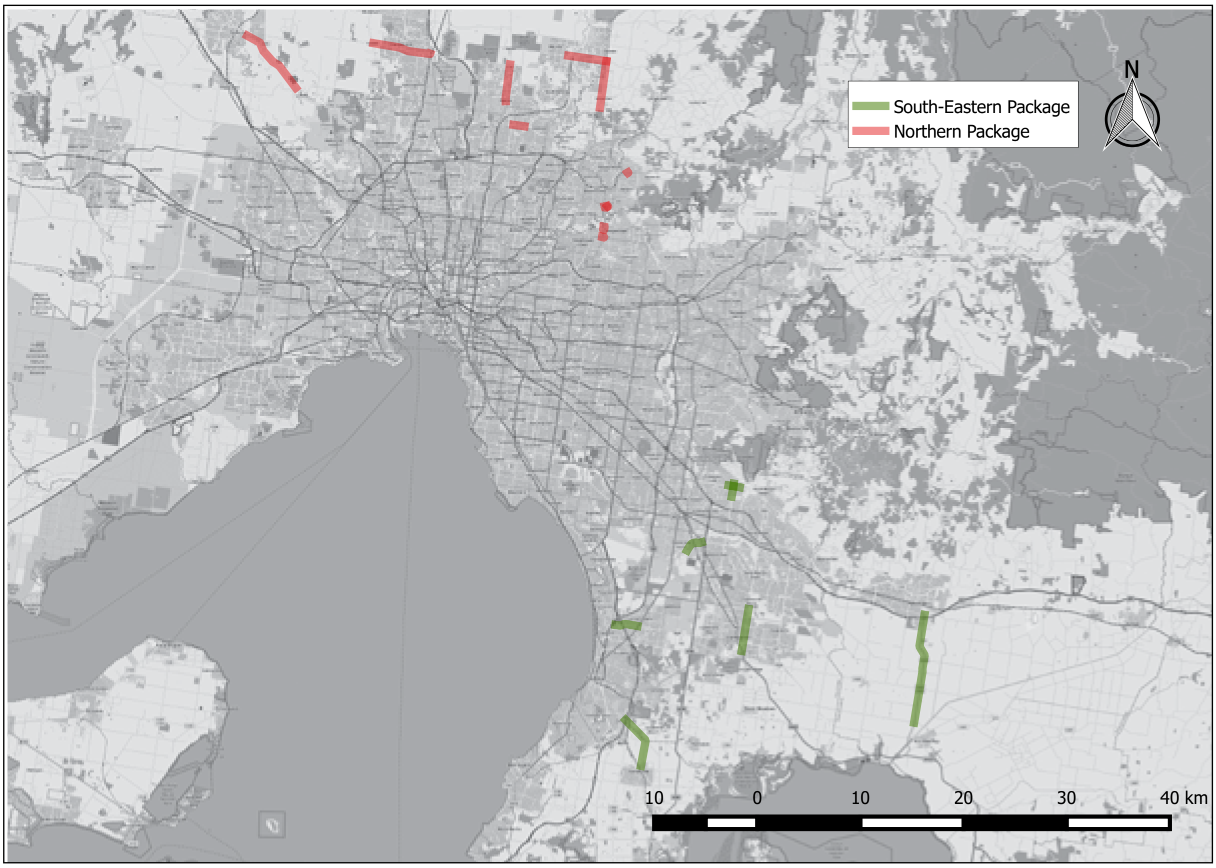
As part of this work, SSA were undertaken for the northern and south-eastern packages consisting of twelve road projects. These were, from the northern package:

- Childs Road, from Beaumont Crescent to Prince of Wales Avenue, Mill Park;
- Craigieburn Road, from Mickleham Road to the Hume Highway, Craigieburn;
- Epping Road, from Craigieburn Road East to Memorial Avenue, Epping;
- Fitzsimons Lane, consisting of various intersection upgrades in Eltham and Templestowe,
- Sunbury Road, from Bulla-Diggers Rest Road to Powlett Street, Sunbury;
- Yan Yean Road from Bridge Inn Road to Heard Avenue, and
- Bridge Inn Road, from Plenty Road to Yan Yean Road, Doreen.

