Safe System for Universities: curriculum guideline

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1.0	08 Dec 2019	C Stokes	Draft release
1.1	01 Jul 2020	C Stokes	Added Module 2, 3 and 4 information

Contents

1 Introduction

The Safe System is a safety philosophy that provides an argument for adopting and aligning strategies and treatments, both traditional and innovative, for the goal of eliminating systematic harm to people. The Safe System has evolved from the epidemiological learnings of William Haddon Jr in the latter part of the twentieth century (Tingvall & Lie 2017). While the idea of a systems approach to safety can be found in different fields, and with various names, the term "Safe System" was devised for the field of road transportation safety and has been developed with this field in mind. However, the Safe System is applicable to a wide range of engineering disciplines where errors are an unavoidable result of system usage. Even within the road transport industry, the Safe System is known by a variety of names, such as Vision Zero in Sweden and Towards Zero in the state of Victoria. It is important to note that while these strategies are known by different names, their overarching philosophies of eliminating harm through a systems perspective are the same.

Concepts similar to the Safe System can be found in areas such as medicine, occupational health and safety, civil aviation and the nuclear power industry. While each approach is different, they all share the similar goal of using a systems approach to eliminate harm, rather than a mono-dimensional approach where human behaviour is seen as the cause and solutions are sought that aim only to improve compliance and human performance. In a Safe System, compliance is desired, but user error should be expected, and the system should provide adequate protection to ensure use does not translate to harm.

In this curriculum guideline, the theory and practical application of a Safe System will be explored through four modules. In the first module, the Safe System is explored through the lens of the general field of engineering. This module is aimed towards students who are new to the field of engineering and is designed to give them an appreciation of the philosophy, ethical imperatives and applications that underpin engineering safety and the Safe System.

The second, third and fourth modules are focussed on the Safe System in the field of road transportation. As such, these modules are aimed at students with a working understanding of road transportation engineering. In these modules, students will be guided through the objectives and concepts behind the Safe System, the principles and practices of Safe System design, and how to manage the transition to a Safe System, respectively.

1.1 Identification of graduate capabilities

The Safe System for Universities (SS4U) Support Group convened on the 8th of February 2018 for a planning workshop. The main aim of this workshop was to identify and agree on desired graduate capabilities for engineering graduates versed in Safe System theory, practice and application. These graduate capabilities were used to inform the curriculum learning objectives and learning material, which in turn were mapped to the Engineers Australia Stage 1 Competencies (Engineers Australia 2017)

By the time a graduate road transportation engineer enters the workforce, it is desired that they:

- Can recognise and communicate the principles, moral and ethical imperatives, and objectives of the Safe System.
- Can recognise and communicate the need for a Safe System to be integrated within the road transport industry, including in the areas of strategy, planning, concept and design, operations and maintenance.
- Can demonstrate fundamental differences between Safe System aligned and non-aligned design and operation of road infrastructure and can apply Safe System principles consistently to the design and operation of road infrastructure.
- Can apply Safe System principles in the context of standards and guidelines, recognise the need for innovation beyond the context of standards and guidelines, and develop well supported arguments for working beyond this context when required.
- Can communicate the need for and use of evaluation and design tools aligned to Safe System principles and apply the use of select tools to evaluate Safe System alignment of road infrastructure design and operation.
- Can demonstrate the inter-relationships and inter-dependencies between Safe System pillars and recognise the need for road transportation engineers to apply a systems perspective to the design and operation of a road transportation system.
- Can demonstrate transition to the Safe System and recognise potential areas of resistance to the Safe System, and opportunities to overcome resistance.
- Can recognise the inter-relationships between the Safe System and current and future technologies such as connected, autonomous vehicles.
- Can recognise the need for communication and integration with external contributing organisations such as police, health and government

1.2 Safe System learning framework

This curriculum guideline is part of a wider Safe System learning framework that outlines possible implementation of Safe System learning at different levels of education (Figure 1). This curriculum guideline is aimed at Safe System learning at a tertiary level. There are practical reasons for implementing Safe System learning at other levels, such as at a polytechnic or certificate/diploma level and at a postgraduate coursework level:

- Polytechnic: Many practicing transport engineers have limited knowledge of the Safe System. The relative novelty of the Safe System means that many transport engineers have not been exposed to the Safe System. Safe System learning at a polytechnic level may allow practicing engineers to develop Safe System skills that they did not have the opportunity to learn while at university.
- Postgraduate coursework: Safe System development relies on good research. This requires a pool of potential postgraduate researchers to be versed in Safe Systems. Safe System learning at a postgraduate coursework level may improve pathways for students to transition into Safe System postgraduate research.

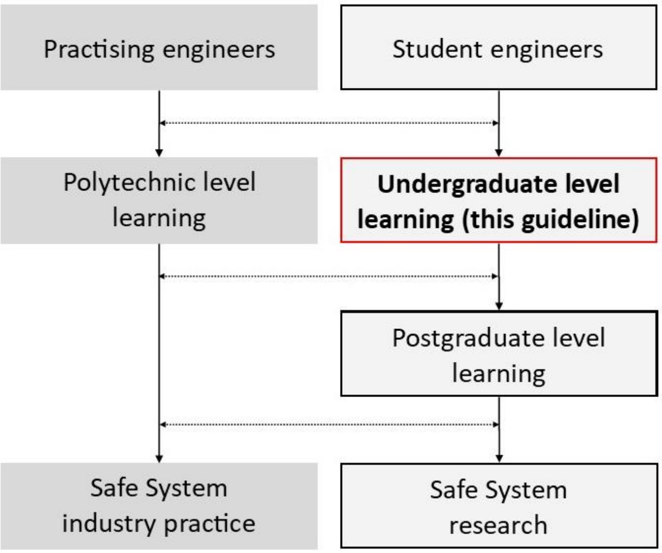

Figure 1: Safe System learning framework.

1.3 References

Engineers Australia (2017), *Stage 1 competency standard for professional engineer*, Engineers Australia, Australia.

Tingvall, C. & Lie, A. (2017), *Traffic safety from Haddon to Vision Zero and beyond*, in Annual report on automobile safety in China, Social Sciences Academic Press, pp. 316-333.

2 Curriculum overview

The following chart represents an overview of the Safe System for Universities curriculum structure and details where each module, snippet and tutorial sits in the overall curriculum and with respect to each other (Figure 2).

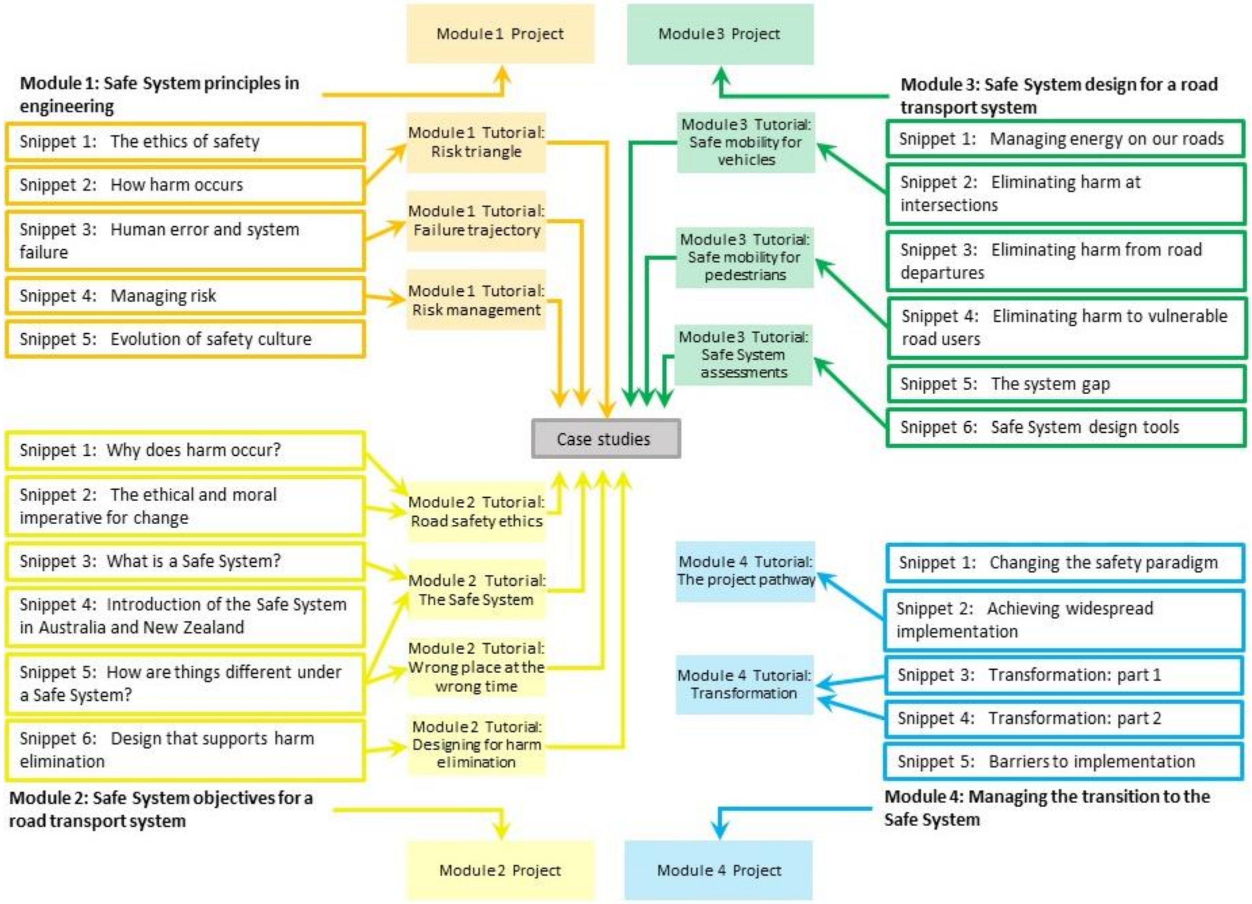

Figure 2: Overview of the Safe System for Universities curriculum structure.

2.1 Snippets

Learning information for each module is delivered through several snippets. There are six snippets to each module (five snippets for Module 4). Information pertaining to each snippet can be found in Section 3 to Section 6. Transcripts for each snippet can be found in Appendix A to Appendix D.

2.2 Tutorials and projects

Tutorials are available for each module and are linked to the snippets contained within their respective modules. Tutorials for modules 1 to 3 are linked to case studies. Each tutorial is presented in a question and answer style.

A project is available for each module. Each project present an open-ended style of learning that links to the concepts presented within a module.

2.3 Case studies

Case studies are available for use with or independently of the tutorials. Several case studies are linked to the tutorials presented for modules 1 to 3. Three case studies are available for Module 1 and are presented for a range of engineering related industries. Fifteen case studies are available for modules 2 to 4 and are based on Australian road transportation industry projects.

2.4 Example assessment questions

Example assessment questions and answers are available for each snippet of each module.

3 Module 1: Safe System principles in engineering

Module 1: Safe System principles in engineering provides students with an introduction into engineering safety within a range of engineering related industries. Examples are drawn from the aviation, road transport, mining, oil and gas, nuclear, manufacturing and construction industries. Topics will address the principles, ethics and cultures of safety within systems, as well as harm as an outcome of gaps within system safety. Module 1 is aimed towards students being introduced to the field of engineering and those undertaking basic engineering subjects.

Snippet 1: The ethics of safety

Ethics are the moral principles that we use to guide our conduct. Ethics can exist at a range of levels, including personal, organisational and societal. In this snippet, we discuss ethics related to the field of engineering safety and the ethical obligations of a professional engineer. We look at the ethics of safety in relation to the Engineers Australia code of ethics and discuss the notions of shared responsibility and an engineer's duty of care. The relationship between ethics and legal liability is then discussed. Finally, we look at ethical questions that can be used to guide engineers in their response to a risk of harm.

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1.0	08 Dec 2019	C Stokes	First release
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Snippet 2: How harm occurs

Harm is the outcome of bodily injury or damage to property. Harm results when failures to protect from harm occur in a system. In this snippet, we cover mechanisms of harm through a number of concepts that include system failures and the system deficiencies and error provoking conditions that lead to failure. We also discuss the idea of latent conditions; mechanisms that may lay dormant in a system for some time before leading to failure under the right conditions. Finally, we discuss the factors that lead to a risk of harm and the outcomes that can occur as a result of failure.

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Snippet 3: Human error and system failure

Failure is often associated with only the immediate actions that led to its occurrence; the active errors made by system users. However, failures occur through a trajectory that includes latent errors that lead to latent conditions within a system, and active errors that occur immediately before a failure. In this snippet, we look at the concept of failure trajectory through Reason's Swiss cheese model. We then discuss modes of failure through the concept of Kimber's model of failure, as related to the road transport industry. Finally, we discuss a key example of failure and the trajectory that led to its occurrence: The Piper Alpha drilling platform disaster of 1988.

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Snippet 4: Managing risk

Engineering related industries can be substantially risky to both their workforce and the broader public. Different industries deal with this risk in different ways. In this snippet, we discuss the factors that can help determine the applicability of different risk management approaches. Well-known elements of risk management from different industries are then drawn upon: The Hierarchy of Controls used in the manufacturing and resources industries; the Safety Management System from commercial aviation; and the Safe System as practiced in the road transport industry.

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Snippet 5: Evolution of safety culture

Safety culture, or the way an organisation or industry responds to safety, is critical to the success of mitigating harm. Safety culture can manifest in a range of responses, from treating safety as a barrier to success, to active practice, to in-depth integration into business as usual. In this snippet, we discuss the levels of safety culture through Hudson's well known five-step safety ladder. We then discuss transformation up through the safety ladder and end with an overview of the key elements that contribute to a strong safety culture.

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Snippet 6: Leading practice

Hudson defines a generative safety culture as the leading form of safety culture. In his model, a generative safety culture is defined by four critical components: an informed culture; a trusting culture; an adaptable culture; and an improving culture. In this snippet, we discuss the idea of leading practice through the lens of a leading safety culture and the four critical components that. Through this process, we examine what it means to perform as a leading practice culture.

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3.1 Key learning messages

Key messages	**LOs***	**References**
Snippet 1: The ethics of safety • The ethics of safety • Ethical obligations of engineers • Relationship between ethics and legal liability • Ethical responses to a risk of harm	1.1, 1.2, 1.3, 1.4	Engineers Australia (n.d.) Texas A&M University (n.d.)
Snippet 2: How harm occurs • Harm as a result of system failure • Mechanisms of failure • Outcomes of failure	1.1, 1.2, 1.4	Airline Pilots Association (n.d.) Reason (1990, 2000)
Snippet 3: Human error and system failure • Types of error and its relation to failure • Trajectory of failure • Modes of failure • Example of failure trajectory and modes of failure	1.1, 1.4, 1.5	Kimber (2005) Macleod & Richardson (2019) Reason (1990, 2000)
Snippet 4: Managing risk • Overview of risk management approaches • Hierarchy of Safety (manufacturing and resources) • Safety Management System (commercial aviation) • Safe System (road transportation)	1.1, 1.4, 1.5, 1.6	Federal Aviation Administration (2019) NIOSH (2015) Woolley et al (2018) *pp. 10-19*
Snippet 5: Evolution of safety culture • Safety culture and responses to harm • Transformation of safety culture and components of a strong culture	1.3, 1.4, 1.5	Hudson (2003)
Snippet 6: Leading practice • Leading practice through the lens of leading safety culture • Component 1: Informed culture • Component 2: Trusting culture • Component 3: Adapting culture • Component 4: Improving culture	1.3, 1.5, 1.6	Hudson (2003) Lie & Tingvall (2009)

*Relevant learning outcomes (see Section 0)

3.2 Learning outcomes

Item	**Learning outcome**	**Stage 1 element of competency^**
1.1	Recognise, from a systems perspective, why harm occurs and the role of a safety in harm mitigation	1.5, 1.6, 2.1, 2.3, 3.1
1.2	Communicate the objectives of harm mitigation and safety compliancy	
1.3	Communicate the moral and ethical imperatives that drive safety in engineering, and the cultural shift that these require	
1.4	Recognise and communicate the core differences in the objectives of system thinking and safety focussed on user causation	
1.5	Recognise the importance of safety beyond a procedural context and placing safety as the primary driver of design	1.6, 2.1, 3.1
1.6	Recognise the key attributes of a leading safety culture and what is required to maintain a leading practice in safety	

^Mapped to Engineers Australia *Stage 1 Competency Standard for Professional Engineer (https://www.engineersaustralia.org.au/resource-centre/resource/stage-1-competency-standard-professional-engineer)*

3.3 Module 1 references

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Hudson, P. (2003*), Applying the lessons of high risk industries to health care,* Qual Saf Health Care, 12 (Suppl 1): i7-i12

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Macleod, F., Richardson, S. (2019), *Piper alpha: the disaster in detail*, The Chemical Engineer, viewed 5 Dec 2019, https://www.thechemicalengineer.com/features/piper-alpha-the-disaster-in-detail/

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4 Module 2: Safe System objectives for a road transport system

Module 2: Safe System objectives for a road transport system provides students with an introduction into the Safe System as applied to the road transport industry. Topics will address the adoption and objectives of the Safe System and the physical concepts of harm through energy transfer and the need for energy management in the road transportation system. Module 2 is aimed towards students with prior learning experience in basic engineering subjects and who have an interest in developing knowledge about road transport engineering.

