MONASH University
Accident Research Centre

A centre within the Monash University Injury Research Institute

AN APPLICATION OF THE SAFE SYSTEM APPROACH TO INTERSECTIONS IN THE CAPITAL REGION – PILOT PROJECT

TASK 6 – WORKSHOP
TASK 7 – ROAD SAFETY AUDITING

Report to
Capital Region Intersection Safety Partnership (CRISP)

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January 2014

1 INTRODUCTION

This brief report documents the comments and outcomes of the workshop held in Edmonton to assess the design feasibility of the innovative intersection designs proposed to address problematic intersections within the Edmonton Capital Region. Following is a summary and analysis of the comments made by workshop participants who reviewed a number of innovative intersection treatments proposed for the following sites:

- Baseline Road & Broadmoor Boulevard, Strathcona County
- Wye Road & Sherwood Drive, Strathcona County
- 34 Avenue NW and 91 Street NW, Edmonton
- St Albert Trail and St Anne Street, St Albert
- St Albert Trail and Villeneuve Road, St Albert
- 107 Avenue and 142 Street, Edmonton

Individuals were asked the following questions regarding the application of the treatment at each site:

- What do you like about this configuration? What are its advantages/pros?
- What do you not like about this configuration? What are its disadvantages/cons?
- What changes or modifications would you make to this configuration? Describe any changes below, draw them on the plans provided or use the sticky notes to annotate the plans provided on the table

Comments made in the groups were reviewed and summaries were prepared regarding the acceptability of each innovative design, noting particularly if any obstacles or perceived barriers to implementation could be overcome. It was found that most comments made in regards to design disadvantages pertained to intersection capacity/volume issues. Other issues noted, including 'driver confusion', the requirement for longer signal phasing or the insertion of rumble strips were thought generally to be able to be accommodated within the detailed engineering design process that intersection would need prior to building.

2 RESULTS

2.1 Squircle

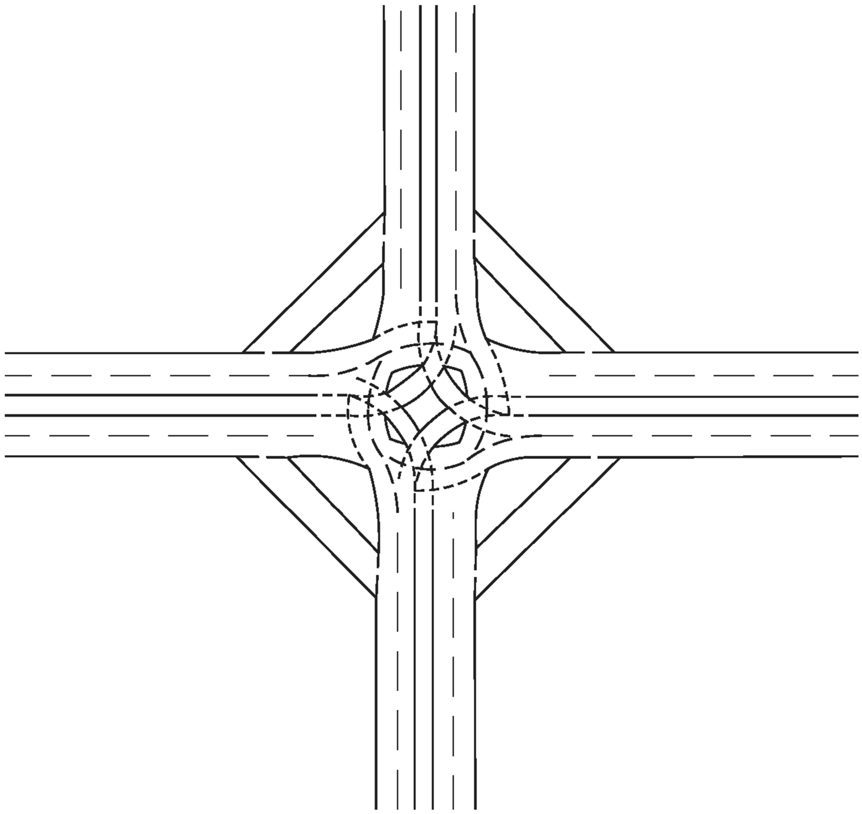

Figure 1. Squircle intersection schematic.

Summary

Perceived benefits:
Reduced collision speeds, favourable impact angles

Perceived disadvantages:
Capacity issues
Potential to cause driver confusion
Winter maintenance

Individuals seemed impressed with this design as a generic engineering solution to a generic problem but were hesitant to consider it for the intersections in discussion. It should be noted that the original design concept was intended for undivided roads intersecting under existing traffic signal control. Thus, the potential for the squircle to apply at the intersection of divided roads is limited; for divided roadway cases, the Cut-through design was developed specifically.

At St Albert Trail and Villeneuve, St Albert, participants saw some benefits in the squircle, particularly with regard to its compact layout and lower speeds. Similar views were held for 94 Ave and 91 St, Edmonton and Baseline Road and Broadmoor Boulevard in Strathcona County.