From the south-eastern package:

- Golf Links Road, from Peninsula Link to Baxter-Tooradin Road, and Grant Road, from Baxter-Tooradin Road to Frankston-Flinders Road, Langwarrin South;
- Healesville – Koo Wee Rup Road, from Princes Freeway to Manks Road, Pakenham South;
- Hallam North Road, from Heatherton Road to James Cook Drive, Endeavour Hills;
- Lathams Road, from Oliphant Way to Frankston-Dandenong Road, Seaford;
- Narre Warren – Cranbourne Road, from Thompsons Road to the South Gippsland Highway, Cranbourne; and
- Pound Road West, with a new bridge over Cranbourne rail line to connect to Remington Drive, Dandenong South.

The majority of the roads within both project suites are dual carriageways with signals the most common control type for significant intersections. The locations of the works are shown in Figure 1.



Fgure 1. Northern and South-Easter Package Locations (Base map source: OpenStreetMap)

Safety in the Tendering Process

Given the long term nature of a Public Private Partnership (PPP) procurement model it is essential to ensure that safety outcomes are appropriately addressed in the contractual agreement. Also, while it is tempting to rely purely on performance based measures (i.e. injuries and deaths) there are drawbacks with this from both the public and private perspectives. Relying on a pattern of crashes is a reactive measure to assessing road safety as it relies on addressing road trauma after it occurs and often focuses thinking on localised issues and treatments rather than taking a network wide view. For tenderers there may be concerns about contractual penalties for road trauma that is due to systemic (or other) factors beyond their direct control.

Adopting an infrastructure focussed, lead indicator will help ensure a best practice approach to reducing the likelihood that a road user will experience trauma. It is important to be able to quantifiably measure and compare the relative performance of a range of road designs as part of the tender evaluation process. Use of the Safe System Assessment Framework presented an opportunity to quantify road safety risk within the tender process so as that a comparison of competitive tenders safety performance could be made against contractual requirements.

Methodology

This section introduces the Safe System Assessment Framework approach and outlines how it was used as a Key Performance Indicator into the tender assessment criterion for the project suite.

The Safe System Assessment Framework

The underlying principle of the Safe System is that humans are fallible, and sooner or later mistakes (and hence crashes) will happen. When they do, the system should be designed so as that a fatal or serious injury outcome does not occur.

The Safe System Assessment Framework (SSAF) is a practitioner assessment tool to assist in the methodical consideration of Safe System objectives in road infrastructure projects. The tool was developed by ARRB and contributing partners for Austroads (2016) to ensure Safe System objectives are met by prompting consideration of a number of key crash types that most commonly result in death or serious injury on our roads. The crash types addressed by the SSAF are:

- Run-off-road (ROR)
- Head-on (HO)
- Intersection (INT)
- Other (any other crash type considered relevant, typically including rear-end/side-swipe)
- Pedestrian (PED)
- Cyclist
- Motorcyclist (M/C)

For each crash type, the three components that constitute risk are assessed. These components are the exposure (generally synonymous with volume of traffic), the likelihood (how likely that a crash would occur given the infrastructure and other local considerations) and the severity (in the event that a crash does occur, how likely is it someone will be killed or seriously injured). Each of these risk components are scored out of 4 (with half scores permissible) for each crash type and multiplied to provide a maximum score of 64. Multiplication is used as it demonstrates how a hazard can be effectively eliminated by removing any of the three risk components (i.e. it is given a zero score). The crash types are then summed for a maximum score of 448 for a design.

The assessments that were undertaken for this project were an extended rapid SSA that has been conducted in accordance with VicRoads Safe System Assessment template (VicRoads 2018) and Austroads Safe System Assessment Framework (Austroads 2016). An example of how to undertake a Safe System Assessment is given in the Austroads guidance.