Snippet 1: Why does harm occur?

Harm occurs when the human biomechanical tolerance to harm is exceeded. In a basic sense, this means that the force placed on the human body exceeds the body's own ability to resist that force before damage occurs. Our body's own tolerance to forces is not the only barrier to harm in a road crash; barriers exist at many levels before the crash has even occurred and may be ability-, design- or administration-based. While historically harm has been attributed to user error, such as a driver's inability to keep his or her car on the road, there is growing concern that such a model of harm causation is both incomplete and counter-productive in terms of finding solutions to the continuous stream of death and injury that occurs on our roads. Instead of focussing solely on user failures, we must consider all barriers to harm and draw solutions that also strengthen resistance to the other modes of failure within the system.

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Snippet 2: The ethical and moral imperative for change

Ethically and morally speaking, there is no justification or reason why people should be harmed as a consequence of using the road transportation system. There is a growing movement to acknowledge this imperative and the understanding that any other position is counter-productive to the goal of eliminating harm. While such an imperative will not by itself lead to a road transportation system free of harm, it provides an aspirational platform against which system performance can be measured and towards which strategies can be directed.

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Snippet 3: What is a Safe System?

Meet Graham[1]. He is a human designed to survive a low-speed crash. Unfortunately, we have not evolved to resemble Graham and so it is inevitable that at even modest speeds, we are likely to be harmed. The traditional resolution to this problem has been a notion that people should not crash. The problem of this notion is people make mistakes. Every day, in every part of life, people make errors. In the road transportation system, these errors can easily result in harm. The Safe System brings this acknowledgement to the way we plan, design and manage the system. Harm elimination cannot just focus on the user; errors will continue to occur as long as people are granted access to the system. Harm elimination can only come from a system perspective that draws solutions from all aspects of the system.

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Snippet 4: Introduction of the Safe System in Australia and New Zealand

The Safe System has been acknowledged in Australia for well over a decade but in this time, little has been achieved to practically implement an agenda of harm elimination. The Safe System has underpinned the *National Road Safety Strategy* in Australia since 2003 and the *Road Safety Strategy* in New Zealand since 2010. However, the high-level positioning of these strategies and other guidance has not been widely translated into practice. While much evidence has been disseminated and industry-leading programs have begun to put Safe System thinking into practice, there is a consensus among experts[2] that dramatic change in road safety management is required to see realisation of the harm elimination agenda.

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Snippet 5: How are things different under a Safe System?

A common perception is that when a crash occurs, the road user is to blame. There is further still a perception that crashes are caused by extreme behaviour; when crashes occur, it is because people have chosen to break the rules of the road. In the community, this perception fosters a consensus of accepting harm as a price that must be paid for a functioning road transportation system. When held by system managers, this perception creates a culture of acceptance that nothing can be done to resolve the problem, beyond that the primary focus is on education and enforcement. The evidence shows this

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[1] http://www.meetgraham.com.au/

[2] Raised as a substantial issue across the broad range of consultation undertaken as part of the Inquiry into the National Road Safety Strategy 2011-2020, published September 2018

perception to be unfounded. Most crashes occur due to errors; mistakes that any and every person can make. A Safe System must break from this culture of blame and in its place build a culture of responsibility where users aim to comply with system rules and managers in-turn oversee a system that does not place users in situations where error can translate to harm.

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Snippet 6: Design that supports harm elimination

Appropriate road design is a key driver of harm elimination. It cannot by itself eliminate harm but is a vital component of the solution. There are three ways that we can design for harm elimination: exposure to the source of harm; likelihood of the crash occurring; and severity should the crash occur. Historically, we have focussed on likelihood. Moving to a Safe System, exposure and severity will need to be considered. Key to the Safe System is a hierarchy of solutions that incorporates consideration for each of these three factors. Primary solutions, those closest to Safe System performance, have a strong focus on removing exposure or eliminating severe outcomes. These solutions should always be considered first. Only when high performance options are exhausted should road designers consult solutions with lesser alignment to the Safe System.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

4.1 Key learning messages

Key messages	**LOs***	**References**
Snippet 1	2.6, 2.7	
• Harm and the human biomechanical tolerance to harm		Corben et al (2010) *pp. 13-26*
• The barriers to harm *Reason's Swiss Cheese model*		Reason (1990) *pp. 31-33* Reason (2000) *pp. 769*
• User failures versus system failures *Kimber's model*		Kimber (2005) *pp. 6-9*
Snippet 2	2.1, 2.2, 2.3, 2.4	
• The ethical and moral imperative for change		Woolley et al (2018) *pp. 10-11*
• Ethical policy *Vision Zero (Sweden)* *The Tylösand Declaration of Citizen's rights to road safety (Sweden)* *Safer Journeys (New Zealand)*		Belin et al (1997) Tingvall and Harworth (1999) Sweden (2007) Ministry of Transport (2010) NZTA (2014)
• Targeted imperatives *Safe journeys to school* *Volvo's Vision 2020*		Silverman and Billingsley (n.d.) iRAP (2017) Volvo Car Corporation (2017) Volvo Car South Africa (2016)
Snippet 3	2.1, 2.2, 2.3	
• Harm elimination *Meet Graham: the human evolved to survive a crash*		TAC (n.d. b)
• System perspective		Woolley et al (2018) *pp. 3-4*
• A manager's responsibility		Woolley et al (2018) *pp. 17-19*
• The Safe System		Woolley et al (2018) *pp. 17-19*

*Relevant learning outcomes (see Section 0)

Key messages	LOs*	References
Snippet 4	2.1, 2.3	
• Introduction of the Safe System in Australia and New Zealand		
New Zealand and Australian state-based strategies		ACT Government (2011) Government of South Australia (2011) New Zealand Government (2019) Northern Territory Government (2018) Office of Road Safety (WA) (2009) Tasmanian Government (2016) TMR (2015) Transport for NSW (2012) Victoria State Government (2016)
National Road Safety Strategy (NRSS) and the Inquiry into the NRSS		ATC (2011) Woolley and Crozier (2018)
• What we have achieved		
Strategy		*See above list of state-based and national strategies*
High level guidance		NZTA (2011, 2013) Cairney (2013)
Showcase projects		Government of South Australia (2015) TAC (n.d. c)
Program alignment		TAC (n.d. d)
Evidence-based research		Jurewicz et al (2017) Woolley et al (2018)
Public campaigns		TAC (n.d. a)
• What is still required		
Snippet 5	2.4, 2.5, 2.6, 2.8	
• A change of focus		Woolley et al (2018) *pp. 12, 17-18*
• Factors of harm		
Factors is fatal and serious injury crashes		Wundersitz et al (2014) Wundersitz et al (2011)
A Safe System lens on fatal crashes		Baldock et al (unpublished) Stigson et al (2008)
• A system focus		Woolley et al (2018) *pp. 17-18*
Snippet 6	2.5, 2.7, 2.8	
• Achieving zero harm		Turner et al (2016) *pp. 14-19*
• Design that supports harm elimination		Woolley et al (2018) *pp. 36-46, 52-54, 68-82*
• Harm elimination examples		Woolley et al (2018) *pp. 59-63, 87-93*
• Identifying Safe System design		Woolley et al (2018) *pp. 28-48*

*Relevant learning outcomes (see Section 0)

4.2 Learning outcomes

Item	Learning outcome	Stage 1 element of competency^
2.1	Critically analyse what a Safe System is, from where and why the concept developed, and what is currently international best practice	1.5, 1.6, 2.1, 2.3, 3.1
2.2	Communicate the objectives of harm elimination and Safe System compliancy	
2.3	Critically analyse the moral and ethical imperatives that drive Safe System thinking, and the cultural shift that these require	
2.4	Recognise and communicate the core differences in the objectives of a Safe System and historical road and traffic safety	
2.5	Recognise the role of a Safe System in supporting mobility without trading off against a safe road transport system	
2.6	Demonstrate, from a systems perspective, why harm occurs	1.1, 1.4, 1.5, 2.1, 2.2, 2.3, 2.4, 3.3
2.7	Demonstrate, using theories of energy management and biomechanical tolerance to harm, the need for a Safe System	
2.8	Recognise the core differences between Safe System aligned and non-aligned design	

^Mapped to Engineers Australia *Stage 1 Competency Standard for Professional Engineer* (*https://www.engineersaustralia.org.au/resource-centre/resource/stage-1-competency-standard-professional-engineer*)

4.3 Module 2 references

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5 Module 3: Safe System design for a road transport system

Module 3: Safe System design for a road transport system builds on the knowledge learned in Module 2 and provides students with further insights into the practical application of the Safe System. Topics will address the underlying physical mechanisms of harm and the practical solutions that can be used to address these mechanisms. Students are also introduced into the application of these solutions and the tools that can be used to decide what is done where. Module 3 is aimed towards students with prior learning experience in basic engineering subjects and who have an interest in developing knowledge about road transport engineering.

Snippet 1: Managing energy on our roads

Road safety has historically been driven from by the desire to correct undesired actions that are taken by road users and that increase the risk of crashes. From one perspective, this has come from the assumption that road users are to some degree in control of their failings, and so can be corrected through enforcement and education. Speeding and intoxication are well known examples to which this method has been applied. From the other perspective, road safety design and operation has developed from the notion that road users can be guided to not make errors. While these perspectives have benefitted road safety and will continue to play a critical role, another key element has been overlooked. We know people will continue to make errors and that no amount of enforcement, education or design can stop all errors from occurring. If harm elimination is to ever be achieved, then focus needs to be placed on reducing the severity of crashes that will continue to occur. This means controlling the level of energy in crashes to which road users can be subjected. While the concept is simple, its application is proving to be much more challenging, as much of our current road network pays little homage for the need to control energy to which road users are exposed.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 2: Eliminating harm at intersections

Intersections play a critical role on our road network. They allow traffic streams to cross one another, and for vehicles to move from one stream to another. Because of all this activity, intersections are also the locations where crashes generally most likely to occur. Historically, intersection crashes have been dealt with through design that informs and guides the road user to do the correct thing. While huge safety gains have been made, a small risk of fatal and serious injury crashes still exists at most intersections. Because of the huge volume of road users travelling across our networks, this small risk has equated into a substantial road safety problem. The future challenge for road practitioners will be to implement intersection design that manages the severity of the crashes which continue to occur.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 3: Eliminating harm from road departures

Road departures, especially along the high-speed roads which dominate rural and peri-urban environments, are another substantial contributor to the harm that occurs on our roads. While road departure crashes can be comparatively unlikely compared to the likes of those occurring at intersections, the vast exposure to these scenarios – a product of long travel distances – means they contribute a large proportion of the harm issue. Magnified by the generally high speeds at which these crashes occur, the toll of fatal and serious injury outcomes is high. Recent developments have changed the way we look at treating this problem. While the solutions are not complex, the vast lengths of road that need to be treated means the economic challenge is immense and it is impractical to think that road design alone will solve the problem. Harm elimination will need to incorporate other pillars of the Safe System. Currently, the best alternatives to road design alone are speed limits/management and the ever-increasing developments in vehicle safety technology.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 4: Eliminating harm to vulnerable road users

We are all vulnerable road users at some point in our journeys. Vulnerable road users present a unique challenge in terms of road safety. Unlike with other modes of transportation, vulnerable road users lack any occupant protection that can absorb some of the energy from a crash, before it is transferred to the human body. This means that vulnerable road users can generally withstand much lower crash forces before they are seriously injured or killed. The essential determinant for vulnerable road user survivability is speed. Coupled with the tendency to consider in Australia and New Zealand the needs of vulnerable road user as an afterthought, and the issues faced by vulnerable road users are quite substantial. Allowing vulnerable road users to safely access our road transportation system will require a reassessment of how we prioritise travel modes and will challenge our long-held view of motor vehicle domination on our road networks.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 5: The system gap

The system gap is what we need to fill in order to achieve zero harm throughout our road transportation system. The system gap means that the solution to harm will come from more than just isolated improvements in each pillar of the Safe System. Harm elimination will only be achieved if all pillars work in a concerted effort to optimise safety. The essential ingredient to overcoming the system gap will be the way we view optimal outcomes in the road transportation system. We can no longer afford to accept the safety we get in order to achieve the mobility we expect. Mobility will need to become a function of safety. In other words, we will need to accept the level of mobility that we can get while attaining the level of safety that we expect.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 6: Safe System design tools

Achieving the Safe System objective of harm elimination will require skilled work by those at the forefront of managing the road transportation system. All skilled workers require their tools, and those working to achieve the Safe System are no different. A number of tools are available to strategically and practically implement harm elimination objectives. The best of these tools give explicit consideration to the consequences of crashes, as well as their likelihood, and provide methods for prioritising where and how we go about the task of eliminating harm from our road network. We will explore a sample of the best available tools which can be applied from the strategic level – overlooking large sections of the road network – to the project level, which can be used to inform the detailed design and operation of individual locations.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

5.1 Key learning messages

Key messages	LOs*	References
Snippet 1	3.1, 3.2, 3.3, 3.4	
• The historical approach to road safety		
• Mechanisms of harm		Corben et al (2010) *pp. 13-26*
• Focus on consequence		Woolley et al (2018) *pp. 49-58, 66-95, 107-110*
• A design problem		Woolley et al (2018) *pp. 21-27*
Snippet 2	3.1, 3.4	
• How does harm occur at intersections?		Woolley et al (2018) *pp. 49-58* Jurewicz et al (2017) *pp. 4-15*
• Harm elimination mechanisms		Woolley et al (2018) *pp. 58* Jurewicz et al (2017) *pp. 28-30*
• Primary treatments		Woolley et al (2018) *pp. 58-65* Turner et al (2016) *pp.17* Jurewicz et al (2017) *pp. 31-84*
• Supporting treatments		Woolley et al (2018) *pp. 58-65* Jurewicz et al (2017) *pp. 31-84*
Snippet 3	3.2, 3.4	
• How does harm occur from road departures?		Woolley et al (2018) *pp. 66-95*
• Barriers vs. clear zones		Woolley et al (2018) *pp. 66-95*
• Primary treatments		Woolley et al (2018) *pp. 66-95* Jurewicz et al (2014) Turner et al (2016) *pp.15-16*
• Supporting treatments		Woolley et al (2018) *pp. 66-95* Turner et al (2016) *pp.15-16*
Snippet 4	3.3, 3.4	
• How does harm occur to vulnerable road users?		Woolley et al (2018) *pp. 96-102*
• Primary treatments		Woolley et al (2018) *pp. 96-102, 146-152* Turner et al (2016) *pp.18*
• Supporting treatments		Woolley et al (2018) *pp. 96-102, 146-152* Turner et al (2016) *pp.18*
Snippet 5	3.4, 3.5	
• The system gap		Turner and Ahmed (2018)
• Filling the gap		Woolley et al (2018) *pp. 17-27, 28-48*
• Known unknowns		Woolley et al (2018) *pp. 102-110*
Snippet 6	3.4, 3.6	
• What are Safe System tools?		Woolley et al (2018) *pp. 117*
• Road assessment programs		iRAP (2017)
• Crash modification factors		Turner et al (2015) *pp. 45-47*
• Safe System assessments		Turner et al (2016)
• KEMM-X		Corben et al (2010)

*Relevant learning outcomes (see Section 5.2)

5.2 Learning outcomes

Item	Learning outcome	Stage 1 element of competency^
3.1	Demonstrate the mechanisms of and way to eliminate severe injury outcomes associated with crashes at intersections	1.1, 2.1, 2.2, 2.3, 3.3
3.2	Demonstrate the mechanisms of and way to eliminate severe injury outcomes associated with lane departure crashes	
3.3	Demonstrate the mechanisms of and way to eliminate severe injury outcomes associated with crashes involving vulnerable road users	
3.4	Demonstrate the role of speed in harm causation and recognise Safe System speeds for key crash configurations	
3.5	Describe how the principles and practical solutions provided by the Safe System can be applied to achieve harm elimination across the road transport system	2.1, 2.2, 3.3
3.6	Describe the application of Safe System tools, and apply selected Safe System tools under specified situations, to analyse system failures and evaluate the effectiveness of treatments used to improve Safe System alignment	

^Mapped to Engineers Australia *Stage 1 Competency Standard for Professional Engineer* (*https://www.engineersaustralia.org.au/resource-centre/resource/stage-1-competency-standard-professional-engineer*)

5.3 Module 3 references

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6 Module 4: Managing the transition to the Safe System for a road transport system

Module 4: Managing the transition to the Safe System for a road transportation system provides students with an insight on how the theoretical and practical learning of the Safe System may be operationalised over the broader road transportation network. Topics will address the problems being faced with achieving widespread implementation of the Safe System, an approach to transforming the road transportation system and key institutional barriers that need to be overcome to achieve transformation. Module 4 is aimed towards students with prior learning experience in basic engineering subjects and who have an interest in developing knowledge about road transport engineering.