While most groups acknowledged that the squircle would, in principle, reduce collision speeds and promote more favourable impact angles, and potentially reduce the number of collisions, individuals expressed concerns about capacity and volume. There were also several comments made regarding the potential for the squircle (at the intersections being considered) to cause driver confusion due to its unconventional nature. It was also noted that from a practical point of view that winter maintenance of a squircle may be difficult.

It was noticeable that when suggesting improvements to the squircle (to make the design more acceptable), that the design concerns were those which could be overcome if the squircle was engineered specifically for the above locations, i.e., increasing the number of lanes, providing better signage to warn of changed traffic conditions, changing signal timings.

2.2 Cut-through

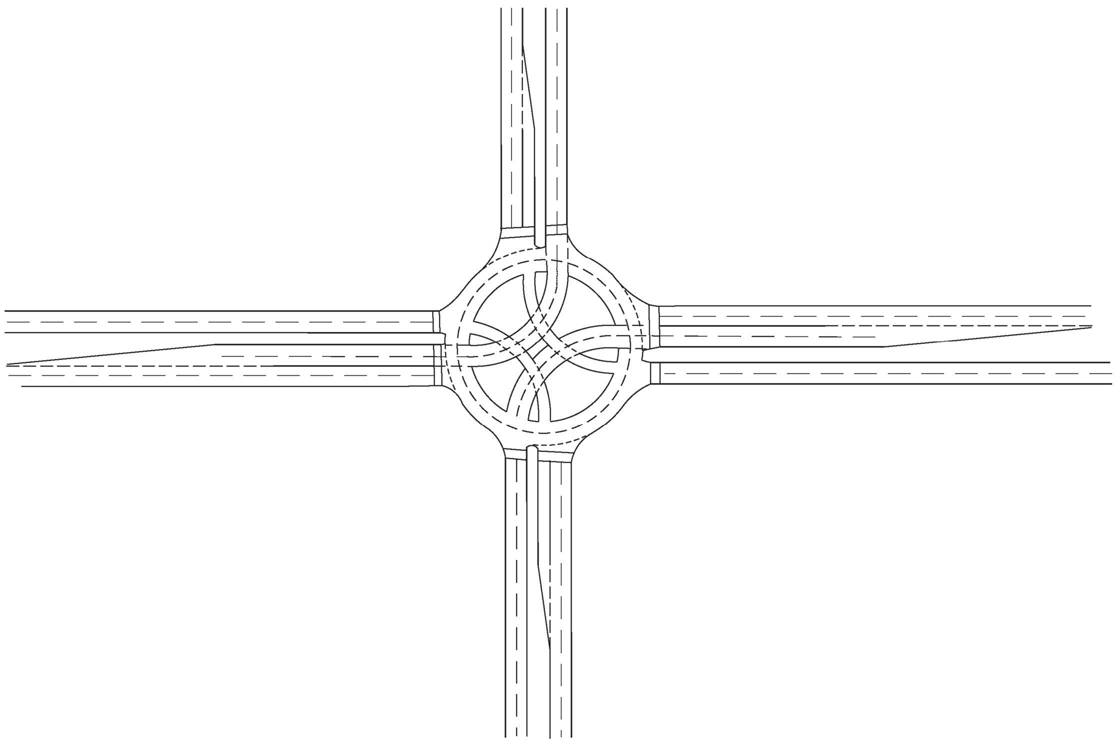

Figure 2. Cut-through intersection schematic.

Summary

Perceived benefits:
Less complicated than existing intersections
Reduce incidence of right angle and left turn across path collisions
Reduced number of conflict points
Reduced conflict speeds
Improved conflict angles

Perceived disadvantages:
Accommodation of heavy vehicles
Signal timing issues

This intersection design was well-received because it appeared to the groups to be more suited (in terms of its size) for application to the subject intersections. As noted in Section 2.1 (squircle) above, the Cut-through was designed to suit divided road, signalised intersections, while the squircle was intended for undivided signalised intersections. Two groups had noted that it 'fits in' immediately. It was also noted that this design was less complicated and would most likely reduce right angle and left turn across path collisions, such as a side-angle collision occurring between two vehicles using a channelised right-turning bay. It was also noted that it reduces conflict speeds, the number of conflict points and improves entry angles.

The cut-through design seemed to be favoured more for the Baseline and Broadmoor site, for Wye Road and Sherwood Drive, Strathcona County and for St Albert Trail and Villeneuve Road.

The problems identified in the workshop were primarily operational in nature, relating to the difficulties trucks might find in manoeuvring through the Cut-through intersections, as well as signal timing issues. It was noted specifically that at 107 Ave and 142 St in the City of Edmonton, the Cut-through was thought to be unlikely to fix the problem that currently existed at the intersection, involving a large number of – relatively minor – collisions on the approach to and within the existing traffic circle due to a number of factors including its large size causing higher speeds, poor pedestrian sightlines and weaving within the circle. The improvements suggested were in relation to signalising the intersection and in all cases, paying extra attention to the needs of the right-turn/left-turn lanes since this was mentioned at four of the five intersections discussed. It is worth noting that, despite its perceived disadvantages, the cut-through would still be more favourable than a conventional signalised four-leg intersection due to reduced collision speeds and more oblique impact angles. Minor collision incidence may not be influenced positively, but serious and fatal collisions should be significantly reduced.