Assessment Scope

The focus of the assessments were reference designs prepared by MRPV as part of the request for tender documentation. No assessment of existing conditions was made as the intent was to provide insight into the safety performance of the reference designs rather than to make comment on existing conditions. This establishes a baseline level of safety against which the tenderer's designs can be compared and presents the opportunity for tenderers to focus their efforts on the elements of the reference designs where the greatest safety performance improvements are likely to be gained.

Given the scale of the projects, providing a single assessment was not considered appropriate as it would not provide an adequate level of granularity to allow for the easy identification of specific risks. As such, the projects were broken down into homogenous stereotypes, each of which were individually assessed. The identification of what constituted a different stereotype for a project was based on assessor judgement with key considerations including not only the design of the infrastructure but also factors such as adjacent land use. Some of the key considerations included, for midblock stereotypes:

- Road cross-section (number and widths of lanes, presence of a median, road-side barriers etc.).

- Road geometry (horizontal and vertical alignment).
- Adjacent land use (residential vs industrial, presence of schools or aged care facitilies etc.).
- Access control (whether properties have direct access to the road, frequency and nature of side road intersections).
- Speed (both speed limit and design speed).

And for intersections:

- Intersection type (signalised, roundabout, uncontrolled etc.).
- Size (number of lanes and lane width).
- Presence of slip lanes.
- Geometry (alignment of approaches both vertical and horizontal etc.).
- Proximity to other other intersections.
- Adjacent land use.
- Speed (both speed limit and design speed).

As these are transformative projects often on the urban fringe, it was also key that the assessment considered the future use of the road; it is anticipated that there will be considerable changes over the life of infrastructure. Much of the adjacent land for a number of the projects was noted to be undeveloped. As this land is developed the manner in which in interacts with the road environment will change, most notably, higher intensity land use will bring more road users to the area. The projects themselves are also expected to change road user behavior. An example of this is the construction of cycling facilities where there were none previously, which is expected to increase cyclist numbers in the area.

To help account for these anticipated future changes , the assessors drew upon Movement and Place assessments that had been undertaken for each of the roads within the project area. The Movement and Place classifications had been developed with the project upgrades in-mind and as such provided insights into the types of future activity expected on the roads based on the road's functional classification within the Movement and Place framework. It is noted that the VicRoads Movement and Place Framework provides classifications by mode, demonstrating a road's strategic importance as a freight, bus or cycling link. This information was supplemented by current and predicted traffic volumes, as available, and in the case of cyclists, whether the road formed part of the current or proposed Principal Bicycle Network (the principal bicycle network is a bicycle infrastructure planning tool used in Victoria that identifies existing and proposed bicycle infrastructure).

The assessments were undertaken by ARRB staff over a period of three months in early 2019 with MRPV staff joining the assessment team on a number of projects to provide additional localized knowledge.

A comparative metric

The intended use of the assessment scores was to provide a safety comparison between baseline reference designs and tenderer's submitted designs to allow for an assessment of safety performance to be built into the tendering process. As such, the final metric used for the comparison needed to be flexible enough to account for the fact that a tender design may vary substantially enough from the reference design to change both the number and types of stereotypes defined for the project. For instance, if the baseline reference design has a single homogeneous midblock stereotype and the tenderer decided to improve a key cycling route by introducing an off-road cycle path for path of that length — reducing cyclist risk — this would introduce a second stereotype. As it was not considered appropriate to compare these two 'new' stereotypes to the single stereotype in the reference design, an overall project score was needed in order to provide a comparative metric between baseline and tender designs.

Several methods for calculating the project score were considered. The first was a simple average of the scores of like elements (midblocks and intersections), however this was considered too simplistic as it did not consider the relative exposure to each of the stereotypes. Returning to the above example with the cycle path, if the path is only introduced only for a 500m section of a 5km road, a simple average would weight the cycle path stereotype too highly. In addition to not providing a realistic reflection of total risk, this method could be easily 'gamed' by making substantial improvements to a small section of the project.