Snippet 1: Changing the safety paradigm

Transitioning to the Safe System will mean a shift in the way we think about and practice road safety: a paradigm shift. Paradigm shifts have arguably occurred before in road safety. The last time this happened, we started looking at road safety through the lens of economics. We started talking about road safety in terms of its economic cost to society. Now, the Safe System is supporting a further change in the way we view road safety: from looking at economics and the economic cost to society, to looking at people and the personal cost of suffering. In this snippet, we will discuss this change, and what it means from a practical standpoint in the way we think about and practice road safety.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 2: Achieving widespread implementation

Achieving widespread implementation of the Safe System will require a transformation in the way we look at road safety and the way we deal with it inside the wider road transportation system. Current practices tend to lead us to the notion that any improvement across the road transportation network improves safety, and that any improvement means we are doing our job to protect road users. To break this cycle, we need to transform the way we approach road safety. We will explore two key parts to this transformation: moving from making roads safer to making them safe outright; and implementing safety as an integral part of road projects.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 3: Transformation: part 1

Transformation itself will take years to occur. It is unrealistic to think that we can transform the road transportation system into a Safe System overnight. The timeframes to achieve transformation themselves create problems: we are good at perceiving short-term changes but often loose track of the longer-term. Zero 2050 is the state of Victoria's pathway to transformation. In this snippet, we will look at how the concepts in Zero 2050 can be used to remain on-track over the longer-term. In part 1, we will look at defining the future of zero harm, and mapping the current state of our road transportation system.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 4: Transformation: part 2

In the snippet Transformation: part 1 we looked at the first two concepts within the Zero 2050 transformation strategy. In part 2, we will look at the remainder of the concepts that are being used by the state of Victoria to achieve harm elimination across the road transportation system. We will look at setting achievable boundary conditions under which elimination can be achieved, creating future scenarios and undertaking a gap analysis between the current situation and ones that lead to zero harm, and using key performance indicators to track performance as we proceed with harm elimination strategies.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

Snippet 5: Barriers to implementation

There are several barriers to transformation that revolve around the way we deal with our duty to protect road users. Currently, there is much concern from system managers about how to protect road users, but they are restricted by the perceptions that we hold around liability and ability to act. In this snippet, we will discuss such barriers through the lens of how we perceive liability and the effect of this perception on how we use our primary design tools, which are the standards and guidelines that system managers use to design and operate the road transportation system.

Revision	Date	By	Revisions
1.0	01 Jul 2020	C Stokes	First release

6.1 Key learning messages

Key messages	LOs*	References
Snippet 1	4.1	
• Evolution of the system		Hakkert and Gitelman (2014) Tingvall and Lie (2017)
• Economics of safety		
• Transforming the paradigm		Haddon (1970) Haddon and Goddard (1962)
Snippet 2	4.1, 4.2	Department of Transport Victoria Zero 2050 approach (unpublished)
• From safer to safe		
• Safe System first		
• When we think about safety		
• A transformative approach		
Snippet 3	4.3, 4.4, 4.5	Department of Transport Victoria Zero 2050 approach (unpublished)
• Zero 2050		
• Defining the future		
• Mapping the current state		
Snippet 4	4.3, 4.4, 4.5	Department of Transport Victoria Zero 2050 approach (unpublished)
• Setting achievable boundary conditions		
• Gap analysis & future scenarios		
• Key performance indicators		
Snippet 5	4.4, 4.6, 4.7	
• How we perceive liability		
• The role of standards and guidelines		
• The design domain		Veith et al (2006) *pp. 9-12* McTiernan et al (2019) *pp. 8-12, 101-102*
• Liability in a Safe System		

*Relevant learning outcomes (see Section 0)

6.2 Learning outcomes

Item	Learning outcome	Stage 1 element of competency^
4.1	Recognise the limitations of current road safety implementation strategies and the need for transforming the way implementation is undertaken	1.6, 3.1
4.2	Communicate the need for integrating a Safe System throughout the planning, development, design and construction phases of road and traffic engineering projects	1.6, 3.1
4.3	Explain where and why barriers to Safe System outcomes may arise, and is needed to overcome these barriers during the transformation process to a Safe System	1.5
4.4	Recognise the responsibilities of system managers in a Safe System	1.6, 3.1
4.5	Communicate the key steps in transformation and apply transformation modelling strategies to form road safety investment scenarios	2.1, 2.2, 2.3
4.6	Recognise risk aversion tactics resistant to Safe System objectives and the legal liability issues that accompany them	1.5
4.7	Recognise the roles and limitations of design standards and guidelines in a Safe System	1.6, 2.1

^Mapped to Engineers Australia *Stage 1 Competency Standard for Professional Engineer* (*https://www.engineersaustralia.org.au/resource-centre/resource/stage-1-competency-standard-professional-engineer*)

6.3 Module 4 references

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Appendix A. Module 1 transcript

The following transcripts are from snippets 1 to 6 of Module 1.

Appendix A1. Module 1, Snippet 1 transcript

Slide 1

Welcome to Module 1, Snippet 1 of Safe System for Universities. In this module, we will take a look at safety in engineering related industries and what best practice in safety can look like. Throughout this module, we will look at such things as failure and harm, risk and error, and how to address these issues. We will also address some misconceptions of safety along the way.

In this snippet, we will start by exploring the ethics of safety and look at some of the ethical responsibilities that engineers must consider.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can press the loudspeaker icon at the top right of each page to listen again.

Slide 4

Firstly, let's have a look at what is meant when we talk about ethics.

Slide 5

Ethics are the moral principles that we use to guide our conduct and behaviour. Ethics can be personal, such as your own ethical beliefs regarding the treatment of others, or belonging to a group of people. Common ethical beliefs can be seen among communities, religious groups and ethnical groups. Some beliefs can be common across humanity, such as our belief in the value of civilised community. Ethics can also be related to organisations and professions, including the engineering industry.

Ethics is practiced in many professions and is a widely researched field in the professions of law and medicine. While less mature in the profession of engineering, the field of professional ethics is becoming a vital consideration of the practicing engineer. There are different ethical considerations that a professional engineer must understand and comply with. In addition to personal ethics, an engineer needs to consider the ethics of their profession and the ethics of the organisation under which they practice. These can relate to legal issues, business interests, public interests and more.

In this snippet, we will cover ethical considerations specific to the field of safety. Even within this domain, the way in which ethics is approached can vary between contexts and so the information contained here may deviate from specific ethical considerations of some industries and organisations.

Slide 6

Let’s now look into the ethical obligations of a practicing engineer.

Slide 7

Engineers Australia is the principle professional association for practicing engineers across Australia. Engineers Australia acts to accredit individual practicing engineers as well as engineering education and training. Engineers Australia provides a code of ethics for engineers practicing in Australia, and this is based on four key principles.

The first principle in their code of ethics is to demonstrate integrity by acting on the basis of a well-informed conscience, being honest and trustworthy, and respecting the dignity of all people.

The second principle is to practice competently by maintaining and developing knowledge and skills, objectively representing areas of competence, and acting on the basis of adequate knowledge.

The third principle is to exercise leadership by upholding the reputation and trustworthiness of the practice of engineers, supporting and encouraging diversity, and communicating honestly and effectively, while taking into account the reliance of others for their engineering expertise.

The final principle is to promote sustainability by engaging responsibly with the community and other stakeholders, practising engineering to foster the health, safety and wellbeing of the community and the environment, and balancing the needs of the present with the needs of future generations.

Slide 8

Three key points of importance stand out within the Engineers Australia code of ethics. These effect safety in all the activities that we undertake as engineers, which can include such things as the planning, design, implementation and operation of works.

First of these is the need to seek continuous improvement. Such actions can be seen throughout mature safety systems. All practitioners are responsible for the safety of those working within the industry and the public effected by the industry. Part of this responsibility is the acknowledgement that safety will likely never be perfected and so we must continue to advance our knowledge and understanding of risks, and our ability to mitigate such risks through our influence on the systems in which we work.

Second is the need to understand and act on risks. Through continuous improvement, we can better understand the safety risks of our engineering activities. However, we must also make sure to act on these risks to ensure they are mitigated as far as is reasonably practicable. This means we must never knowingly allow an activity to be undertaken when a safer process, design or mode of operation, or a safer alternative to the proposed activity is available.

Extending from the first two key points is the need to never knowingly implement activities that may cause harm. Any activity that has the potential to lead to harm, and where this harm is foreseeable using knowledge of the day, should be considered unfit for service until the risk of harm is mitigated. It is therefore the responsibility of the engineer to seek continuous improvement to understanding the risks, find strategies to mitigate these risks, and act on eliminating or if not possible, reducing the risk that harm will result as a consequence of our activities.

Slide 9

Shared responsibility is an idea upon which the Safe System philosophy of road safety is predicated. At the core of the Safe System is the concept of maintaining a system free of harm, with responsibility for obtaining this shared between managers and users of the road system.

Firstly, it is the system managers' responsibility to implement and maintain a system that does not knowingly introduce an unacceptable level of harm onto system users. In the realm of road safety, an unacceptable level of harm has been identified as death or serious injury. Any lesser level of harm is undesirable, but ultimately accepted as a possibility as it is understood that with currently knowledge, eliminating all levels of harm is unachievable.

It is then the system users' responsibility to use the system in accordance with its design and to not knowingly introduce additional risk of harm through their own actions. This is where the idea of shared responsibility can break down as the question often arises: what if a risk of harm is identified that has been caused by inappropriate behaviour on the part of the system users?

Ideally, the answer to this question is that it is always the responsibility of the system managers to maintain a system free from harm, no matter how that harm may arise. In other words, the system should be designed so that users cannot act in such a way that introduces additional risk of harm. In practice, however, this can be a challenge and is an area of much debate. Nonetheless, such debate should not prevent system managers from taking responsibility and acting on foreseeable risks of harm to the best of their abilities.

Slide 10

Closely linked to an engineer's ethical responsibility is their duty of care. Next, we will look at what is meant by a duty of care and what it requires.

Slide 11

Duty of care is a concept closely aligned to that of shared responsibility. While a system manager's duty of care is arguably intrinsic in all steps in this cycle, it is when a previously unforeseen risk is identified that the ethical dilemma can become complicated.

While risks that are identified in the system can be due to oversight on the part of the system designers and operators, they often include an aspect of system use that deviates from expectation. Because these deviations of use usually lead to the active errors that result in failure, it is easy to attribute causation of failure to the system users. This is especially the case when system use that results in a failure has been in extreme violation of the rules and expected behaviour of system users.

This attribution of blame to the system user can lead to a breakdown in the duty of care that lies with system managers. The question can often arise: shouldn't the system users change their behaviour to conform to the system? While this approach may be favoured by some, it is ultimately fraught – behavioural change is one of the hardest things to accomplish. This means that changing the system to conform to user behaviour is often the most viable action. The responsibility to action such change form part of the duty of care.

Slide 12

As we previously acknowledged, a key barrier to maintaining duty of care has been the culture of blame. A culture of blame exists when responses to an incident or accident centre around finding and penalising those who are considered at fault, in order to disincentivize future wrongdoing.

In the earlier aviation industry, blame created a culture of non-reporting, where flight crews were unwilling to report incidents for the fear of being punished. In the road industry, this attitude was commonplace, with responses to serious crashes being centred around finding the at-fault party and deciding whether prosecution was appropriate. A culture of blame still pervades media reporting of accidents, perpetuating the common belief that harm can be attributed to a single party and is able to be solved through greater levels of enforcement.

A no blame culture is necessary for maintaining ethical practices. A no blame culture removes focus from the system user and their error or wrongdoing that contributed to harm. Instead, focus can be adjusted to a systems perspective, where each part of the system can be analysed for gaps that led to an outcome of harm. Emphasis is put on the responsibility of system managers, highlighting the ethical obligation to maintain a system free from harm. Enforcement and other responses aimed at the system users may form a part of this approach, but should not be the only response.

Slide 13

Now, let’s look at the topical discussion of ethics and its relationship to legal liability.

Slide 14

In most situations, engineers are given a scope of works that sets boundaries for the activities being undertaken, but does not necessarily define in detail the final outcome or how to get there. In this sense, engineers are given freedom to practice their professional judgement.

It is therefore often necessary for engineers to make decisions that affect the direction of an activity, such as a design or operational procedure. When making such decisions, engineers will use a combination of their professional knowledge, evidence, standards and other formal guidance to decide on the appropriate action.

Two critical components of this decision making process are to consider the legal and ethical outcomes. In many situations, it is obvious which options conform to both ethical standards and reduce the risk of the engineer’s and their organisation’s legal liability. For example, when designing a roofing structure for a building, a design that conforms to understood requirements to prevent structural failure is a good option from both ethical and legal liability grounds.

However, sometimes the best option may not be as obvious. Some options may provide better outcomes from the perspective either an ethical standpoint or legal standpoint, but not both. A broad example can be drawn from the road transport industry, where legal liability concerns are used as reasoning for avoiding novel approaches that promise substantial safety gains.

Slide 15

Australia and New Zealand's road transport industry is heavily influenced by professional guidelines developed through individual state road agency experiences. These guidelines are established through Austroads, an organisation made up of member road agencies, and are a primary source of planning, design and operational guidance for road design and operation activates undertaken in Australasia.

While these guidelines officially serve as guidance to acceptable minimum levels of practice, they are often treated as a benchmark in best practice. Subsequently, there can be hesitation in diverging from the guidance that is provided. A reason for this is the perception of legal liability if a diverging design or operation results in harm. This has facilitated a climate where implementing innovative design is difficult to enact, regardless of the benefits that may result.

This raises important questions. Firstly, are there actual legal liability risks that go with the perception or are deviations from the guidelines acceptable if proper risk management processes have been followed, such as gathering a sound evidence base to show the safety of a design or mode of operation? Secondly, even if a real legal liability risk exists, should this usurp an ethical obligation to provide to road users the safest possible system? These questions are not easy to answer, but recent development in the industry suggest that the legal liability risk is not as real as it is perceived to be, and that engineers should be implementing the safest possible solutions while practicing sound risk management processes.

Slide 16

In this last section, we will take a look at ethical responses to the risk of harm.

Slide 17

As engineers, our ethical obligations extend to our ourselves, our co-workers, our organisation and the larger industry, and the public community. Our responses will vary from situation to situation but as a general guideline, we can ask ourselves:

Will my action create a new or greater risk of harm?

Am I allowing a risk of harm to continue, which could otherwise be mitigated?

And, am I obtaining the greatest foreseeable net benefit in harm reduction?

It is important to remember that it is not only actions that can result in ethical dilemma, but also inaction.

It is also important to remember that not all ethical situations are clear. For example, an action that provides greatest benefit to the larger population may disbenefit a specific community, or may come at the expense of creating a new risk that otherwise did not exist. The responses to such situations are not easy to navigate.

Slide 18

Of course, ethics is a complicated field and the responses that you as an engineer will need to make are dependent on the situation and stakeholders. Nonetheless, ethical considerations are arguably as or more important than the technical or legal considerations that we make. They can also be highly nuanced and can have substantial effects on ourselves and others. It is therefore important to be mindful of our ethical obligations and practice according to our ethical responsibilities.

If you would like further information regarding ethics in engineering, the Texas A and M University Civil Engineering ethics website provides useful information and case studies, much of which relates to historical, real-world cases of ethical questions and dilemmas. A link to the Texas A and M Civil Engineering ethics website can be found here.

Slide 19

(No transcript)

Appendix A2. Module 1, Snippet 2 transcript

Slide 1

Welcome to Module 1, Snippet 2 of Safe System for Universities. In this snippet, we will take a look into the mechanisms and outcomes of harm.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Let’s start by having a look at how harm occurs.

Slide 5

There are a number of ways harm can occur. Harm could occur from physical, chemical, biological, electrical or a number of other mechanisms. Physical harm is a common mechanism throughout industry, and so we will focus on this. Other types of harm can be industry or even job specific.

There are two general mechanisms that lead to harm, latent conditions and active failures. As we go through this snippet, we will explore the differences of each of these mechanisms, and the contributions that they make along the trajectory towards harm.

Slide 6

Harm occurs from failure within a system. In this context, a system could be a process, organisation or even an entire industry. Failure may not always lead to harm, but harm will not occur if a failure does not occur in the first place.