2.3 Quadrant roadway

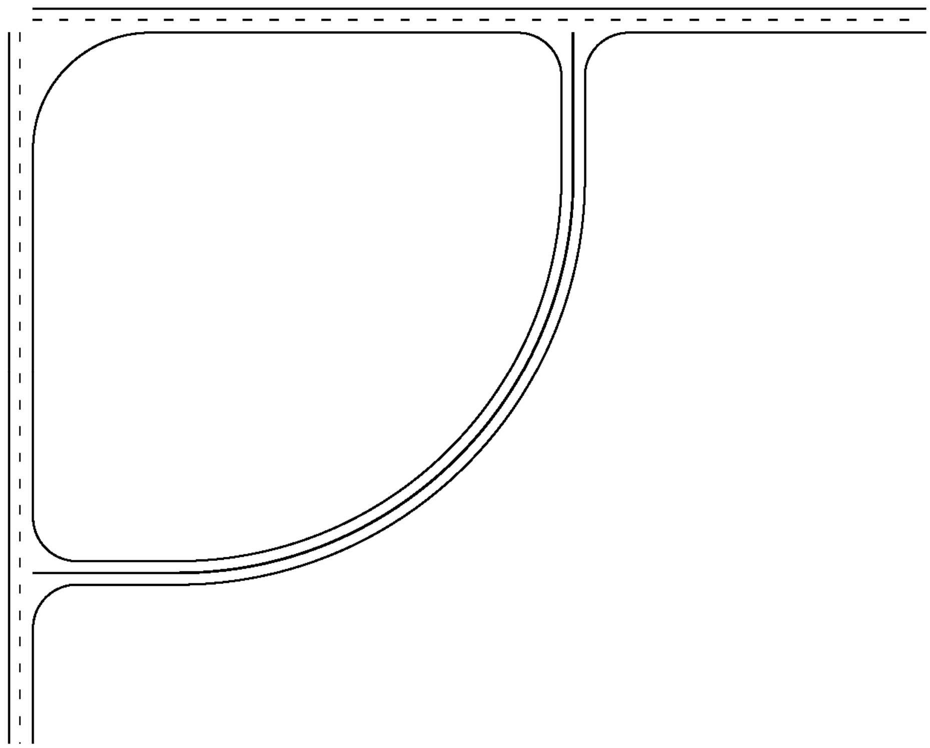

Figure 3. Quadrant Roadway intersection schematic.

Summary

Perceived benefits:

Reduced traffic volumes, improved capacity (subject to appropriate signal timing)
Removal of problematic left-hand turns

Perceived disadvantages:
Land acquisition requirements
Rerouting of turning traffic along local streets
Some right-angle conflict points remain

This intersection design was discussed with some reservations by groups considering it as a replacement intersection at the following sites:

- 34 Av and 91 St, Edmonton
- St Albert Tr and St Anne Street, St Albert
- 107 Ave and 142 St, Edmonton

Those discussing the St Albert Tr and St Anne Street intersection regarded it as not feasible for this location, most likely due to the land acquisition required. Discussions regarding the Quadrant Roadway design at two intersections in Strathcona County (Baseline and Broadmoor and Wye and Sherwood) were more positive, with the groups seeing benefits of this design particularly in terms of reducing volumes and improving capacity at the site, in addition to removing problematic left-hand turns. Both groups noted surmountable obstacles with the Quadrant Roadway such as signal timing and capacity issues, but noted the potential for left-turn and right-angle collisions at Wye and Sherwood to remain, as well as the possibility of the need to acquire considerable additional land to accommodate the design. Concern was also expressed at the undesirability of re-routing turning traffic along neighbourhood streets.

2.4 Super Street

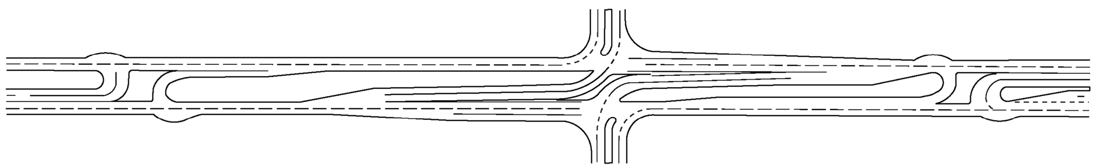

Figure 4. Super Street intersection schematic

Summary

Perceived benefits:
Reduced conflict points

Perceived disadvantages:
Higher speeds
Traffic flow 'turbulence'

While all groups acknowledged that the Super Street was capable of reducing a number of conflict points (including right angle, rear end collisions on the north-south legs and left-turn across path), they also made note that this design did not address speed concerns and created 'turbulence' for traffic flow. Again, this design was considered 'not applicable' due to the very high number of left-turns at St Albert Tr and St Anne Street, St Albert and so was not discussed further as a solution for that particular site. Those considering the application of the Super Street to Baseline/Broadmoor, Strathcona County and 107 Ave/142 St Edmonton, were more accepting of the design, noting some concerns which could, in general, be readily addressed, such as the placement of signals, reducing approach speeds and adjusting lane dimensions.