A simple total was also considered, where the score for each stereotype is summed to form a total score, but the potential for the number of stereotypes to change made this problematic. Again, returning the cycle path example, the addition of a second stereotype would have the potential to double the final score for the same length of road, which again, would not provide a realistic reflection of the risk.

More complex methodologies using volumes to weight road user exposure to the different stereotypes were also considered, however was also not considered appropriate. As exposure is already a key input into the undertaking of SSAs, weighting the scores by volume would count road user exposure twice in the final score.

Ultimately, it was decided that a weighted average would be the best approach. This was done through the calculation of a weighted average of like elements (midblocks and intersections) with the (1) total length of midblock and (2) the number of intersections used for the weighting. This allowed for overall average midblock and intersection scores to be calculated which were in turn averaged to provide the final score, termed the 'total baseline SSA score', for each project design. An example of this scoring process is shown in Table 1.

Table 1. Example Total Baseline SSA Score Calculation

Stereotype	Extent	Key Crash Risk Scores							Total Risk Score per stereotype	Mid-block / Int average	Total baseline SSA score
		ROR	HO	Int	Other	Ped	Cyclist	M/C			
Midblock Type 1	0.5 km	4/64	0/64	48/64	24/64	32/64	48/64	40/64	278/448	181/448	208/448
Midblock Type 2	3.3 km	12/64	0/64	24/64	30/64	20/64	40/64	40/64	166/448		
Intersection Type 1	1	6/64	4/64	40/64	16/64	24/64	32/64	40/64	162/448	235/448	
Intersection Type 2	1	12/64	6/64	56/64	32/64	40/64	48/64	48/64	242/448		
Intersection Type 3	2	12/64	12/64	48/64	36/64	36/64	40/64	40/64	224/448		
Intersection Type 4	1	10/64	12/64	64/64	42/64	56/64	56/64	40/64	280/448		
Intersection Type 5	1	8/64	12/64	64/64	42/64	56/64	56/64	40/64	278/448		

For this example, there were two midblock stereotypes, dubbed 'Midblock 1' and 'Midblock 2'. Midblock 2 was considerably longer than Midblock 1 (3.3km vs 0.5km) and as such was weighted proportionally as follows:

$$\frac{Extent_{MB1} \times Total\ Risk_{MB1} + Extent_{MB2} \times Total\ Risk_{MB2}}{Extent_{MB1} + Extent_{MB2}}$$
$$= \frac{0.5km \times 278 + 3.3km \times 166}{0.5km + 3.3km}$$
$$=181$$

The same approach was taken for the intersections, with the 'extent' being the number of intersections present for that particular stereotype. For instance, in this example there were two intersections contained within Intersection Type 3 as opposed to one for the others. As such, Intersection Type 3 would be weighted twice as heavily.

By determining an overall score of this nature, flexibility is allowed in the comparison of the designs. Risk may increase, compared to the baseline design, for some aspects and/or stereotypes of a tenderer's design, but this can be offset by safety improvements elsewhere in the design.

Applications in Tendering Process

Historically, road safety requirements within PPP projects have typically been based on a compliance model. For example, stating the proposed designs must be in accordance with the relevant standards and guidelines. If this is so, it is considered 'safe' for the purposes of the contract. In practice, this approach is essentially a pass/fail and no weighting is given to designs providing a higher degree of safety. This is not in line with the current Safe System and 'Vision Zero' philosophy of eliminating fatal and serious road trauma by 2050. Indeed, the historical approach may encourage tenderers to provide less safe designs if it means improving the score on a quantified metric — such as traffic capacity — provided the minimum levels of compliance are met. Some additional contract components may be included, such as financial penalties for poor crash performance post-construction, but these are, at best, reactive measures.

The use of the SSAF supports prioritisation of safety, and the Safe System alignment of designs by providing a quantified measure of safety. In the case of this suite of projects, the requirement was that all tender designs were encouraged to achieve an SSA score better than the baseline designs with poorer results in the SSA score considered a design weakness. This approach encourages tenderes to maintain or improve safety in the design. The proactive nature of the assessment also allows for changes in the design to be made when it is most cost effective to do so – i.e. without any abortive works - and without relying on reactive safety indicators such as crash history.