Failure occurs when latent conditions are present within a system. Latent conditions have been described as "resident pathogens within a system" (Reason 2000). They arise from decisions made by system managers and system users. They can be mistakes, but can also be deliberate.

Latent conditions can have two types of effect. The first are error provoking conditions, in which pressures and constraints placed on those operating within the system can lead to errors. Error provoking conditions can take the form of such things as time pressures, inexperience, inadequate equipment and hazardous operating conditions.

The second effect of latent conditions are system deficiencies. System deficiencies are longstanding weaknesses within the system's defences. These could take the form of such things as design deficiencies, structural weaknesses and ineffective procedures.

Slide 7

Error provoking conditions lead to errors being made by those operating within the system, whether they be formal system user such as pilots in the aviation industry, or informal system users such as the public driving on our roads.

Error provocation can be through pressures placed on system users and hazards placed in the way of system users.

A common example is found on our road transportation networks. Almost all car crashes include a component of human error. Errors occur because of pressures placed on road users, such as the need to keep within a lane or select gaps in traffic when traversing an intersection. When these errors occur in the presence of hazards, such as exposure to other moving traffic or unprotected obstacles, failure can occur with harmful outcomes.

Slide 8

A prime example of system deficiency is the 1981 Hyatt Regency walkway collapse, which resulted in the deaths of 114 people and over 200 additional injuries. The disaster occurred when structural failure of the supporting mechanisms used to hold the hotel lobby's elevated walkways resulted in the collapse of the walkways. The collapse was made so disastrous because it occurred during a function that saw both the walkways and lobby area below crowded with people.

The structural failure occurred for multiple reasons. The foremost reasons were inadequate design of the steel rods and box channels supporting the walkways and a change in the design of the steel rods, which connected the walkways to the building structure. This change in design doubled the load on the top of two walkways that were connected together through the supporting system. Ultimately, the effect of this design change was never realised until after the collapse occurred.

Slide 9

Next, let’s take a closer look at the mechanisms of failure.

Slide 10

The trajectory from latent conditions to system failures can occur very quickly, or may take many years to occur. In this sense, latent conditions create an environment of risk. The more latent conditions or the greater their magnitude, the greater the risk that failure will occur and harm can result.

When failure occurs, it is often because a number of latent conditions, both system deficiencies and error provoking conditions. While each latent condition may have existed for some time, it is only when each of these conditions align that the failure can occur. A prime example of multiple latent conditions leading to failure is the Tenerife airport disaster, in which two Boeing 747s collided on the runway of the airport.

On March 27, 1977, two Boeing 747s were using the main runway at Los Rodeos Airport on Tenerife Island, part of the Canary Islands. As a Pan Am 747 was taxiing down the runway for takeoff, a KLM 747 started its takeoff in the opposite direction. The disaster occurred in heavy fog and so neither aircraft’s crew nor the air traffic controller could see what was about to happen until it was too late. The 747s collided with one another midway along the runway, with 583 people being killed and 61 injured. This disaster occurred because of a number of latent conditions, including the foggy environment restricting visibility, the taxiway not being used for taxiing because of the unusually large number of aircraft crowding the airport’s apron, and miscommunication between the two aircraft’s crew and the air traffic controller.

Slide 11

The risk triangle presents an analogous model of the factors that lead to a risk of harm. These factors change in specifics from field to field, but generally cover the three same factors of risk: exposure, likelihood and consequence.

Exposure, the first factor, is the exposure to an event that could result in harm. For example, this could be exposure to an elevated position that has the potential to lead to a fall. Likelihood, the second factor, is the likelihood that, when exposed to an event, a failure will occur that could result in harm. The final factor, consequence, is the magnitude of harm that results from failure.

The risk triangle visualises the risk of harm presented by a combination of the three factors. While risk can be lowered by reducing any of these factors, the model highlights the benefit of reducing multiple factors to bring greater reductions in risk. The model also highlights that while all the factors are non-zero, a risk of harm, no matter how small, still exists.

Slide 12

Now let’s explore the potential outcomes from failure.

Slide 13

The outcome iceberg is used to highlight the potential consequences of failure. These consequences can range from the very serious, such as death or serious injury to people, to the less serious, such as property damage, to the consequences that may go unnoticed, such as an incident or error.

Above the water line of the outcome iceberg are the consequences that result in some sort of loss to those on the receiving end of a failure. At the very top are the outcomes that result in fatal or serious injuries to people. Such outcomes are rare, but have substantial effect on those involved. In the middle are the less serious injuries that more commonly occur. While these are unlikely to result in long-term suffering, they can nonetheless be traumatic for those involved. At the lowest end are failures that result in some form of property damage but no more serious forms of loss.

Below the water line of the outcome iceberg are the consequences that result in no loss to those involved. At the highest end are the near misses, in which a tangible consequence very nearly occurred but was avoided by some form of corrective action. For example, this could be a driver of a vehicle needing to take corrective action to avoid hitting another vehicle. Next are the incidents, where an unwanted event occurred. For example, this could be two aircraft flying within a dangerously close proximity of one-another. At the very lowest level of the outcome iceberg are the errors, the unwanted actions taken by people that do not result in any further event. For example, this could include a machine operator activating the wrong control, but with no adverse outcomes.

Slide 14

Understandably, the more serious a consequence is, the less acceptable it is within our society. For this reason, greater emphasis is generally placed on reducing or eliminating the number of serious outcomes to failure. In some industries, such as mining, actions are taken to isolate people from areas where they can be exposed to failures of any magnitude. In other industries, such as aviation, much effort is taken to reduce the likelihood of failure, as the consequences of failure as very often disastrous. In yet other industries, such with our road transportation network, emphasis is now placed on reducing the consequences of failures, as it is understood that eliminating all failures is unlikely to ever occur.

Within immature safety systems, consideration is often given to only the events that result in loss. This is evident within the road transportation industry, where there are processes to document all crashes and those resulting in more severe outcomes are sometimes investigated, but there are no mechanisms available to learn from the plethora of no-loss failures that occur every day.

A common trait of more mature safety systems is the consideration of no-loss failures. While these types of failures may not result in loss to anyone involved, they occur much more frequently and are often closely related to failures that do result in loss. When documented and investigated, the learnings from such no-loss failures can be used to prevent failures that do result in loss.

Slide 15

A good example of a mature safety system comes from the aviation industry. Prior to the 1970s, the aviation industry had a respectively poor safety culture, where incidents and errors went unreported by flight crews and any reactive measures in response to accidents were informal and lacked organisation. Financial losses from fewer passenger numbers and slow business recovery following accidents became a major motivation to improve safety within the industry.

In the last few decades, safety systems such as the Safety Management System, Safety Risk Management, Crew Resource Management and Threat and Error Management Training have been instigated to improve and formalise safety management within the aviation industry. Importantly, a culture of no-blame has developed to help improve the reporting of no loss events. This means that flight crews and other operators are not punished for errors that did not result from blatant misconduct.

Formalised reporting and investigation of no loss events has played a major role in the improved safety record of the aviation industry. For every aviation accident, there are approximately 500 near misses that precede it. Moreover, there has come a realisation that these accidents and near misses share common traits. Today, the aviation industry has transformed its safety culture to a point where all accidents and incidents, whether actual or theoretical, are investigated and the knowledge gained is fed into a loop of continual improvement.

Slide 16

(No transcript)

Appendix A3. Module 1, Snippet 3 transcript

Slide 1

Welcome to Module 1, Snippet 3 of Safe System for Universities. In Snippet 2, we discussed mechanisms of failure, including one type of latent condition that can lead to error, known as error provoking conditions. In this snippet, we will look closer at error and the role it plays within system failures.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let’s revisit errors and their effect.

Slide 5

Errors occur when latent conditions provoke erroneous decisions made by system managers and system users. The latent condition that leads to errors is known as an error provoking condition. Error provoking conditions can take many forms and may not always be obvious, as we may consider them a part of normal operating conditions. Two examples are the time pressures placed on engineers when completing a design, and the necessity for drivers to pick a gap in traffic in order to turn at an intersection.

Errors do not always lead to harm. Most errors will result in no-loss failures, which are failures that do not result in property or injury loss to those involved. These types of failures are referred to as near misses, incidents and no-incident failures. Some no loss failures such as near misses, are easily recognisable. Others, such as non-incident failures, can easily go unnoticed.

Some errors will lead to harmful failures, which are commonly referred to as accidents. Harmful failures lead to some form of loss to those involved, whether it be loss of property, injury or loss of life. As with no-loss failures, the errors that lead to these events may be intentional or unintentional.

Slide 6

Errors can be either latent or active.

Latent error refers to errors that cause latent conditions within a system. They are usually due to decisions made by system managers, such as planners, designers and operations managers. Examples could be inadequate design, inappropriate procedures, understaffing and hazardous operating conditions.

Active errors are those made directly before a failure occurs. Active errors are usually made by system users, such as front line workers and the public. Examples of active errors could be a pilot undertaking a hazardous manoeuvre, a machine operator activating the wrong control, or a pedestrian crossing the road when traffic is present.

Slide 7

Failure trajectory refers to the chain of conditions that lead to a failure. In this section, we will look at a well known model of failure trajectory.

Slide 8

James Reason's swiss cheese model a well known example of failure trajectory. In it, barriers to failure are represented as layers through which the failure trajectory must navigate.

Holes in these layers, which represent latent conditions and subsequent errors, must align in the right place and at the right time for a failure to occur. In other words, a window of opportunity forms through which the failure trajectory can traverse.

When the holes in the layers do not align, the failure cannot occur. Much like a person walking through a succession of doors to reach a destination, it only takes one locked door in order to prevent the person from reaching their destination. Like this analogy, it only takes one layer to form a barrier for failure to be prevented.

It is important to note that holes within one layer can circumvent the effects of other layers. For example, policy implemented by system decision makers may be weakened if it is not implemented properly by line management, or followed by system users.

Slide 9

Each layer represents a different level of activity where barriers are created and where failures can occur.

The first layer represents the objectives and strategic directions that decision makers will choose to follow. An example can be the directions made by an organisation within their strategic planning.

The second layer represents line management, which is responsible for implementing system functions. An example of line management can be the introduction new policies in the operation of a manufacturing plant.

The third layer represents the preconditions that exist within a system. Preconditions can be the use of appropriate and reliable equipment, the availability of appropriate design and operation conditions, and the undertaking of system use by skilled and compliant users. An example can be the type of controls used at intersections along a roadway.

The fourth layer represents productive activities, the actual performance of equipment and users who undertake tasks within a system. Examples of productive activities can be the performance of pilots flying an aircraft, of workers using construction machinery, or of a reactor core used in the production of electricity at a nuclear power plant.

The last layer to failure represents the defences that safeguard from failure. Examples of defences include the use of driver assistance technology in vehicles or the autopilot systems used in aircraft. Examples can also include failsafe and emergency shutdown mechanisms employed on equipment and machinery, and physical barriers used to separate workers from large vehicles at mine sites.

Slide 10

While the swiss cheese model as developed by Reason gives us a good understanding of the trajectory to failure, its focus is aligned only towards the likelihood of failure and not its consequences.

If we introduce consideration of the consequences of failure in addition to factors that affect likelihood, we can transform the model to that which represents a trajectory to harm.

Consequence, here represented by the size of the holes in each layer, dictates the magnitude of harm when failure occurs. Each layer has the ability to affect the magnitude of harm.

We can see that there are now two ways in which harm can be prevented. Each layer can form a barrier to prevent failure from occurring, by removing the latent conditions and subsequent errors from the failure trajectory. In this scenario, the barriers have worked to prevent failure from occurring in the first place.

But we also know that failure cannot be prevented 100% of the time. The second way harm can be prevented is by using each layer to reduce the magnitude of consequence. While latent conditions and their subsequent errors are allowed to occur, actions undertaken within each layer affect the magnitude of harm. Used appropriately, each layer has the opportunity to reduce the magnitude of harm to a point where the failure may occur, but harm is avoided.

Slide 11

Now, we will take a look at Kimber’s model, which helps highlight two very different ways of perceiving failure. It is important to note that this model was developed specifically as a way to represent failure in the road transportation industry.

Slide 12

Kimber's model is used to describe the relative contributions of different factors in the causation of road crashes. The model is shown as a Venn diagram of failure modes in which a single factor is deemed responsible, as represented by the non-overlapping areas of the circles, and of failure modes in which more that one factor is deemed responsible, as represented by the overlapping portions of the circles.

As shown here, the model represents three factors commonly associated with road crashes. These are the driver that is in control of a vehicle, the road environment on which a vehicle is being driven, which includes the speed limit along the road, and the vehicle that is being driven. This model as we see it here identifies the relationships between the different factors, but does not attribute the magnitude of contribution by each factor.

If we consider the relative contribution of each factor, we can see that driver error contributes to most crashes, while road and vehicle failures, such as reduced pavement friction or defective brakes, contribute to a lesser proportion of crashes. In this sense, the model is correct, but of what use? In short, its use is limited when an important omission within this model is considered. This model give no consideration to error provoking conditions, which ultimately lead road users to make the errors that contribute to most crashes.

Slide 13

A more appropriate model is that of Kimber's revised model, which draws a perspective on system failures, rather than isolating human error. In this form of the model, we can also appreciate the contributions of error provoking conditions. Seen through this perspective, we can now see that system failures, which stem from both system deficiencies and error provoking conditions, are responsible for the vast majority of crashes. Human error in isolation is responsible for only a small number of crashes, which generally involve either extreme non-compliance or inexperience.

We can now see that system failures, as shown here, represent the multitude of latent conditions and active errors that lead to a crash. The benefit of this perspective is to take focus away from just the contribution of error made by the driver. When we draw focus to the system perspective, we can see that driver error is just one link in a chain of actions that led to a crash. Take any of these links away, and the crash would not occur in the first place. This then begs the question, is driver error really to blame when it was weaknesses within the system that allowed error to translate to a crash?

While Kimber's model was created specifically to demonstrate the fallibility of focusing solely on human error in finding the causes for car crashes, it can be applied equally as well to many other industries. The point of the model is to demonstrate that the entire system, comprising latent conditions as well as active errors, contributes to failures. By looking at the entire system, instead of focusing on one small part of it, we are able to better understand the conditions that lead to failures and employ more diverse solutions for mitigating their damaging results.

Slide 14

On 6 July 1988, a drilling platform in the North Sea, about 190 kilometres north-east of Aberdeen in Scotland, was engulfed in a series of explosions that ultimately destroyed the platform and cost the lives of 167 people. This platform, named Piper Alpha, is a prime example of the intrinsic relationships that occur between human errors and system failures. As with many disasters, it is easy to pinpoint the failures on Piper Alpha to the mistakes made by the work crew operating the system. On the surface, these mistakes may appear to carry the bulk of responsibility for what occurred. But when we look a little deeper, the failures that occurred within the system, some lying unnoticed for many years, ensured that the mistakes that occurred on 6 July 1988 resulted in such a catastrophic outcome.

Slide 15

Using Reason's swiss cheese model, we will attempt to reconstruct the failure that occurred on Piper Alpha. While this will not be an exhaustive reconstruction, it will enable us to visualise, from a system's perspective, some of the latent conditions and errors that led to the disaster.

Piper Alpha was constructed in the early 1970s and began oil production in 1976. The platform was chosen to act as a central transfer point for production, with nearby drilling platforms transferring production to Piper Alpha before being piped to the mainland. This decision would play a critical role in the disaster.

For safety reasons, personnel areas were kept well away from the most hazardous areas of production. In 1980, the platform was converted to allow gas production in addition to oil. With this conversion, a number of hazardous operations were brought closer to crew areas, including locating the gas conservation module near the crew's accommodation quarters.

In the late 1980s, upgrade and reconstruction work to the platform had begun. Part of this work called for upgrade of a gas conservation module, or CGM. While the CGM was being upgraded, the decision was made to continue oil production and transfer of gas from the other drilling platforms, instead of ceasing production altogether.

Part of the upgrade works occurring at the time required divers to be in the water under the platform. Procedure called for the normally automatically controlled firefighting pumps to be placed in manual mode whenever divers were working. After the first explosion, system controls were destroyed to the extent where the firefighting equipment could not be manually started.

On 6 July, 1988, Pump A of two condensate pumps was scheduled for routine maintenance. These pumps were used for removing condensate from gas being transferred from the other platforms, before it was piped to the mainland. The pump's pressure safety valve was removed during this work. Because the maintenance could not be completed before shift change over, a temporary cover plate was used to seal the pump's open pipework. Because it was meant to be temporary, the plate was only hand-fastened.

When the shift change over occurred, the maintenance engineer filled in the appropriate paperwork notifying that Pump A was offline and not to be started. Because he could not speak to the oncoming shift controller, the engineer did not inform him of the situation. While the paperwork was completed, it was stored in a different location to the original maintenance work permit form and was never found by the oncoming crew.