2.5 Turbo Roundabout

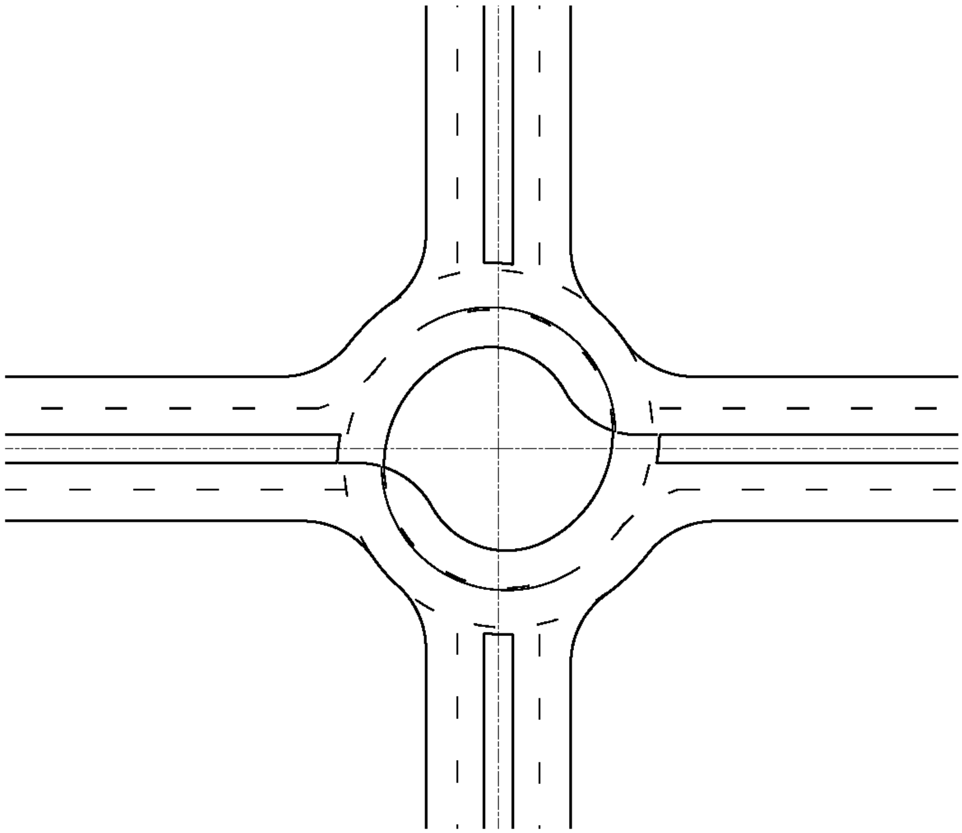

Figure 5. Turbo Roundabout schematic.

Summary

Perceived benefits:
Improved conflict angles
Reduced speeds
Efficient use of land

Perceived disadvantages:
Capacity limitations
Winter maintenance
Accommodation for cyclists and pedestrians

The turbo-roundabout was viewed favourably as a potential Safe System solution for all intersections discussed, with groups highlighting its ability to reduce collision speeds and angles, and making note of its ability to use land space efficiently. It was, however, noted that the turbo roundabout may not be able to address capacity issues at each site, and on a more practical note, could not be used as an engineering solution at 107 Ave and 142 St due to the site being part of the Groat/107/142 'race track', although it should be noted that the turbo design is specifically targeted at reducing entry speeds to well below 50 km/h. Concern was also raised regarding winter maintenance, and accommodating bicycle and pedestrian movements if the turbo roundabout was installed at Wye and Sherwood. As with the squircle, the concerns were felt to be more able to be addressed during early phases of design if the turbo roundabout was to be used at any of the sites. Workshop participants had a number of ideas for improving the turbo design, all of which appear achievable, including allowing for 'double movements', retaining right-turn slip lanes to maintain intersection capacity, and either installing rumble strips or raised lane dividers to address winter maintenance concerns. It was also suggested that the turbo roundabout could be signalised, if required, to improve intersection operation.