Results and Discussion

Although the project's key focus was to produce metrics to compare the road safety performance of different tender designs to baseline designs, a useful by-product was that a large amount of data on Safe System conformance of designs was accumulated. This has provided valuable insight into the aspects of current road design where greatest conformance with Safe System principles has been achieved, and where gaps still lie. The authors note that the use of the Safe System Assessment Framework is a relatively new approach, and in particular practitioners use and application of the approach is varied and evolving. The approach and observations outlined below are based on the authors' experience.

Use as a Key Performance Indicator

This paper presents a method that was developed for using the Safe System Assessment Framework as a Key Performance Indicator in the review of road design options. In this instance, the total weighted average scores were used, as it allowed for a flexible, holistic view of the safety performance of the project – but it is by no means the only way the framework can be used. Due to the level of disaggregation between crash types, any of the assessed scores could be used as a measure of safety performance. For instance, the pedestrian and cyclist scores could be used for a vulnerable road user project to provide particular emphasis on these types of user groups. This flexibility allows this method to be applied in a variety of manners to incentivise the achievement of safety objectives of any given road project. The next step would be a review and evaluation of the tenderer's submitted designs in order to assess the methodology's effectiveness in encouraging safer designs.

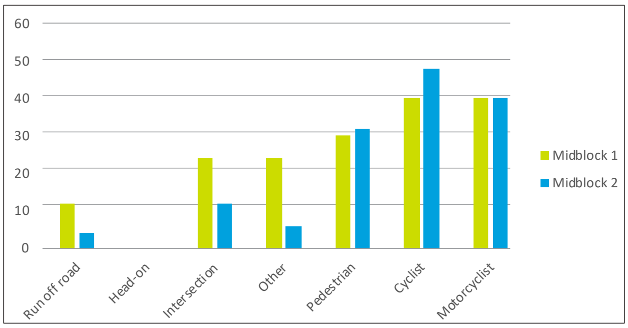


Figure 2. Midblock Stereotypes – Epping Road Example

Use of Stereotypes

The use of stereotypes in the undertaking of the assessments proved to be essential to providing a useful indication of crash risk within projects, as the characteristics of the road can vary substantially across the project length. An example of this is given in Figure 2 from the assessment of the two midblock stereotypes for the Epping Road project. Both midblock stereotypes consisted of very similar stereotypes; both were dual carriageways with road-side and median safety barriers provided. As they were contiguous sections of road, the AADT was also expected to be similar.

A key difference between the two sections was the speed limit; the speed limit for Midblock 1 was 80km/h compared to 60km/h for Midblock 2. This lead to higher risk of 'run-off-road', 'intersection' and 'other' related crashes. Perhaps counterintuitively, the pedestrian and cyclist risk was assessed to be higher in the lower speed environment. This was due to a higher intensity of land use in the vicinity of Midblock 2 — including a shopping precinct — which meant anticipated pedestrian exposure was higher and that fact that off-road cycling facilities were included in the design for Midblock 1, while Midblock 2 featured on-road, non-segregated facilities.

Table 2. Assessed crash risk components by intersection and crash type

	Exposure			Likelihood			Severity		
	X-Int	**T-Int**	**Rndabt**	**X-Int**	**T-Int**	**Rndabt**	**X-Int**	**T-Int**	**Rndabt**
ROR	4	4	3.75	2.34	2.23	2.5	1.05	1.13	1.13
HO	4	4	3.75	1.57	1.02	0.81	1.75	1.67	1
Int	4	4	3.75	3.7	3.02	1.56	4	3.79	2.06
Other	4	4	3.75	3.5	3.02	2.88	2.93	2.67	1.63
Ped	3.21	3.04	2.13	3.16	2.31	2.06	4	3.96	3.19
Cyclist	3.64	3.29	2.38	3.23	2.38	1.75	4	3.98	3.25
M/C	4	4	3.75	2.73	2.75	2.88	4	4	4
Total	26.85	26.33	23.02	20.23	16.73	14.44	21.73	21.2	16.26

These kinds of details would not have been adequately quantified if only providing a project level assessment.