At some point, Pump B, which had being taking the entire condensation load, failed and was not able to be restarted.

As the on-duty crew was not aware of Pump A's condition, it was started. The temporary cover plate failed to hold and gas started to escape from the pipe. The gas ignited and exploded.

The firewall designed to isolate the condensate pump was not designed to withstand such an explosion and so it failed, leaving the nearby control room to be destroyed and disabling several critical control systems.

Without the control room, the platform's chain of command soon collapsed and proper emergency procedures failed to be actioned. Upon learning of the explosion, the majority of the platform's crew escaped to the fireproof accommodation quarters.

The firefighting equipment was still in manual mode. The equipment's manual control systems were damaged during the initial explosion, ensuring the platform's own firefighting equipment would not start. Even if it had been started, Piper Alpha was transferring gas and oil from nearby platforms. Due to company pressure to maintain production, the crews of these platforms had not shut down production upon hearing of the emergency. Despite Piper Alpha's own production being stopped, gas was still flowing at a rate that made the fire virtually unstoppable.

Due the intensity of the fire and subsequent explosions, the platform's structure nearest to the initial explosion started to disintegrate. The accommodation quarters were one of the initial structures that collapsed and fell into the sea, resulting in the deaths of all who were sheltering inside.

Slide 16

While it is easy to point to the crew's communication mistakes for the disaster, Reason's swiss cheese model helps us to visualise the wider scope of holes that formed in each barrier along the trajectory to failure.

We must therefore ask ourselves, does it help to focus our attention on the errors made by the crew? Would it help to take a broader perspective of the events that led to the disaster? Hopefully, you can see how a system wide focus can help understand all of the events that led to failure.

In taking a system wide focus, we also enable ourselves to see the wider scope of responses that could have prevented such a disaster from occurring, or at least lessened the magnitude of the harm that it caused. This is the real power of viewing failure as a system wide problem, rather than a result of only user error.

Slide 17

(No transcript)

Appendix A4. Module 1, Snippet 4 transcript

Slide 1

Welcome to Module 1, Snippet 4 of Safe System for Universities. In this Snippet, we will take a look at the different ways in which risk is managed within industry

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

In this first section, we will take a look at the general considerations required when considering the suitability of risk management approaches.

Slide 5

The way we manage the risk of harm really depends on the system in which the harm can occur. While there are likely many factors that need to be considered, one important factor is the level of control that system managers possess over the system.

The amount of control that system managers possess is largely dependent on their control over people operating within the system. In highly controlled environments referred to as closed systems, like a mine site or a nuclear power facility, strict control is maintained over those working within the system. Access to potentially hazardous locations or tasks is strictly limited to need and the performance of users can be maintained at a very high level through training and procedure.

At the opposite end of the scale, low control environments referred to as open systems are those where public access is largely unlimited and access conditions are minimal. The road transport system is a prime example. While a driver’s license is required for using a motor vehicle, this provides a very low threshold of training. Other access conditions, such as for pedestrians, are uncontrolled. With such little control over access to the system, it is virtually impossible to ensure any level of performance of those operating within the system.

Slide 6

Another important factor is the consequence of harm, should it be allowed to occur. This not only refers to the severity of harm that may be experienced by an individual, but also the scale of harm that could occur. A good example is fire control in buildings. While building fires come with the potential for severe consequences any context, high occupancy buildings such as apartment towers are especially concerning given the number of people that may be effected by a single failure.

While consequence may be severe, the response to it will depend on how effective are the mitigation strategies able to be employed. In some contexts, mitigation may be a feasible approach and so a focus on reducing the consequence of failure is beneficial. Sometimes, the consequence of failure is likely to be so intolerable or the effects of mitigation strategies so ineffective that allowing any failure to occur is unacceptable. The nuclear power industry is a prime example of such a situation. Because of this, the main focus in this industry is eliminating the likelihood of any failures that involve the release of radioactive material, which is the prime danger presented by the industry.

Slide 7

Now, let's consider the case of a widely known approach to safety management, that utilised by the manufacturing and resources industries.

Slide 8

When we think of the word industry, the manufacturing and resources industry is front of mind for many people. This industry employs a substantial proportion of people in Australia and New Zealand, incorporates a wide variety of activities, and sees a substantial amount of exchange within the workforce. Because of this, importance is placed on employing controls that can be widely understood and applicable at a general industry level.

The hierarchy of controls is a well known system that has become the benchmark for managing safety within the manufacturing and resources industry. The hierarchy is generally applied at an activity level of operation, such as a process for undertaking a specific task or the operation of a specific type of equipment. It provides guidance for the appropriate order in which controls should be considered, giving priority to categories of control that provide the most effective means for mitigating harm.

A key enabler of the hierarchy of control is the environment in which it is applied. The method of categorising and prioritising controls is well suited to systems where control over access and use is well established. The high level of system control by system managers, and the high level of access control and task specific training given to system users means that controls in each category can be strictly applied with minimal non-conformance. While the hierarchy of controls can be applied to systems with much less control over access and use, its effectiveness would be limited by the low level of control that could be utilised before non-conformance becomes a substantial issue.

Slide 9

At the top of the hierarchy of controls is elimination. Wherever possible, priority should be given to eliminating the source of harm. This could mean eliminating a non-essential activity, removing people from a task that can be automated, or removing people from an area where a hazardous task is being undertaken. A good example is the elimination of mining personnel from areas where heavy mining machinery is being operated.

If the source of harm cannot be eliminated, then it should be substituted with something less harmful. This could mean substituting with a less harmful task, process or product. Substitution is commonly used as a method for reducing the harm associated with consumer products, such as paints, pesticides, cleaning products and building materials. Substitution works well when the hazard being mitigated is not replaced with another hazard, such as producing a less hazardous product for end consumers that requires a more hazardous production method for those making the product.

If the hazard cannot be eliminated or substituted to the extent where a hazard no longer exists, then engineering controls can be employed to protect people from the effects of the hazard. Engineering controls generally take the form of barriers to separate people from the hazard, lockout and shutdown controls to contain a hazard, and ventilation systems to extract toxic substances before they become inhaled. Engineering controls could also take the form of ergonomic treatments to prevent injury through repetitive actions.

Administrative controls should be employed only when the hazard cannot be removed or people protected from the hazard. Administrative controls are used to alter the way in which people work within a hazardous activity. This could mean changing work procedures, undertaking training, placing warning signs or changing the time or location of an activity to one less hazardous, such as rescheduling outdoor work to cooler times of the day during summer.

PPE, or personal protective equipment, is used as a last line of defence when all other controls are inadequate to protect a person from harm. PPE is generally used to shield a person from a hazard, such as with the use of respirators and chemical gloves, to reduce the risk of harm from a hazard, such as through the use of hard hats, or to reduce the likelihood of error, such as by wearing high visibility clothing.

Slide 10

Next, we'll take a look at safety management within the aviation industry.

Slide 11

The aviation approach to managing risk, especially for the larger airline industry, has evolved into a system with a focus on eliminating failures that result in intolerable outcomes, and reducing the consequences of failures that may result in less catastrophic levels of harm.

Part of the success of safety within the aviation industry has been down to a culture of shared responsibility. Safety responses within the aviation industry are at a system level. This means that when a problem is identified, the entire industry responds.

Another part of the success of this approach has been through the investigation of no harm failures to better understand and develop controls against failures that do result in harm. Learnings from these investigations are critical to understanding the mechanisms of failure and implementing controls to mitigate their effects.

Success has also been established on global communication within the industry that helps maintain a level of consistency in the approach throughout the industry. This has been facilitated by the fact that the airline industry works across international boarders.

Slide 12

The latest safety management mechanism employed in the aviation industry is the Safety Management System, or SMS. This system marks a shift towards a systems based approach to safety, and away from the human error based approaches that were previously practiced.

The Safety Management System is based on four pillars. Safety policy establishes senior management's commitment to safety. Safety risk management determines the need for and adequacy of risk controls, which safety assurance then evaluates the continued effectiveness of these controls. Finally, safety promotion creates a positive safety culture through training and communication.

SMS brings a systems approach to assess and control risks, while ensuring that controls remain adequate. Unlike previous generation safety systems such as Crew Resource Management, SMS is aimed all levels and areas of the aviation industry, rather than through a focus on front line employees alone.

Slide 13

Lastly, let's look at a new way safety management is being approached in the road transport industry.

Slide 14

With regard to the management of safety, the road transportation industry is defined by its low level of access control. While licencing provides some measure of control for those using motor vehicles, all other access is largely uncontrolled. This makes any form of control over individual use of the system almost impossible. While previous efforts to curtail substantial non-compliance through education, training and enforcement have provided success, there is a growing understanding that any chance to eliminate severe harm will require an additional focus on consequence.

This focus on consequence has come from the understanding that, with such low levels of access control, system users will continue to make errors at a rate that means severe harm is a foreseeable and all too common event. In light of this, the approach to safety has been shifted to a systems based approach that prioritised the reduction of failure consequence.

This approach is the Safe System, which is based on the philosophy that people will continue to make errors, but that the road system should not allow these errors to translate to severe harm. Contrary to historical approaches that have focussed almost exclusively on reducing user error, the Safe System places the onus of eliminating severe harm on system managers.

Slide 15

The Safe System is based on the fundamental understanding that system users will make mistakes. The philosophy behind the Safe System is that severe harm should not result as a consequence of these mistakes. To align with this philosophy, a systems based approach is used to focus on eliminating severe consequences while also reducing exposure and the likelihood of crashes.

The Safe System is often represented as four pillars, which refer to the need for safe roads and roadsides that are forgiving of error, safe road users that comply with system rules, safe vehicles that cushion crash forces, and safe speeds that ensure crash forces are not allowed to exceed the human body's physical limits before severe harm occurs.

While the Safe System calls for a shared responsibility between system managers and system users, the onus is placed with system managers to ensure that severe harm does not occur. This means that when severe harm does occur within the system, it is the responsibility of system managers to take corrective action and control the level of harm that can possibly occur.

Slide 16

(No transcript)

Appendix A5. Module 1, Snippet 5 transcript

Slide 1

Welcome to Module 1, Snippet 5 of Safe System for Universities. In this snippet, we will take a look at the evolution of safety culture through its different steps, and the process of transforming into a culture that prioritises safety.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let's take a look at the different levels of a culture's response to harm.

Slide 5

A well-regarded model of safety culture is Patrick Hudson's cultural ladder. Hudson's model describes the levels of safety culture that can be obtained as a series of steps along a ladder, with each step up the ladder representing a step-change in attitude towards safety.

A number of major industries, such as aviation, oil and gas, mining and the nuclear power industry can now claim to possess high levels of maturity within their safety cultures. However, these industries started and often remained for long periods with immature safety cultures, only progressing because of outside intervention and a realisation of the financial implications of poor safety outcomes.

Today, a number of these industries are looked to as examples of exemplary safety culture. However, while some parts of an industry, or certain organisations or locations within the industry may be able to claim high levels of achievement, others may be lagging. A good example is the mining industry. While top organisations such as the International Council on Mining and Metals member organisations record relatively low fatality numbers, other organisations and jurisdictions contribute hundreds or even thousands of fatalities each year.

Slide 6

The first step on Hudson's ladder, the pathological response, is the least effective but most commonly attained level of response. Characterised by an attitude of "no issue, provided we don't get caught", pathological responses treat risk of harm as something to ignore or hide, rather than something to act upon. Pathological responses were a common trait among early industry. As an example of behaviour commonplace in a pathological culture, one famous photograph shown here clearly depicts workers atop the Rockefeller Plaza in New York City, during its construction, with no safety provisions to prevent harm as a result of a fall.

Pathological responses were commonplace in the early aviation industry and even up until the 1970s. A common trait was a lack of reporting on incidents. It was commonplace for flight crews to stay silent about incidents for fear of reprisal. This approach was markedly different to today's aviation culture, in which reporting is mandatory and seen as a benefit to the entire industry, rather than an exercise in attributing blame.

Pathological responses have been, until quite recently, largely commonplace in the road transportation industry. While much effort is being made to improve the safety culture in this industry, a substantial amount of the response to road crashes stops at the point of determining whether those involved should be prosecuted. This has driven a culture where a common response to road trauma is the determination that drivers need to be better behaved, with any mitigation efforts being limited to improving enforcement of the road rules.

Slide 7

The next step up the ladder of safety culture is a reactive response. The reactive approach to safety is characterised by reactive efforts to curtail the reoccurrence of individual accidents. These efforts then tend to fall away once the initial excitement of the accident has subsided and normal operation resumes. While reactive efforts can result in the formation of mitigation strategies, these are often limited in effectiveness as they directly target the specific accident that has occurred and not the wider risks that led to the accident in the first place.

A reactive culture is often a first response to safety. Hampered by a lack of incident reporting and an overall lack of knowledge and organisation, early efforts within the aviation industry placed onus on investigating accidents to prevent reoccurrence. The benefits of such an approach were limited as reactive efforts failed to take into account the large variability and complexity of mechanisms that led to such accidents.

While safety culture within the road transport industry has to some extent progressed beyond a pathological response, it is still largely limited to being a reactive culture. Reactive efforts are targeted towards so called low-hanging fruit, such as the easily identified issues of drink driving and the wearing of seatbelts. More specific efforts are placed at so called blackspot locations on the road network, which have a history of abnormally high numbers of severe injury crashes.

Slide 8

Driven by a top-down approach where safety is imposed upon rather than being owned by those affected by accidents, a calculative response to safety places much emphasis on management systems and processes to manage hazards and risks. A calculative culture often places focus on the collection of data to identify trends. While subsequent safety performance is arguably better than with more immature responses, the calculative approach runs the risk of "normalising" harm as responses are only seen as needing improvement when crises and abnormally high levels of harm develop.

Post the 1988 Piper Alpha disaster and subsequent accidents, the oil and gas industry started to transform its safety culture with the realisation that safety performance was a reliable indicator of economic performance. However, the image of the macho oilman remained engrained in the workforce, and so safety performance was largely process driven and pushed by upper management at the behest of financial motivation.

Slide 9

A key sign of a mature safety culture is the proactive response to hazards and risk. Proactive cultures place a large emphasis on driven continual improvement of identifying and treating hazards and risks that does not depend on the occurrence of accidents in the first place. Safety is also often driven from system users, rather than just managers that oversee the system but are at little risk to personal loss in the event of harm.

The advent of safety system doctrines in the 1990s, predicated on increasing accident rates, has seen the aviation industry transform to one based on proactive responses. Crew Resource Management was an earlier approach to managing safety that was introduced in the 1970s and focussed on minimising errors within the cockpit environment, The latest approach, the Safety Management System, is focused at a system level and includes the concepts of Safety Risk Management, Safety Assurance and Safety Promotion.

Within the road transport industry, the latest approach to safety, known as the Safe System philosophy, has brought the safety culture towards a proactive response. Safe System shifts responsibility and accountability for harm on the road network to that of system managers and places on them an ethical imperative that fatalities and serious injuries should not occur. A result of this has been a shift to the practice of identifying risks before crashes occur, rather than treating accident prone locations on a site by site basis.

Slide 10

In Hudson's model, a generative safety culture represents the highest level of response. A generative response sees safety becoming an integral part of business at all levels of an organisation or industry. At this level, safety is no longer an added part of work, but is core to the foundation upon which work is undertaken. Key to such a culture is the understanding that safety will likely never be perfected, and so we must not become complacent about the level of safety that has already been achieved. In other words, it encompasses continual improvement.

The nuclear power industry represents an industry that encompasses to a high degree the fundamental aspects of a generative safety culture. This culture has stemmed from the wake of disasters such as Chernobyl, Three Mile Island and more recently, Fukushima. Some standout features of the industry's safety culture include a strong, independent regulatory authority; deeply inbuilt safety systems and international standards; and frequent, peer moderated review.

Aspects of the aviation industry also show a generative response to safety. All accidents and incidents are investigated to understand failure mechanisms and provide measures for mitigating future failures. This level of response is undertaken for predicted failures in addition to actual failures, meaning that failure mechanisms and potential mitigation strategies can be investigated before the failure occurs in real life operation.

Slide 11

Now that we've discussed the different levels that safety culture can obtain, let's take a look at some of the ways in which different industries have transformed their safety cultures.

Slide 12

History shows that we have tended to default to a pathological mindset. Progressing to improved safety cultures has taken disciplined and continuous effort. It is worth remembering this point as it can be all too easy to expect change to occur without the need to continuously keep it moving, just like pushing a ball down a hill. In reality, change is more like pushing a ball up a hill. Without constant effort, it is easy to roll back down to where we started.

As an example, the mining, construction and oil and gas industries have long been seen as inherently dangerous. The culture within these industries was dominated by the attitude that death and injury was part of normal operation. Safety was considered a "dirty word" and a willingness to confront occupational dangers without question was looked upon favourably. Those unwilling to tolerate such conditions were often seen as unfit to work in the industry. The transformation of safety culture within these industries has often taken the occurrence of disasters to spark change, and then social outcry and regulatory intervention to maintain momentum.