2.6 Roundabout

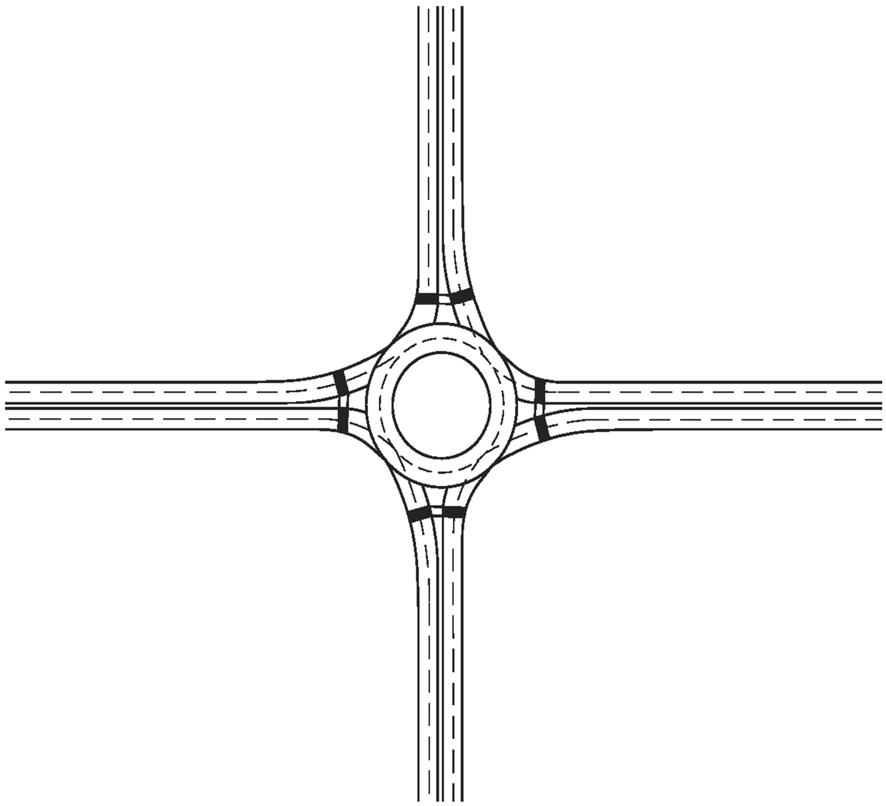

Figure 6. Roundabout schematic.

Summary

Perceived benefits:
Elimination of right-angle impacts
Reduced conflict speeds
Improved conflict angles
Driver familiarity

Perceived disadvantages:
Capacity issues
Accommodation for heavy vehicles

Like the turbo roundabout, the traditional roundabout was also well received by each of the groups as a potential solution to each of the intersections discussed. Groups acknowledged the ability of the roundabout to eliminate right-angle impacts, reduce collision speeds and improve collision angles while meeting 'driver expectations', most likely because roundabouts and traffic circles are relatively well-known compared with the more innovative designs considered. It was considered preferable to the turbo roundabout at St Albert Trail and Villeneuve Road and also considered for 107 Ave and 142 St as well as 34 Ave and 91 St, Edmonton. At the Baseline and Broadmoor, and Wye and Sherwood locations, signalised feeder lanes were thought an option for making the roundabout practical at these sites. However, all groups did note that addressing capacity issues is important and further stated that accommodating pedestrians, trucks and buses might be a challenge (at three separate intersections). Given that these issues are likely to be able to be accommodated during the design phase in the generic case, it was considered likely that roundabouts would be well received and yield promising results at each of the subject intersections. While participants provided specifics regarding how the roundabout could be engineered to fit 107 Ave and 142 St Edmonton, general improvement suggestions made for the other intersections included the insertion of raised cross-walks, geometry adjustments and signalised feeder lanes to overcome potential operational problems during peak periods. Overall, the roundabout, as with the turbo roundabout, appeared to be more readily accepted with most participants' concerns and general issues able to be addressed.

2.7 Reduced speed limits and raised platform intersection

Summary

Perceived benefits:
None noted

Perceived disadvantages:
Difficulty of enforcing lower speed limits

Only a few comments were made about these solutions in regards to concerns about intersection safety. No positive comments were noted by any group (at any particular intersection). The only comments made regarding lowered speed limits were in reference to it being difficult to enforce (at Baseline and Broadmoor) and the intervention being of 'no benefit' (at 107 Ave and 142 St). The number of negative comments made regarding reduced intersection speed limits and the installation of intersection platforms gave the strong impression that these solutions were not well-received as a whole. Given that reducing and enforcing lower speed limits and installing raised platforms are both relatively cost-effective means of achieving reduced impact speeds, and given that capacity/volume concerns were of frequent concern in the other intersection treatments proposed, it is of some concern that these ideas were not more viewed more favourably.

2.8 Other options

When asked if there were other designs/options that could be considered for each of the intersections in discussion, several ideas were raised for Baseline and Broadmoor in Strathcona County. These included some stop-gap solutions such as re-grading the intersection, as well as some permanent and promising options such as reducing intersection approach speeds, reducing the allowable number of manoeuvres at the intersection and considering grade-separation (a 'fly-over'). Grade-separation was also proposed for Wye and Sherwood in Strathcona County, and 107 Ave and 142 St Edmonton. Minimising left turns and installing a grade-separated roundabout to handle all turning movements were also suggested as means of addressing problems at Wye and Sherwood.

Aside from grade-separation, no innovative designs were suggested for 107 Ave and 142 St, but it was suggested to signalise the site. A diverging diamond interchange was suggested as a potential engineering solution to the 34 Av and 91 St intersection in Edmonton, while no other ideas were provided for St Albert Tr and St Anne Street in St Albert.

3 SUMMARY

The Squircle, turbo-roundabout and traditional roundabout appear to have been well-received by the participants as potential solutions to problematic intersections. These designs were viewed favourably in most instances and most concerns were thought to be addressable during the design phase. While the more innovative designs such as the Cut-through, Quadrant Roadway and Super-Street designs were also accepted as potential solutions, participants noted a number of issues with them. While some of the concerns expressed could be addressed by careful design (such as eliminating a specific turn), there were also some more practical and valid issues why these designs may not be suited to a particular site (e.g. due to roads being divided or the specific problematic manoeuvres at a particular site or a design being inadequate in addressing the current problem). Surprisingly, there was little support for reduced intersection approach speeds or raised intersection platforms, despite their substantially lower cost, although these were noted as potential options when 'other designs' were considered. The most significant concern for workshop participants was that, given the need to enforce a reduced speed limit for 100m around the intersection, the proximity of adjacent intersections would result in a *de facto* reduced speed limit for entire road sections. Given the cost-effect nature of the latter two solutions and its ability not to hinder traffic flow/capacity/volume, closer examination would be worthwhile.