It is noted that the use of the term ‘stereotypes’ is perhaps misleading in this context, as it implies only a high-level assessment of standard designs, without consideration of the site-specific details or design variances which were assessed in this work. Future applications of the SSAF in this way may benefit from alternative terminology such as ‘sections’ which may be more appropriate however for the purposes of this work the discrepancy is considered innocuous.

Safe System Alignment of Midblocks vs Intersections

There were a total of 29 midblock and 73 intersection stereotype variations across the suite of projects. The average risk score recorded for midblocks was 158 compared to 205 for intersections out of a maximum risk score of 448. This higher risk, on average, at intersections compared to midblocks aligns with current understanding for the potential for high severity crashes due to the typical collision forces and impact angles at intersections.

Midblock Features

Three general types of midblock were observed within the project suite these were dual carriageways (21 stereotypes), single carriageways (5 stereotypes) and service roads (3 stereotypes).

Service roads were assessed to be of lowest risk with an average risk score of 80/448. This was largely due to their lower speed limit — 50km/h in all cases — limiting both the likelihood of all crash types and the severity of all non-vulnerable road user crash types (noting the Safe System speed for vulnerable road users is 30km/h). In many cases, service roads were also one-way; reducing the number of possible conflicts.

Somewhat counter-intuitively, single carriageways were assessed to be of lower risk on average than dual carriageways (105 vs 151). On closer inspection however, this was due to four of the five single carriageway stereotypes occurring on lower volume roads with little to no pedestrian and cycling activity. This mitigated the risk by reducing exposure scores across all crash types, with very low exposure for pedestrian and cycling crashes. It is noted that the one high-volume single carriageway stereotype recorded the third highest midblock risk score which was again partially mitigated by low pedestrian and cyclist numbers.

Common midblock design features included excellent access control (majority of minor road access points were left-in/left-out only and often via a service road), divided carriageways and use of wire rope safety barriers. This was effective in reducing the risk associated with the intersection, head-on and run-off-road type crashes in particular (intersection risk in the midblock environment was typically associated with left-in/left-out arrangements of lower order local roads and property accesses that did not warrant their own intersection stereotype). The way in which these risks were managed is also a good demonstration of how risk can be reduced overall by managing any of the three risk components; exposure, likelihood and severity. Head-on risk may be managed by reducing or in some instances virtually eliminating the likelihood of a head-on crash by separating the opposing traffic streams with a median and wire rope safety barrier (thereby managing likelihood). In the case of run-off-road crashes, where roadside wire rope safety barriers are present the likelihood of a crash occurring remains unchanged (as a vehicle can still run off the road) however in the event one does occur the WRSB will help manage the kinetic energy of the impact such that the opportunity for an FSI outcome is reduced or eliminated (i.e. reducing severity).

Intersection Features

There were a number of variations in intersection stereotypes in the project suite, however by far the most common were signalized intersections (52 of the 73 intersection stereotypes), consisting of 28 cross- and 24 T-intersections. The majority of these were in an 80km/h speed limit environment (32 of 52) with the remaining 20 intersections split between 60 and 70km/h environments. Cross- and T-intersections were assessed as having the highest risk across any of the stereotypes in the project suite with average scores of 256 and 212 respectively, particularly in higher speed environments.

The primary drivers of risk for these intersection stereotypes related to intersection size and complexity(often featuring multiple through and turning lanes), high-speed environments and the potential for severe right-angle crashes. This resulted in high likelihood and severity scores across the majority of crash types, and a high overall SSA score.

Comparatively, roundabouts – of which there were six (6) stereotypes – were amongst the best performing stereotypes overall with an average SSA score of 97. The lower speeds, reduced number of conflict points and lower impact angles associated with roundabouts helped drive down both likelihood and severity of crashes at these locations. It was noted that one of the proposed roundabout locations was on a lower volume road, which meant a lower exposure score for this location also contributed to a low overall SSA score for this location.