The example of women in the workplace provides another, albeit unconventional, perspective on the transformation of safety cultures. Only a couple of generations ago, it was commonplace for women to be excluded from labour intensive occupations under the ethical pretence that they were too dangerous or too physically demanding. Flipping this argument on its head, we can ask whether it is then ethically acceptable to operate workplaces in such a way that we feel the need to exclude certain people, because of our unwillingness to place them in situations of danger. The transformation to more inclusive workplaces and greater safety outcomes have both required concerted efforts to change cultural mindsets to a point where onus is placed on improving the system, rather that excluding those who we feel cannot fit the system.

Slide 13

Progression towards a more mature safety culture often follows the occurrence of substantial accidents and disasters that put safety issues into the public consciousness. As an example, the Piper Alpha drilling platform disaster was not the sole instigator of change within the oil and gas industry, but it did play a key role in building the momentum of change that ultimately saw transformation occurring. Unfortunately, such disasters can be needed to instigate widespread change of perceptions and spark an outcry for improvement.

Motivations for change within industry itself are often based on self interest. These motivations can be financially based, such as coming from the financial burden of real or artificial costs of failure. They can also be based on interventional motivations, such as from the power of regulatory authority. Perception can also be a substantial motivation for change, such as the wish to avoid negative public and regulatory perception similar to that that stemmed from the 2016 Dreamworld Thunder River Rapids ride on the Gold Coast in Queensland.

Lasting, transformative change requires commitment from the top-down. In other words, safety must become an integral value for high-level management, which must then drive system-wide transformation. While system users and front-line workers are also important drivers of change, they are alone rarely successful in instigating change as they lack access to direct mechanisms for change that are available to the system's gate-keepers.

Slide 14

In addition to his cultural ladder, Patrick Hudson also describes four dimensions to which advanced safety cultures are reducible.

To start, the culture is informed at all levels. This means that information about what is going on within a system and what has and can go wrong is actively pursued.

Being informed allows trust to be exhibited by all. Trust is built through a culture of openness and fairness. Failures and gaps within safety are freely shared, accepted and acted upon without becoming a justification for punishment.

An informed and trusting culture is then adaptable to change. The system is flexible and lessons learned from both good and poor outcomes are fed into a continuous cycle of improvement.

A mature culture also worries. It does not become complacent to and accepting of current standards of safety. Continuous improvement is pursued under the knowledge that safety will likely never be perfected.

With all four elements in place, we can close the loop and create momentum for a culture of leading safety practice. We will discuss more about leading practice and these elements in the final snippet of this module.

Slide 15

(No transcript)

Appendix A6. Module 1, Snippet 6 transcript

Slide 1

Welcome to Module 1, Snippet 6 of Safe System for Universities. In this final snippet for Module 1, we will take a look at what it means to be at the forefront of leading practice in safety. In doing so, we will draw upon the concept of a leading safety culture.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Leading practice, also known as best practice, is a continuously evolving way of doing things that provides the best possible outcomes, given our current level of understanding. In this first section, we will look at what a leading practice culture may look like.

Slide 5

Leading practice means doing things in the best possible way, given the state of knowledge that currently exists. For leading practice to translate into leading performance, a strong culture that is well aligned to doing things in the best possible way is essential. It requires those managing and using a system to be informed, trusting and trustworthy, so that appropriate decisions can be made and actions can be taken, especially when risks are identified.

As its description also suggests, leading practice requires continuous development to keep pace as the state of knowledge grows. This then forms a continuous feedback loop, as new knowledge feeds new ways of doing things and this in turn leads to new knowledge. In a leading practice culture, it is important that change be adopted as normal practice.

Leading safety practice is embodied by a generative safety culture. In Snippet 2, we discussed the evolution of safety culture by using Hudson's culture ladder model. At the very top of this ladder sits a generative safety culture, in which safety becomes embedded into all facets of operation, from senior management of a system to those working within the system. Generative safety means additional effort does not need to be made to make everyday operations safe, because safe practice translating into safe performance has become a core part of everyday operations.

Slide 6

Embodied as a generative safety culture, leading practice in safety features four critical components that not only allow safety to be put into practiced, but allow it to translate to tangible safe performance outcomes.

Firstly, an informed culture is one where system managers and system users are all kept on the same page as to where safety stands.

Secondly, a trusting culture is one where system users and system managers trust each other to put safety rhetoric into practice.

Thirdly, an adaptable culture is one that is able to respond to safety risks as they are identified, and to new practice as the knowledge base evolves.

Finally, an improving culture is one that readily acknowledges that safety will never be perfected and so seeks new knowledge and puts this new knowledge into practice.

In the remainder of this snippet, we will take the core messages that we have learned and apply them to the framework of leading practice to see what a leading practice culture can look like.

Slide 7

Being informed is the first step to a culture of leading practice. Now, we will take a look at what it means to be informed.

Slide 8

Information is a key asset of a mature safety culture. An effective safety culture is an informed culture. The first part of this equation is the pursuit of information. This means not only accepting information as it comes, but actively seeking information to improve knowledge about the safety performance and identify safety problems before they translate to harmful outcomes. The second part of this equation is to openly inform all system stakeholders of safety performance, safety policies and safety problems. Both system managers and system users should have easy access to knowledge and be encouraged to seek such knowledge. Even when the news is bad, in a mature safety culture it can be digested as information, to be used to inform action, rather than to seek punishment.

Importantly, information needs to be acted upon. For a culture to embrace safety, system managers must demonstrate a willingness to both listen to the information and respond to the problems that have been identified. For example, greater maturity is being shown in the road transport industry with proactive safety improvements to the road network and improved consistency of enforcing unacceptable behaviours, rather than resorting to blame and punishment every time a crash occurs.

In-depth investigations are a key example of seeking and providing information and are, in various forms, pursued in a number of industries. Some, like those used in road transportation and construction, are reserved for accidents, while others extend to incidents. A core differentiation between in-depth investigations and other investigations, such as those undertaken by enforcement agencies, is a focus on informing public forum and ultimately, to drive remedial action. Some, such as those undertaken within the commercial aviation industry, extend to theoretical risks, as well as those having already resulted in failure.

Slide 9

Trust is a crucial element of leading practice. Without it, progress is stifled. Next, we will discuss how to obtain a culture of trust.

Slide 10

A strong safety culture is a trusting culture and for this, it should be based on an ethical foundation. This means the overarching reasons for the practices put into place are based on ethical imperatives that clearly outline the intended outcomes. Engineers Australia's code of ethics provides a strong example of an ethical foundation, with the overarching message that their members will create solutions for a sustainable future and serve the community ahead of other personal or sectional interests.

While a strong ethical foundation will outline intended outcomes, it does not tell us how these outcomes will be achieved. A strong safety culture needs more than just rhetoric. An ethical foundation must be backed by visible and tangible actions that clearly demonstrate a willingness to follow through and achieve the intended outcomes, such as through hazard reporting and safety briefings with timely and meaningful outcomes. A trusting culture also requires that even when these intended outcomes are not achieved, both managers and users can tell and be told bad news, which can be taken as information to drive action, not justification for punishment.

There are no surprises in a trusting culture. Firm lines are drawn between what is appropriate and what is inappropriate practice. This includes the practices of both system managers and system users. There are clear lines drawn between what is acceptable and what is not acceptable. These lines apply to both managers and users. When lines are crossed, there are agreed consequences and these are followed through. The mining industry provides a good example, where major safety breaches such as on the job intoxication and speeding on site roads, and the consequences of such breaches, are well understood and consistently applied.

Slide 11

The Tylösand declaration, drafted in 2007 by leading Swedish road safety policy makers, sets out an ethics-based vision in-line with harm elimination policies in road safety, which are often known as the Safe System, Vision Zero and other similar names around the globe. This declaration provides a strong example of an ethically-based safety culture. It states that "everyone has the right to use roads and streets without threats to life or health" and, furthermore, without unintentionally imposing such threats on others.

The Tylösand declaration sets down more than just ethical rhetoric, as it also outlines the principles by which system managers should be held responsible. It is the public's right to be informed about safety problems and the level of safety of any part of the road transport system, including the policies and actions used to operate and evolve the system. An obligation to undertake corrective action following the detection of any safety hazard is also stated, further highlighting the responsibility of system managers to lead safety.

Finally, the declaration outlines the outcomes that can be expected. It clearly tells both system managers and system users that road use should not result in threat to life or health, and that the public should be able to expect systematic and continuous improvement of safety.

Slide 12

Any leading practice culture needs to be adaptable. Adaptability is what enables a culture to remain at the leading edge in a changing world. Now, we will look at some of the elements that make a culture adaptable.

Slide 13

A core tenet of safety is that it will never be perfected. A mature safety culture must therefore be an adaptable culture. Change can be driven from different directions, both inside and outside the control of those managing the system. Change may be driven from legislation or through regulatory powers. Change can also be driven by stakeholder and public response. Change is not always driven by safety developments. Change can be driven by financial interests or market pressures. Even when change threatens to weaken safety, a mature safety culture can navigate such change without adverse outcomes.

Key to achieving this is an expectation of change. When change is expected, policies and procedures can be at the ready and when needed, put into practice to help guide this change. Moreover, expecting change means that the culture is more likely to react with logical and agreeable actions based on informed knowledge and experience, rather than emotional, poorly judged actions that lead to divisiveness.

Adaptability also comes from learning what works and what doesn’t work. This knowledge can then be applied to situations of change, both to control outcomes when reacting to change and to improve outcomes when risks are identified. Knowing what works and what doesn’t work comes from being informed about the system, the hazards that threaten safety and the treatments that can be employed when things do go wrong.

Slide 14

Improvement is the final element in the cycle of leading practice. Improvement allows practice to remain leading. Now, we will discuss how improvement can be embodied in a culture of leading practice.

Slide 15

A mature safety culture is a culture that worries. It knows that safety will not be perfected and so it worries about what may go wrong, no matter how good its performance has become. In practice, this means that complacent and risk aversive responses are acknowledged as counter-productive. Practices are put into place that ensure that, even when things seem to be going right, improvement is still sought.

Core to an improving culture is the idea of continuous improvement. Information and the seeking and reporting of it, trust within the culture, and adaptability to change all feed into a continuous cycle of improvement in the way things are done. When problems are identified, stakeholders are informed, responses are agreed upon and solutions are sought, which are then put into practice and become part of normal operation. Failure must be recognised as a normal part of the cycle. The trick to appropriately handling failure lies in managing risk so that failure does not result in harm.

Innovation is a key part of continuous improvement. Innovation engenders the idea that leading practice is continually evolving. Seeking innovation means acknowledging that the status quo does not always provide the best or even all of the answers. Risk aversion tactics are countered by managing the risk of innovative practices. Moreover, standards are treated as safety nets that define minimum acceptable performance, and improvements are sought that build upon current knowledge and that, in time, become normal operation and the new standards to which accountability is held.

Slide 16

(No transcript)

Appendix B. Module 2 transcript

The following transcripts are from snippets 1 to 6 of Module 2.

Appendix B1. Module 2, Snippet 1 transcript

Slide 1

Welcome to Module 2, Snippet 1 of Safe System for Universities. In this snippet, we will discuss some of the reasons why harm from road crashes occurs, and some common mistakes that are made when attributing reason to the causes of harm.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let's take a look at the mechanisms that can cause harm to road users.

Slide 5

There are a number of ways harm can occur. Harm could occur from physical, chemical, biological, electrical or a number of other mechanisms. Physical harm is a common mechanism within the road transport industry, and so we will focus on this.

There are two general mechanisms that lead to harm, latent conditions and active failures. Active failures are the errors and mistakes made just prior to a crash. These failures are generally made by road users. Some examples of active failures are a pedestrian choosing to cross the road when a vehicle is approaching; a driver taking a curve along a road at too high a speed; and a driver picking an inadequate gap in traffic when turning at an intersection.

Latent conditions are the other mechanism of harm. Latent conditions can occur at any time and may lay dormant in the system for many years before the circumstances are ripe for failure. Latent conditions can be from recognisable errors, such as building a road below the recognised design standards. Latent conditions can also be hidden in plain sight. A good example are intersections. Many intersections contain the latent conditions that can foreseeably turn a simple mistake made by a road user into a harmful crash. Some intersection designs, such as many roundabouts, remove or reduce these latent conditions by controlling the speeds and angles at which vehicles can interact.

Slide 6

The kinetic energy management model, or Kemm, was developed to demonstrate the way in which road users can be exposed to kinetic energy, which is the cause of physical harm. At the centre of the kinetic energy management model is the human body, which is vulnerable to physical harm.

Radiating out from the central human body are the five layers of energy transfer that can allow a person to be harmed, or if considered appropriately, stop the harm from occurring. The first three layers deal with the consequences of a crash through the generation and transfer of kinetic energy that results from a crash. The fourth layer deals with the likelihood of a crash should road users be exposed to the conditions that could lead to a crash. The fifth and final layer deals with the exposure of road users to situations where crashes can occur.

Every layer within the model represents an ability to protect road users from harm. Traditionally, we have been very good at dealing with the fourth layer, the likelihood of a crash, to offset effects of exposure. In other words, we have managed to reduce the frequency at which crashes occur, even with an ever increasing demand to use the road system. However, we know that crashes will not be completely eliminated. Even with the very small likelihood of being involved in a crash that each person faces, the sheer number of people using the road system ensures that some crashes will occur.

So how can we protect those road users who ultimately end up being involved in a crash? This is where the first three layers of the kinetic energy management model come into play. Historically, we have been rather poor at dealing with the consequences of crashes. However, the model helps to demonstrates the substantial contribution that consequence can play in deciding the harm that road users are exposed to. It also demonstrates the methods that can be used to protect road users from severe consequences, such as through reducing the energy generated in a crash or reducing the transfer of energy to the road users.

Slide 7

We first visited Reason's swiss cheese model of failure trajectory in Module 1, Snippet 3 of the Safe System for universities. Now, we will look at this model in the context of our road transportation system.

Slide 8

James Reason's swiss cheese model a well known example of failure trajectory. In it, barriers to failure are represented as layers through which the failure trajectory must navigate.

Holes in these layers, which represent latent conditions and subsequent errors, must align in the right place and at the right time for a failure to occur. In other words, a window of opportunity forms through which the failure trajectory can traverse.

When the holes in the layers do not align, the failure cannot occur. Much like a person walking through a succession of doors to reach a destination, it only takes one locked door in order to prevent the person from reaching their destination. Like this analogy, it only takes one layer to form a barrier for failure to be prevented. It is important to note that holes within one layer can circumvent the effects of other layers. For example, policy implemented by system decision makers may be weakened if it is not implemented properly by line management, or followed by system users.

Slide 9

As a society, we have become very good at focussing on the role of road users in crashes and the failures that they have made, which contributed to the outcomes. While road users certainly contribute to the occurrence of crashes, such a focus draws attention away from the factors that contribute to crashes and the more manageable aspects of the road transport system that we, as system managers, can influence to reduce the harm that occurs on our roads.

The highest level of intervention that senior system managers can make is commonly through the strategic decisions and policies. Through these strategies and policies, senior system managers can guide the way in which the system is managed and target directions that have a greater focus on reducing and ultimately eliminating harm from our road network. A commonly seen example are the road safety strategies used nationally and by each state to outline their strategic direction in reducing harm from road crashes.

Line managers can also play a role in the reduction and elimination of harm. This can be done by actively considering the potential for harm that is generated through day to day activities. A good example is the proactive consideration of the risk of harm. Proactive risk tools, such as road assessment programs, can be used by line managers to identify where higher levels of risk exist on the road network and use this information to justify the need for funding and prioritise works that have a greater ability to improve road safety.

The preconditions of failure can be influenced by system managers by implementing design and operation of the road network that reduces the risk of harm. For example, this could mean selecting speed limits and managing speeds that are appropriate for the type of road environment. System users can also affect the preconditions, such as by choosing to drive a safer model of vehicle, such as an Ancap five star rated vehicle. Here too, system managers can have an influence by imposing and motivating the use of safer vehicles, such as through the release of safety rating information to influence buyers and fleet purchasing policies that ensure only the safest vehicles will be purchased for fleet use.

Lastly, system managers can affect the defences that safeguard from harm. For example, this could be through ensuring that forgiving roadside and centreline barriers are installed along roads where high speed run off road and head on crashes can occur. System users can also contribute by using vehicles with advanced safety technologies that can help prevent crashes or cushion themselves and others in the event of a crash.

Slide 10

Kimber’s model aims to highlight the different factors that contribute to crashes. We will now take a look at the relative contribution of crash mechanisms through the lens of this model.