Following are the preferred Safe System solutions for each of the sites considered, based on the summary feedback provided by workshop participants.

Baseline Road & Broadmoor Boulevard, Strathcona County

Figure 7. Baseline & Broadmoor, Strathcona County.

As a fairly large, multi-lane intersection, the cut-through intersection design is probably the preferred Safe System solution for this location, although workshop participants flagged this site as a candidate for grade separation or a full interchange.

Wye Road & Sherwood Drive, Strathcona County

Figure 8. Wye & Sherwood, Strathcona County.

Similar to Baseline Rd & Broadmoor Blvd, this site would lend itself to a cut-through intersection, with workshop participants suggesting slip lanes to help alleviate capacity issues.

34 Avenue NW and 91 Street NW, Edmonton

Figure 9. 34 Ave NW & 91 St NW, Edmonton.

Again, as an intersection between two divided roads, the cut-through was preferred for this location, with right-turn slip lanes. Participants were in favour of the speed reduction effects of the cut-through lane diversion characteristics. The roundabout was also considered, with its smaller footprint and lower speed characteristics seen as positive, but outweighed by capacity considerations.

St Albert Trail and St Anne Street, St Albert

Figure 9. St Albert & St Anne, St Albert.

At this site, both turbo and conventional roundabouts were seen as feasible from a safety viewpoint, with the latter slightly preferred by workshop participants due the high number of left turns at the location potentially creating difficulties for the turbo design.

St Albert Trail and Villeneuve Road, St Albert

Figure 11. St Albert & Villeneuve, St Albert.

The intersection of St Albert Trail and Villeneuve Road was seen as more of a challenge, with positive aspects observed for both roundabout types as well as the squircle and cut-through. Overall, the preferred Safe System solution for this location would be the roundabout, providing favourable impact angles and reduced speeds, while being seen as easily understood by road users. Capacity issues were seen as a potential challenge in the future, particularly in the context of potential widening of St Albert Trail in the future.

107 Avenue and 142 Street, Edmonton

Figure 12. 107 Ave & 142 St, Edmonton.

This location, currently a traffic circle, was noted as experiencing a high number of minor collisions. Also noting that there is a possibility that the site might eventually be converted to a signalised four-leg intersection, the cut-through would be the preferred Safe System solution, capturing most of the safety benefits of a roundabout configuration without incurring its capacity issues.

4 ROAD SAFETY AUDITING AND SAFE SYSTEM INTERSECTION DESIGN

This section considers the importance of auditing the expected road safety performance of new intersection designs or of existing intersections being redesigned.

4.1 Road Safety Auditing - Concept and Objectives

Road safety auditing is a technique that emerged in Europe, including in the UK, where it has been a prominent aspect of successful accident black spot programs. It began during the 1970s after road safety practitioners recognised that crash problems being treated at many accident black spot intersections and other locations could easily have been avoided, had the safety performance of the design received proper attention at the planning and design stages. Thus, road safety auditing evolved as a means of avoiding the inadvertent 'building-in' of future road safety problems into major new road projects as well as small-scale road improvement schemes.

Road safety auditing techniques have developed considerably during the intervening period and, in general, are now used more widely than ever before. In the language of today's methods for quality assurance, road safety auditing is a formal process for 'getting it right the first time'.

In its initial form, road safety auditing aimed to cover the full range of stages in the process for building a new road or element of the network. Auditing procedures apply from the early planning stages, where changes to road alignment and associated land acquisition can be highly influential in road safety outcomes, through the stages of concept and detailed design, the construction period, the pre-opening stage and, more recently, extending to the post-construction and final stage of full operation. While road safety auditing can play a potentially valuable role in the identification of safety concerns in all of these stages, it is clear that its contribution in the early stages is particularly valuable, as the cost of correcting the design plans with safety deficiencies is very low when compared with after construction and during operation of the new project. That is, fine-tuning designs is inexpensive when compared with redesign and road re-construction.

To emphasise this advantage more fully, when design deficiencies that produce safety problems are actually constructed and operating as part of the road-transport system, a range of negative impacts can result. Under current methods, and because of the random nature of road crashes, it typically takes a number of years to elapse before a genuine safety problem is accepted as being *genuine*, as distinct from a randomly occurring series of crashes at a single location or along a route. Understandably, there is a natural reluctance among road agencies to invest in costly corrective works until it is clear that the problem is sustained.

Thus, a substantial number of crashes, often injury-producing, must occur before the problem is officially recognised and then, depending upon the nature of the solution and the availability of scarce resources to investigate it thoroughly, determine and design the appropriate solution, consult, secure funding to rectify the situation and, finally, implement the chosen solution, some additional years may typically elapse. During this period, the community continues to be exposed to potentially serious safety concerns and the trauma occurrence continues for, perhaps, 5-10 years before it can be properly addressed. Unfortunately, it is sometimes unaffordable to correct safety problems due to the wrong decision being taken in the vital early stages of planning and design. There will also be the added, but somewhat hidden, costs of traffic congestion (and its downstream consequences) due to avoidable crashes, be they minor or major in severity.