The comparison between signalised cross- and T-intersections and roundabouts can be more directly observed by disaggregating the scores by crash type and the three risk components (exposure, likelihood and severity), as shown in Table 2 below.

Table 2 illustrates the greatest differences between crash risk at roundabouts and the other intersection types relate to crash likelihood and severity. The design of roundabouts mean that vehicle speeds and impact angles are managed such that both the likelihood and severity outcome of a crash are likely to be far lower than at cross- or T-intersections.

Safe System alignment of designs

In the undertaking of this work, a significant amount of data was gathered, with over 100 Safe System Assessments undertaken as part of the project. Across the twelve projects, the number of stereotypes assessed varied from five to 15 stereotypes per project. In all, 102 stereotypes were assessed across the 12 projects. This allowed for significant insight into the current safety performance of top tier road infrastructure projects and best practice. The overall trend is clear. Midblock performance was generally seen to be good where medians and safety barriers are used, significantly limiting the risks associated with run-off-road and head-on crashes. Conversely high risk was often associated with large, high speed cross- and T-intersections where high severity conflicts – well in excess of Safe System thresholds – were possible. Roundabouts were seen to perform much better due to their fewer conflict points and managed angles of conflict and speed. It was noted that many of the roads within the upgrade packages included three lanes of traffic in either direction to accommodate high traffic volumes, and as such conventional roundabouts may not be an appropriate solution due to the number of lanes required.

Solutions to this problem are not clear. Investigation of innovative design solutions may be beneficial to identify safer solutions that also meet design objectives, for example raised intersection platforms to manage speeds or signalised roundabouts to provide enhanced safety without significantly sacrificing intersection capacity.

In greenfield areas, a fundamental rethink in the way the urban realm is designed may be beneficial, with a shift away from a small number of large arterial routes to a larger number of smaller arterials, or, alternatively greater use of urban expressways with full access control and grade separation.

Reflection on SSAF scoring system

It was noted throughout the process that almost all of the roads evaluated were scored 4/4 for exposure for motor vehicle crash types (run-off-road, head-on, intersection, other and motorcycle). As per the Austroads guidance, the volume threshold to for an exposure score of 4 is 10,000 vpd. For significant road projects such as the SRU, this is a relatively low threshold to meet. This may indicate that a review of the SSAF scoring system may be beneficial in order to provide further disaggregation of volumes and/or a higher threshold set for achieving 'maximum' exposure.

Conclusions

The use of Safe System Assessments as key performance indicator presents the opportunity to shine a spotlight on the safe design of infrastructure and its alignment with Safe System objectives, within the major road infrastructure tender process so that safety is not sacrificed to accommodate other design objectives. The paper also outlines an approach for breaking project designs into homogeneous sections or stereotypes to provide a greater level of detail regarding of road safety risk within designs. The approaches and applications of the SSAF detailed in this paper is one such example of its use. The paper also reflects on aspects of current road design with greatest alignment with Safe System principles, and how an evolution of the SSAF scoring system may provide further benefit. The authors note that the use of the Safe System Assessment Framework is a relatively new approach, and that the flexibility of the framework provides great opportunity to adapt it for a variety of road safety project objectives.

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References

ARRB 2019, Suburban Road Upgrade Reference Design Safe System Assessments [series of reports], Australian Road Research Board, Port Melbourne, Vic

Austroads 2016, Safe System Assessment framework, AP-R509-16, Austroads, Sydney, NSW

OpenStreetMap contributors. (2015). Retrieved from https://planet.openstreetmap.org.

VicRoads 2018, *Full Safe System Assessment report template,* VicRoads, Kew, VIC retried from

https://www.vicroads.vic.gov.au/-/media/files/documents/business-and-industry/safe-system-engineering/full-safe-system-assessment-report-template.ashx?la=en&hash=B88BC7F241CE2095404E6B8AE713E978