Slide 11

Kimber’s model is used to describe the contributions of different factors in the causation of road crashes. The model is shown as a Venn diagram of failure modes in which a single factor is deemed responsible, as represented by the non-overlapping areas of the circles, and of failure modes in which more than one factor is deemed responsible, as represented by the overlapping portions of the circles.

As shown here, the model represents three factors commonly associated with road crashes. These are the driver that is in control of a vehicle, the road environment on which a vehicle is being driven, which includes the speed limit along the road, and the vehicle that is being driven. This model as we see it here identifies the relationships between the different factors, but does not attribute the magnitude of contribution by each factor.

Slide 12

If we consider the relative contribution of each factor, we can see that driver error contributes to most crashes, while road and vehicle failures, such as reduced pavement friction or defective brakes, contribute to a lesser proportion of crashes. In this sense, the model is correct, but of what use? In short, its use is limited when an important omission within this model is considered. This model give no consideration to the latent conditions that ultimately lead road users to make the errors that contribute to most crashes.

Slide 13

A more appropriate model is that of Kimber's revised model, which draws a perspective on system failures, rather than isolating human error. In this form of the model, we can also appreciate the contributions of error provoking conditions. Seen through this perspective, we can now see that system failures, which stem from both system deficiencies and error provoking conditions, are responsible for the vast majority of crashes. Human error in isolation is responsible for only a small number of crashes, which generally involve either extreme non-compliance or inexperience.

We can now see that system failures, as shown here, represent the multitude of latent conditions and active errors that lead to a crash. The benefit of this perspective is to take focus away from just the contribution of error made by the driver. When we draw focus to the system perspective, we can see that driver error is just one link in a chain of actions that led to a crash. Take any of these links away, and the crash would not occur in the first place. This then begs the question, is driver error really to blame when it was weaknesses within the system that allowed error to translate to a crash?

While Kimber's model was created specifically to demonstrate the fallibility of focusing solely on human error in finding the causes for car crashes, it can be applied equally as well to many other industries. The point of the model is to demonstrate that the entire system, comprising latent conditions as well as active errors, contributes to failures. By looking at the entire system, instead of focusing on one small part of it, we are able to better understand the conditions that lead to failures and employ more diverse solutions for mitigating their damaging results.

Slide 14

(No transcript)

Appendix B2. Module 2, Snippet 2 transcript

Slide 1

Welcome to Module 2, Snippet 2 of Safe System for Universities. In this snippet, we will look into the ethical imperative that drives the change towards a road transportation system free from harm.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

An ethical imperative is a directive driven by ethical considerations. The ethical imperative that drives road safety is the directive driven by the ethical consideration of eliminating harm. Firstly, let us look further into the ethical imperative upon which the Safe System is founded.

Slide 5

The ethical imperative on which the Safe System is founded is predicated on questioning whether it is acceptable for a few people to pay a high price in order for the rest to have access to the road network. The high prices some people pay are the fatalities and serious injuries that they receive. The benefit that the many receive is a road network with relatively few controls on access and few limitations to mobility. The Safe System raises the question about whether this is acceptable, or whether the cost of mobility should be shifted from the few to the many who receive its benefit. This is not to say that a safe road system will necessarily mean less mobility, but it does mean a shift in the way we perceive mobility and people's right to it.

In this sense, the argument for the Safe System has been perceived as an argument of mobility versus safety. Since we are economically unable to invest into the road network to a point where all roads are made safe for all road users at the current levels of access and speed to which we are accustomed, a higher level of safety will invariably come at some cost to mobility. In other words, should a few pay a high price for the increased mobility of all road users, or should all road users pay a relatively low price for the safety of a few who would have otherwise been harmed? In this argument, we must also consider that the identities of the few who pay such a high price are unknown before they pay, and that these few could potentially be anyone who accesses the road system. They are the unlucky recipients of a lottery draw where the prize is a cost of suffering.

Slide 6

Within the Safe System is proposed a different solution to this question. This is the concept of safe mobility. Safe mobility means that road users are granted access to a system in which its use will invariably not result in harm to those who use it.

Safe mobility means that mobility becomes a function of safety. Our desired level of safety, which in the Safe System means no death or serious injury, is not compromised for the sake of greater movement efficiency. We accept the level of mobility that can be afforded while maintaining a safe road system. A common sticking point to achieving such an outcome is that we currently do not subscribe to such a notion. This means that, in order to achieve safe mobility, we will need to make substantial changes to the way we design, operate and allow access to our road system. As we will see through this series of modules, the goal of safe mobility is more attainable than most people appreciate, and the cost to movement efficiency does not need to be as high as most people expect it to be. However, to achieve safe mobility, we will need to let go of the notion that any cost to movement efficiency is unacceptable and that mobility must always be maintained in the way we currently benefit.

Slide 7

Ethical policies provide the institutional roadway upon which the ethical imperatives of the Safe System are driven. Next, we will look at some of these policies and how they deal with relating the philosophical to the tangible.

Slide 8

Vision Zero is Sweden's spin on the Safe System. Since its adoption into the Swedish Parliament in 1997, Vision Zero has been Sweden's pathway towards a road system free of fatalities and serious injuries. The ethical tug of war between mobility and safety is well summarised in the Vision Zero video released by Business Sweden – safety at every turn. To play this video, press the YouTube play icon in the middle of the screen.

Slide 9

Sweden was one of the first countries in the world to take an ethical standpoint with regards to their road transportation system. Vision Zero poses the question – why would it be ethically acceptable to trade harm in return for objective gains? An engineer's duty is to serve the community in which he or she practices. Even from the perspective of an engineer, it is not acceptable for us to knowingly trade harm in return for gain. But this is what we do with our road system. By building roads that we reasonably know will lead to harm, as it has continued to for past decades, we are complicit in continuing this systemic problem. Vision Zero places the emphasis on those who build and manage roads to create a step-change in the way we operate the road transport system. It places the onus of duty on the builders and managers to ensure that we eliminate the opportunity for harm, wherever harm can be reasonably expected.

Slide 10

Like Vision Zero, the Tylösand Declaration highlights the ethical responsibility of those who build and manage the road system to take the lead in eliminating harm. The declaration outlines the rights of every citizen to be able to use the road system without the risk of threat to their own health, and without the risk of unintentionally causing harm to others. It also calls for harm elimination to be sustainable, and the process of transitioning and arriving at zero harm to be transparent. In essence, every person has the right to expect continuous improvements in safety along a trajectory to zero harm.

Slide 11

Safer Journeys is New Zealand's strategy for implementing the Safe System across the New Zealand road network. The difference between life and death is a twenty minute film that highlights New Zealand's ethical reasoning and directions moving towards implementing the Safe System. To play this video, press the YouTube play icon in the middle of the screen.

Slide 12

A road transportation system free from harm is the ultimate long-term goal, but other more targeted imperatives can be achieved now Next, we will look at a couple of these targeted imperatives and how they are being attained.

Slide 13

Achieving zero harm will take time. It is not realistic to expect that we can achieve zero harm in the immediate future. We have inherited a fundamentally unsafe road transportation system and achieving zero harm will require systematic change across the entire road system, throughout all levels of design, operation and management. However, we need to start the journey and there are areas within the system where we can practically achieve zero within a short period of time. We need to score some early wins to showcase the vision of a Safe System.

School children represent one of these areas. In Australia, we are coming close to achieving widespread zero harm in school zones and there are some locations where this has been achieved. In developing countries, school children represent a large proportion of those hurt by the road transport system – but achieving safe journeys to school also represents a practical target that we can achieve.

Two programs that are prioritising the elimination of harm to children are the FIA Foundation's Safe to Learn program and the International Road Assessment Program's Star Rating for Schools. Both of these programs aim to achieve safe travel for children travelling to school, with a specific focus on the safety of children in developing countries.

Slide 14

Save Kid's Lives is a film that draws upon the aspirations of targeted programs such as Safe to Learn and Star Rating for Schools. It highlights the ethical motivations of these programs and the complexity of issues that they face. To play this video, press the YouTube play icon in the middle of the screen.

Slide 15

Like the targeted imperative of achieving zero harm to school children on their journeys to school, a zero harm aspiration for motor vehicle manufacturers is bold but achievable. Volvo has set a vision for 2020, stating that beyond this time, it aspires for no-one to be killed or seriously injured in a Volvo vehicle. To play this video, press the YouTube play icon in the middle of the screen.

Slide 16

(No transcript)

Appendix B3. Module 2, Snippet 3 transcript

Slide 1

Welcome to Module 2, Snippet 3 of Safe System for Universities. In this snippet, we will unpack the concept of the Safe System and look at what it means for those who are ultimately responsible for the safety of road users, the system managers.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

An ethical imperative of eliminating harm forms the basis on which the Safe System stands. We will start by taking a look at what harm elimination means in the context how we approach the management of a road transportation system.

Slide 5

Errors are a normal part of life. We expect them to occur in almost everything we do. People do not perform at a one hundred percent level, one hundred percent of the time. This means that whenever and where ever people have access to a system, errors will occur. The road transportation system is no exception, and while we have become very good at reducing the likelihood of errors, it is clear that a certain amount will continue to occur. Unless we remove people from all aspects of control or input into the road transportation system, errors will be unavoidable.

When errors occur, they can result in crashes that have the potential to cause harm. Most errors will not result in a crash, and most crashes that do occur will not result in severe injury. This is because the human body has a certain tolerance to physical harm before it breaks. With the developments that have been made on our roads and by the vehicles that we drive, the chances of exceeding this tolerance have been reduced over time. However, exceeding this tolerance is still a distinct possibility for a substantial portion of travel that people undertake within our road transportation system.

Because of the sheer number of people using our road transportation system, even a minute possibility for a single person to be involved in a severe crash translates to a substantial amount of harm that is being done to people. As discussed in Snippet 2 of this module, the ethical imperative that underlines the Safe System calls for no person to be fatally or seriously injured as a result of using our road transportation system. While errors will continue to occur and some of these errors with continue to result in crashes, a Safe System means that harm should not result.

Slide 6

Meet Graham, he is a collaborative creation funded by the Transport Accident Commission of Victoria. Graham represents what the human body could look like if it had evolved to cope with the forces associated with the use of our modern road transportation system. In other words, Graham evolved to survive a crash that other humans would not be able to survive. Unfortunately, the road transportation system is a relatively new concept and humans have not been able to evolve alongside it. Graham is a good reminder that we are not built to cope with the magnitude of forces associated with road use.

Humans did not evolve to survive a crash. Despite this, we have inherited a road transport system that is not very good at considering this limitation. Moving forward, we will need to become better at considering human limitations within our design and operation of the road transportation system. In other words, design and operation will need to shift from a car-centric position to a human-centric position. The road transportation will need to continue to be realigned to the human scale.

Slide 7

Harm elimination has its best chance when the road transport system is approached from a system perspective. Now, Let's take a look at how this changes our approach to road safety.

Slide 8

The Safe System is generally represented as a system of individual pillars. Each pillar represents a different aspect of the system and within each of these pillars are considered the ability for failures to occur and the possibilities to prevent these failures from translating to harm. The notion of these pillars has come from the tendency for questions and answers to the problem of road safety to be related only to the road user. The addition of further pillars represents the ability to question issues and seek answers within other areas of the road transportation system, especially those in which system managers hold responsibility.

Historically, we have heavily relied on drawing solutions from road users and not from the system in which they perform, limiting our ability to solve problems. The Safe System changes this mentality by explicitly focussing on the entire system and drawing solutions from every pillar. The strength of the Safe System lies in the ability to draw solutions from multiple pillars, thereby creating redundancy to counter the effects of failure in one pillar by placing strength in another pillar.

As an example, picture a rural road providing a link between regional centres. Developments in vehicle technologies provide safer vehicles for those using the route, while enforcement activities help to ensure road users remain compliant. The road itself provides solutions to improve the performance of road users driving along the route, through features such as audio tactile line marking to make drivers aware when they drift out of their lane, and sealed shoulders to provide extra space in which to correct their path of travel. At the same time, the surrounding environment takes into consideration the fallibility of road users by limiting speed limits to within safe levels and providing features such as road safety barriers to control the outcomes of crashes when they do occur.

Slide 9

The four pillars of the Safe System represent four distinctly different aspects of the system. Firstly, road users are compliant and act within reasonable boundaries. Enforcement and education are used to maintain these boundaries. Extreme violations such as extreme speeding and drink driving are not tolerated, but errors are expected and lapses in judgement, such as low level speeded, are tolerated.

Roads and the roadside environment are designed and operated to protect users. Road and roadside treatments such as sealed shoulders and road safety barriers are used to reduce the likelihood of crashes and prevent severe outcomes in the case that crashes do occur. Intersections are designed to reduce exposure to other vehicles and reduce confusing situations that could lead to error. At the same time, intersections are designed to ensure that vehicles cannot collide in configurations and at speeds where severe outcomes can be expected. All road users are protected and those that are more vulnerable, such as cyclists and pedestrians, are afforded additional protection and given their own areas of priority over the network. Finally, incompatible situations are eliminated as far as is possible, such as interactions between cyclists and heavy vehicles.

Speed is a key element of the Safe System. Where road design and vehicle technology cannot ensure safe interactions between road users and the surrounding environment, speeds are limited to ensure the human biomechanical tolerance to harm is not exceeded in a crash. Speed is also managed to reduce the likelihood of crashes occurring in the first place. Elements of education and enforcement are used to maintain speeds to within acceptable levels.

Vehicles arguably represent the area of greatest improvement in road safety over the past decades and will likely hold a key place within the system. Vehicle technology acts to reduce road user error and correct driver actions when errors are made. Technologies also improve the outcomes of crashes when they occur. Education, policy and legislation are used to improve the uptake of safety technology and motivate the use of safer vehicles, especially among government and commercial fleets.

Slide 10

Next, let’s discuss how the Safe System impacts upon the role of system managers and their responsibility towards road users.

Slide 11

Shared responsibility is an idea upon which the Safe System philosophy of road safety is predicated. At the core of the Safe System is the concept of maintaining a system free of harm, with responsibility for obtaining this shared between managers and users of the road system.

Firstly, it is the system managers’ responsibility to implement and maintain a system that does not knowingly introduce an unacceptable level of harm onto system users. In the realm of road safety, an unacceptable level of harm has been identified as death or serious injury. Any lesser level of harm is undesirable, but ultimately accepted as a possibility as it is understood that with currently knowledge, eliminating all levels of harm is unachievable.

It is then the system users’ responsibility to use the system in accordance with its design and to not knowingly introduce additional risk of harm through their own actions. This is where the idea of shared responsibility can break down as the question often arises: what if a risk of harm is identified that has been caused by inappropriate behaviour on the part of the system users?

Ideally, the answer to this question is that it is always the responsibility of the system managers to maintain a system free from harm, no matter how that harm may arise. In other words, the system should be designed so that users cannot act in such a way that introduces additional risk of harm. In practice, however, this can be a challenge and is an area of much debate. Nonetheless, such debate should not prevent system managers from taking responsibility and acting on foreseeable risks of harm to the best of their abilities.

Slide 12

Duty of care is a concept closely aligned to that of shared responsibility. While a system manager's duty of care is arguably intrinsic in all steps in this cycle, it is when a previously unforeseen risk is identified that the ethical dilemma can become complicated.

While risks that are identified in the system can be due to oversight on the part of the system designers and operators, they often include an aspect of system use that deviates from expectation. Because these deviations of use usually lead to the active errors that result in failure, it is easy to attribute causation of failure to the system users. This is especially the case when system use that results in a failure has been in extreme violation of the rules and expected behaviour of system users.

This attribution of blame to the system user can lead to a breakdown in the duty of care that lies with system managers. The question can often arise: shouldn't the system users change their behaviour to conform to the system? While this approach may be favoured by some, it is ultimately fraught – behavioural change is one of the hardest things to accomplish. This means that changing the system to conform to user behaviour is often the most viable action. The responsibility to action such change forms part of the duty of care.

Slide 13

Formed on the basis of an ethical imperative of eliminating harm, the Safe System is a philosophy for our approach to road safety. Let's look at what this philosophy means in practice for those managing our road transportation system.

Slide 14

As discussed in the previous snippet, the Safe System starts with the ethical imperative that people should not be harmed as a result of using the road transportation system. As we have discussed here, the Safe System is underpinned by the notion that people make mistakes and that no amount of education, enforcement or design will be able to prevent all error from occurring. There is therefore a need to also manage the consequences of crashes when they occur, to ensure that fatal and serious injuries do not result. While much progress has been made in protecting road users from harm, we still design and operate the road system without much consideration to the consequences of crashes.