A further impact on costs is that the cost of the original design may be wasted, in part or fully, depending on the nature of the corrective solution.

Clearly, there is a strong case for ensuring the design of a new intersection (or other road element) is right from the beginning.

4.2 Relevance of Road Safety Auditing to Intersection Design

There is a wide range of road safety outcomes for the various intersection designs traditionally used. As has been demonstrated in earlier stages of this study, the risk of death or serious injury at an intersection, given a crash, can vary many-fold. The variation has been found to depend, largely, on the speed and angle of impact between the struck and striking vehicles, as well as the difference in masses and design features of the vehicles involved.

This general point is illustrated in Figure 13, which show the relative risk of a fatal injury outcome, in the event of a crash, as a function of travel speeds and impact angle. This relationship was developed as part of a major intersection design research study undertaken by MUARC in Victoria, Australia, for TAC and VicRoads (references). In accordance with the overall goal of developing intersection designs capable of delivering dramatically lower levels of risk of death or serious injury, a corresponding relative risk profile has also been estimated for serious injuries. The relative risk is defined as the risk of a fatal or serious injury outcome, relative to a defined 'Safe System' level of risk.

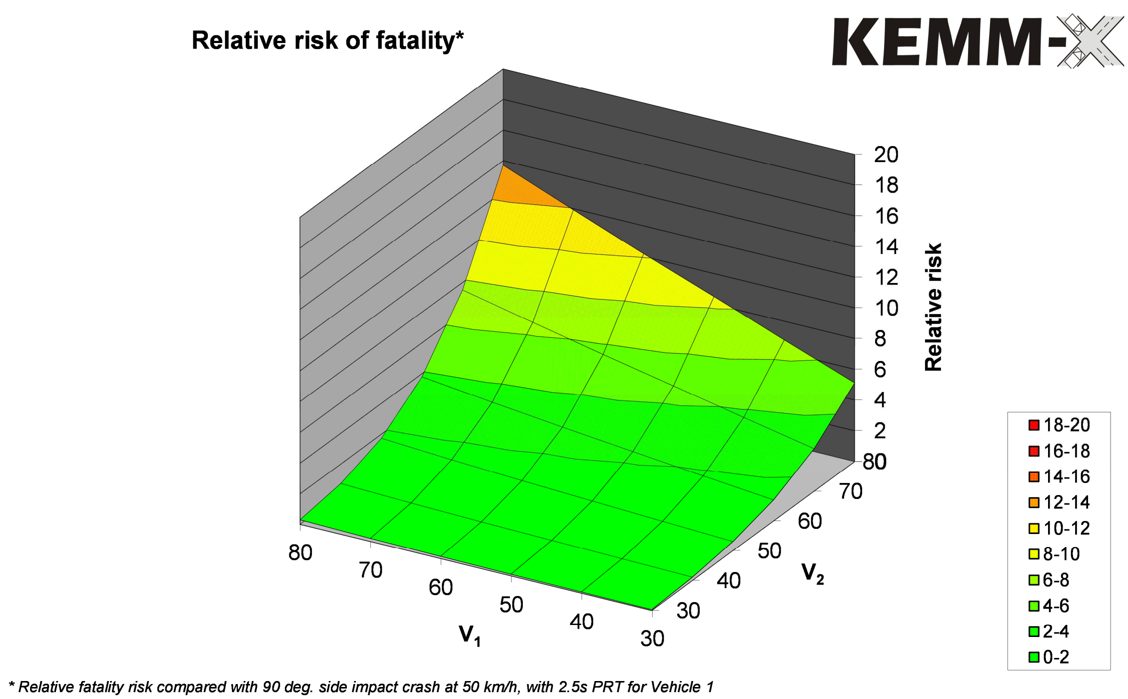

Figure 13. Relative risk (RR) of a fatality to the occupants of V1, as a function of travel speed of V2 (for a given impact angle), compared with a 'Safe System' reference design (RR = 1). In this scenario, both vehicles are assumed to be passenger vehicles of equal mass.

4.3 Key Road Safety Auditing criteria

In order to meet Safe System intersection design aspirations, a two-stage approach is recommended. Firstly, the risk of crashes should be reduced as far as possible. Second, the crashes that will still remain should take place within the biomechanical limits of humans to crash forces and kinetic energy levels. In many real-world circumstances, it is not possible to achieve the latter through the combination of engineering design and speed management. For example, above travel speeds of 70 km/h, it is no longer feasible to adjust the angle of conflict to achieve an acceptable collision outcome, given a crash. In such cases, the only feasible option for achieving Safe System outcomes is to reduce to negligible levels the risk of a crash occurring.

The MUARC Intersection Design study (Corben et al., 2010) identified four principles for Safe System design of intersections. They are proposed for incorporation into the road safety auditing process as follows:

1. **Fewer vehicles** - can the number of vehicles using the intersection be reduced to minimise the total number of conflicts per unit of time?
2. **Fewer intersections** - can the intersection be eliminated from the network?
3. **Fewer conflict points per intersection** - can the intersection be designed to create the least number of conflict points and hence eliminate opportunities for collisions to occur?
4. **Impact speeds and impact angles constrained to biomechanically tolerable levels** - can the intersection be designed to ensure:
    - for 90° conflict angles, impact speeds not exceeding 50 km/h;
    - for impact speeds between 50 km/h and 70 km/h, conflict angles that are 'Safe System compatible' with the travel speeds;
    - for travel speeds above 70 km/h, ensure the lowest practicable levels of crash risk[1].

Does road safety auditing give the answers or more simply discuss the issues? If the latter, the flowchart on the next page provides a guide to reviewing an intersection and selecting appropriate speeds and designs in line with the above principles.

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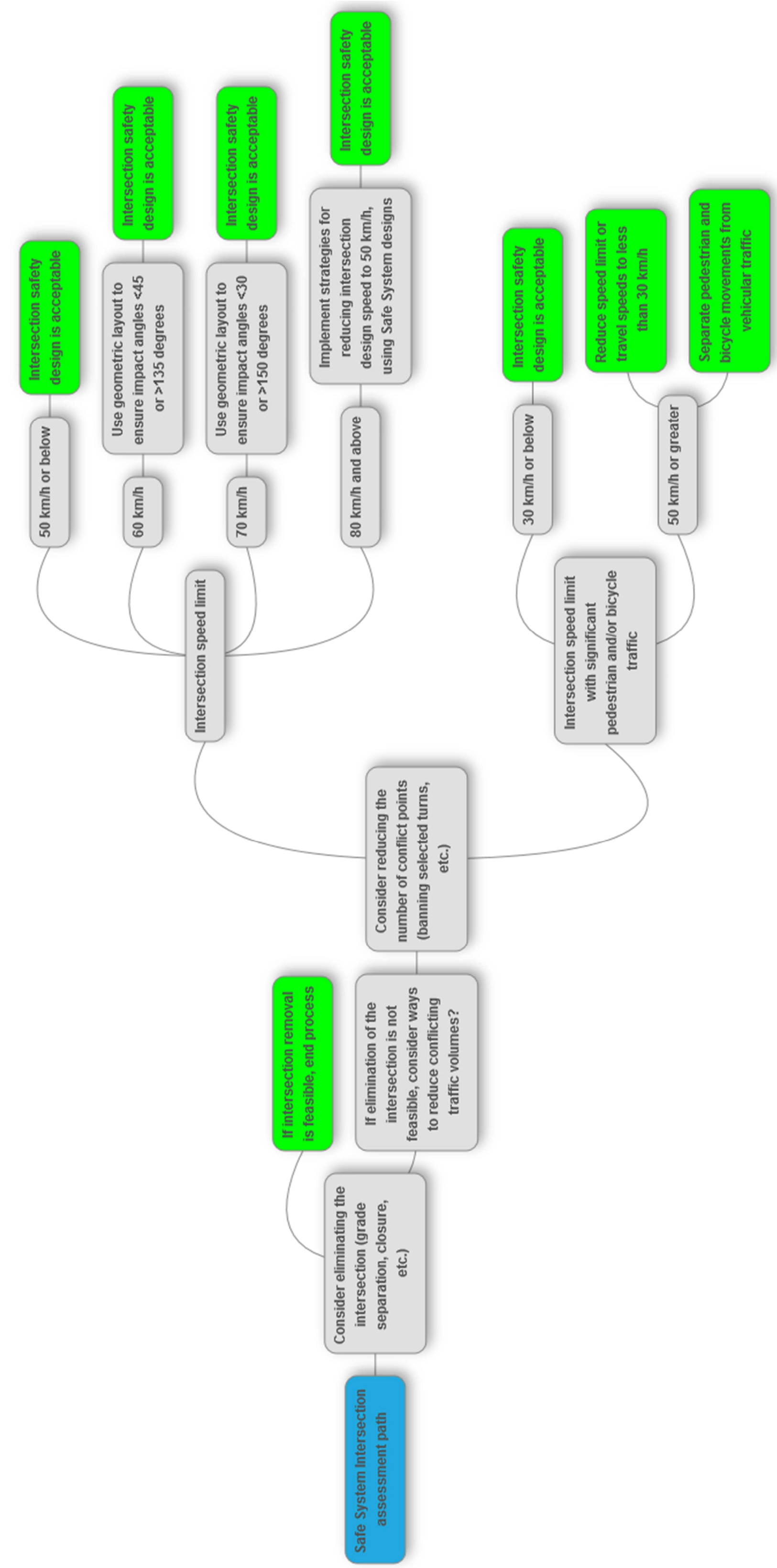
[1] At this stage, there is no research to help define 'lowest practicable level' of risk, but a valuable are for future investigation would be to endeavour to quantify a suitable maximum risk level in exposure terms.

4.4 Proposed Audit Schematic Diagram



5 REFERENCES

B Corben, N Van Nes, N Candappa, D Logan, and J. Archer, 'Intersection Safety Study: Meeting Victoria's Intersection Challenge. Task 3: Developmenet of the Kinetic Energy Management Model and Safe Intersection Design Principles', (2010)