People are harmed in crashes when their biomechanical tolerance to harm is exceeded. In other words, physical forces on the body exceed what it is able to withstand before breaking. This is a key consideration that must be accounted for in the design and operation of the road transportation system, if harm is to be eliminated. A widespread example of how this is not currently being achieved is that of signalised intersections. Signalised intersections are operated on high volume roads with speed limits generally in excess of fifty kilometres an hour. We know that at a fifty kilometres an hour impact between two vehicles travelling on adjacent roads, there is a small but real chance that a fatal or serious injury will occur. As speed increases, the chances of fatal or serious injuries rapidly increases.

Central to the Safe System is the idea of shared responsibility. It is the responsibility of both road users and system managers to ensure harm does not become a result of system use. While road users hold responsibility for their own actions and are expected to remain compliant with no extreme violations, the responsibility for ensuring survivability is ultimately led by the system managers that design and operate the road transportation system. It is the system managers' responsibility to ensure that all reasonable steps are taken to ensure harm does not occur and if it does occur, to ensure steps are taken to rectify the gap that allowed such a failure to occur. This is a system manager's duty of care.

Slide 15

Transitioning to a Safe System means that the way we approach management of the road transportation system will need to change. Traditionally, safety and mobility form part of a multi-criteria approach where both can be traded off against one another in a quest to find an optimal balance in the benefit to each criterion. While this approach aims to increase safety, it does not place a limitation on the minimal level of safety that will be accepted. The result of this can be seen all around our road network, with fatal and serious injuries being an all too common result of system use.

Under the Safe System, this approach is reversed to one where safety becomes a non-negotiable and mobility becomes a function of safety. In practice, this will mean that while safety is an integral part of an multi-criteria analysis, there exists a minimum level of safety beyond which any proposal, no matter how optimal for any of the other criteria, is rejected. In other words, mobility and other functions of the road transport system can be optimised within the boundary of no foreseeable fatal or serious injuries.

What this all means for system managers is a need to ensure roads are designed and operated to tolerate normal human performance and the errors that can be foreseeably expected. Kinetic energy around the road network must therefor be managed to ensure the energy generated during a crash and transferred to the people involved is not above the human biomechanical tolerance to harm. This essentially means that roads must be designed to separate or insulate people from harmful levels of energy, or speeds must be lowered to more tolerable levels. To do this, we will need to focus on the whole system and what each element can lend in the quest for harm elimination, rather than a single focus or approach on any one element.

Slide 16

(No transcript)

Appendix B4. Module 2, Snippet 4 transcript

Slide 1

Welcome to Module 2, Snippet 4 of Safe System for Universities. In this snippet, we will take a look at Australia's and New Zealand's Safe System journey, what has been achieved so far, and what needs to be done as we navigate the path to zero harm.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

The Safe System has been integrated into Australian and New Zealand road safety practices since the early 2000s. Firstly, let's take a look at our journey since we adopted this road safety philosophy.

Slide 5

The Safe System can ultimately be traced back to the pioneering work undertaken by Sweden in the 1990s. In 1997, the Swedish Parliament adopted Vision Zero as their ethical mandate to pursue a new direction in road safety. Headlining Vision Zero was the call for no people to be killed or seriously injured when using the road transportation system. While Sweden still suffers from fatal and serious injury outcomes from road crashes, it has seen a dramatic downturn in the number of people harmed on it's roads and today it represents a as a leading example in the pursuit of zero harm.

Australia's initial moves towards the Safe System occurred in the early 2000s. In the year 2000, Safe System principles were used to underpin Australia's national road safety strategy for the years 2001 to 2010. This was followed by endorsement of the Safe System in 2003 by the Australian Transport Council. Though these initial steps where symbolic, more tangible steps were to be taken in the successive years.

In 2006, the first edition of Austroads' guide to road safety was released as Australia's and New Zealand's leading source of road safety guidance. These guides were headlined by the acknowledgement that the Australian and New Zealand road transportation systems must progressively move towards the Safe System. Since this time, acknowledgement of the Safe System has been included in several Austroads guides. However, as we will later discuss, introduction of the Safe System into Australasian road design and operational guidance has arguably been limited to acknowledgement of the guiding principles of harm elimination, with limited resources for implementing its practical considerations.

Slide 6

Following suit from the federal level, the road safety strategies and action plans for each Australian state and New Zealand place the Safe System and a strategic goal of harm elimination at the top of their agenda. With most of these strategies and action plans due for renewal now or in the near future, each successive strategy and action plan is set to provide a renewed push towards this target. Crucially, each strategy and action plan will now need to clearly state how a sustained, long-term plan towards a target of zero fatal and serious injuries will be managed.

Slide 7

In 2010, Australia's new national road safety strategy for 2011 to 2020 was released. This new strategy renewed the national vision that no person should be killed or seriously injured on Australia's roads. As with New Zealand's latest road safety strategy, which was released in 2019, it is expected that the next

Australian national road safety strategy will continue with this vision of attaining a road system where no person is killed or seriously injured.

Despite these bold visions and equally bold target setting, a national enquiry into Australia's national road safety strategy was announced following a halt to the downward trend in fatal and serious injuries. This enquiry, released in September 2018, detailed some of the failings within the management of our road transportation system. Despite the demonstrated strategic importance of the Safe System, we have failed to implement the Safe System at a practical level. Additionally, safety is often assumed as implicit with every new road project or redevelopment of the existing network. Opportunities are missed when making things safer, rather than outright safe, is accepted as a reasonable outcome. In other words, safety is improved but not optimised.

Slide 8

Despite so far falling short of Safe System ideals, we have nonetheless attained some considerable achievements in road safety over the past two decades. Now, let's take a look at some of our achievements.

Slide 9

In both Australia and New Zealand, the Safe System has been firmly cemented as the future of road safety. Strategic targets have been underpinned by the goal of attaining zero fatal and serious injuries on our road network. However, as highlighted in Australia's current national road safety strategy, it is not an implementation plan. Detailed planning, an informed system management and the right tools will be required to enact such strategy.

Slide 10

High-level guidance is available across Australia and New Zealand. Safe System principles have been implemented to varying degrees. Austroads, which forms the peak organisation of Australian and New Zealand road transport agencies, has recently released its third edition of its guide to road safety. Additional guidance is distributed by individual road agencies, such as supplemental guidelines and New Zealand's high-risk guides.

Slide 11

An increasing number of showcase and demonstration projects have been completed across Australia and New Zealand. Many of these projects highlight design and operational solutions that can achieve near Safe System levels of performance. Further to these projects, some works have been implemented on a scale that has made a perceivable impact. Such examples include the Princes Highway through the eastern region of Victoria, the Bruce Highway in Queensland and the Waikato Expressway in New Zealand.

Slide 12

A number of road safety programs have sought alignment to the Safe System. A key example is the Towards Zero safe system road infrastructure program in Victoria, which has a dedicated one point four billion dollar funding over ten years to implement wide-scale road safety improvements, including Safe System aligned demonstration and targeted projects.

Slide 13

Australia and New Zealand contain a number of university-based road safety research centres. These centres, along with other road safety organisations, have contributed a sizeable amount of literature to the road safety field. Key outcomes of this research include demonstrating the clear link between speed and the risk of fatal and serious injuries, identifying the superior performance of road safety barriers over clear zones, and the creation of Safe System tools aimed towards enabling road safety practitioners.

Slide 14

Australia has arguably led the way in terms of public road safety campaigns. Historically, these have targeted the traditional road user-oriented problem areas such the fatal-five of speeding, drink-driving, seatbelt use, distraction and fatigue. More recently, such public campaigns have started to educate the public on the goal of attaining zero harm and the need for a system-based response to the road safety problem.

Slide 15

Moving forward into the future, there is still a sizable amount of work that needs to be done if we are to realise the Safe System ideal of zero harm. We will finish this snippet by discussing some work that will be required going forward.

Slide 16

Recently, a number of practical guidance publications and tools have been released for use by road safety practitioners. These include the likes of the Austroads' compendium of current knowledge and safe system assessment framework, and New Zealand's infrastructure risk rating tool. This guidance is aimed as supplementing the current Austroads' and other guides and provides Safe System-aligned information at a level that is still largely missing in the traditional guidelines.

Slide 17

While showcase and demonstration projects have highlighted a need for innovation in the way we approach the design and operation of our road network, such innovation is largely missing in mainstream works. Both road safety specific and more general road projects will need to incorporate innovative solutions, backed by suitable guidance and tools that enable innovation to be used.

Slide 18

Professional education is a key enabler of road safety as without knowledge of the Safe System and how to implement its principles as practical solutions, achieving Safe System-alignment will be all but impossible. Some tertiary and professional education is currently available but its availability is sporadic and the quality of content is arguably inconsistent.

Slide 19

Science-based practice is largely missing from the practical implementation of road safety solutions. While a large body of evidence is available, much value is placed on empirical evidence and waiting until practices become mainstream before engaging in them. Unfortunately, this is incompatible with the scale and pace of change that is required. To overcome this, more weighting will need to be placed on theoretical evidence to compensate for where empirical evidence is lacking.

Slide 20

Widespread implementation of Safe System practices will need to be undertaken if harm elimination is to be achieved. At this time, widespread implementation remains unachievable with a lack of knowledge on how this is to be achieved, lack of tools to enable practitioners to prioritise safety, and a lack funding made available and conditional on meeting specific road safety targets.

Slide 21

(No transcript)

Appendix B5. Module 2, Snippet 5 transcript

Slide 1

Welcome to Module 2, Snippet 5 of Safe System for Universities. In this snippet, we will discuss the differences between historical road safety practices and the Safe System, and the reasoning for making the shift to Safe System practice. To do so, we will draw from studies that have looked at harm through the lens of the Safe System to uncover some of the issues with the historical way in which we have approached the field of road safety.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let’s look at some of the core issues behind historical road safety thinking.

Slide 5

Historically, a core focus of road safety has been the road user. This has led to the situation where crashes are thought of in terms of road user fault and solutions are drawn from fixing the behavioural issues of road users. Less attention has been paid to the remainder of the system and its input into the occurrence of crashes. This has led to the situation where we have inherited an inherently unsafe road transportation system.

This user-centric focus has led to an expectation of 100% performance of road users, 100% of the time. While much of road safety has focussed on improving the performance of road users and this focus has been reasonably successful, very little consideration has been given to the forgivingness of the road system in the context of road user error. In other words, our roads are not tolerant of mistakes. An outcome of this has been to view crashes as a failure of user performance.

As a result, substantial focus has been given to drawing solutions from the education and enforcement of road users. The aim of these activities has generally been to improve road user performance, especially in the context of correcting undesirable behaviour. Good examples are the topical issues of speeding and driver distraction. While such issues are problematic, they make up only part of the road safety problem and tend to distract attention from the issue of the inherent risk involved in using the road transportation system.

Another key result of our road user-centric focus is the collection of data biased towards identifying road user error. Historically, police reporting has been the mainstay of crash data collection, and this has focussed on collecting what is necessary to determine fault and who should be prosecuted. As a result, respectively little data exists that points to the other factors of crashes, which has resulted a situation where little attention can or is paid to the wider suit of factors and the solutions that can be drawn from them.

Slide 6

So, how does a Safe System differ from our historical perspective of road safety? The key difference in practice is a focus on the entire system, rather than a primary focus on the road user alone. This means more responsibility being placed on the system managers. This does not mean that responsibility is taken from road users to monitor and correct their own behaviour. Instead, it means that a the realistic performance of road users, including their propensity to make mistakes, is explicitly considered in the management of the road system.

Slide 7

Next, we'll take a look at some recent studies that have highlighted the issues with the historical perspective of road safety. In doing so, we will uncover some of the misconceptions of road safety and what this means for how we must approach it when going forward.

Slide 8

A common misconception within our community is that fatal and serious injury crashes are the result of deliberate acts of risk taking that display extreme and dangerous behaviour. In 2015, a study was undertaken to categorise the factors that led to fatal and serious injury crashes in South Australia. It was found that, for fatal crashes that occurred between 2008 and 2009, under half of the crashes included extreme behaviour as a factor contributing to the occurrence or severity of the crash. In this study, extreme behaviour was classified as high-level alcohol intoxication and speeding, or lower-level alcohol consumption or speeding combined with another activity such as drug intoxication or deliberate reckless behaviour such as dangerous overtaking.

More than half of the crashes were a result of a system failure, where the road user made a mistake that was ultimately allowed to result in a fatal outcome. This included about a quarter of all crashes that included some form of non-compliant behaviour that could reasonably be attributed to error, rather than a deliberate act of risk taking, such as non-compliance with the road rules or low-level speeding.

Slide 9

Next, the study focussed on serious injury crashes that occurred in rural and urban environments.

For serious injury crashes that occurred in the rural regions of South Australia between 1998 and 2000, it was found that less than 10% of these crashes involved some form of extreme behaviour. The majority of crashes involved system failure or, to a lesser extent, some form of illegal system failure.

Slide 10

For serious injury crashes that occurred in urban centres in South Australia between 2002 and 2005, a mere 3% of crashes involved extreme behaviour, with the vast majority resulting from system failure. The results of this study show that the majority of fatal and serious injury crashes in South Australia did not involve extreme behaviours, as is commonly perceived by the community. Instead, crashes resulted from errors made by road users, with harm allowed to occur because the wider system did not adequately protect road users from situations in which the human biomechanical tolerance to harm can be violated. In other words, human error was a factor that led to the crash, but the severe consequences of the crash were due to inadequate protection by the system.

Slide 11

In 2018, another study was undertaken in South Australia that focussed on profiling a sample of fatal crashes that occurred in 2010 and 2011 against the Safe System pillars of safe road users, safe roads and roadsides, and safe vehicles. Each crash was profiled to determine whether the road user, road environment and vehicle were compliant with what was considered safe. For road users, compliance was based on adherence to the speed limit and no intoxication by alcohol or drugs. For the road environment, compliance was based on a European road assessment program star rating of four of more stars. For vehicles, compliance was based on a European new car assessment program star rating of five stars and being fitted with electronic stability control.

The results of the study found that 16 of the 105 profiled fatal crashes occurred as a result of only non-compliance by the road user. A further eight and three crashes resulted from non-compliance of only the road environment and only the vehicle, respectively. In eight of the 105 crashes, all three factors that were considered were found to be compliant.

In contrast to these results, it was found that the majority of crashes resulted from non-compliance across multiple factors. Overall, vehicle non-compliance was found to be a factor in half of all crashes, while road user and road environment non-compliance were found to each be factors in about two thirds of all crashes. The results from this study further demonstrate that, while road user behaviour can be a factor in crashes that result in harm, other factors play into these crashes and their consequences.

Slide 12

Finally, let’s finish by summarising some of the key differences between historical practice and the Safe System.

Slide 13

There are a number of clear differences between historical road safety practice and the principles to which the Safe System subscribes. These differences are less to do with the intent of the ways in which road safety is approached. After all, both historical and Safe System practice is genuinely interested in minimising the harm that occurs on our roads. Instead, the differences are more to do with the way each practice views the system under which it functions. This means that to change the way we practice road safety, we will need to change the way we perceive the system and the responsibilities that we hold as managers of the system.

Historically, we have tended to focus on the role of the road user in crashes more than the role of any other factor. As road user error is a factor in most crashes, it was logical to see crashes as a failure of road users. However, we know that error is an intrinsic part of human behaviour and so a focus on eliminating the errors that lead to crashes is unlikely to completely eliminate harm. Instead, the Safe System treats crashes as a result of system failure. Crashes can result from failures across each part of the road transportation system and so focus is given to solutions from each part of the system.

Historically, we have focussed on preventing all crashes, without much discrimination between the severity of outcomes. The rationale behind this thinking is logical, as a focus on reducing the likelihood of all crashes will surely reduce the likelihood of crashes with severe injury outcomes. However, we know that we cannot prevent all crashes as we cannot prevent road users from making mistakes. Under the Safe System, fatal and serious injury crashes instead become the priority. While preventing all crashes regardless of severity is preferable, fatal and serious injury outcomes are regarded as unacceptable.

Because of our focus on crashes being caused by poor road user performance, we have tended to hold road users responsible for their own safety. In other words, the system was designed and operated with safety in mind, but ultimate responsibility was left with those using the system. Safe System philosophy turns this thinking on its head. Instead, the ultimate responsibility for safety is held by system managers. Road users are expected to perform diligently and act in a compliant manner, but when failures occur, it is ultimately the responsibility of the system managers to prevent these failures from reoccurring.

Historically, mobility and safety have been regarded as output variables to be optimised. This has invariably led to the situation where mobility and safety are traded off against each other, usually ending in a compromised result where safety is improved but harm is still a likely outcome of system use. Within the Safe System, the objective becomes the optimisation of safe mobility. Safety is no longer just a variable to be optimised, but is also a boundary condition that must be met. The task becomes one of maintaining a certain level of safety, which for the Safe System is no fatal or serious injuries, and then optimising the benefit to mobility.

Another trait of historical practice has been the tendency to attain gains within siloed areas of the system. This has come from a result of viewing the system as its individual parts, rather than as a whole. A clear example that we have discussed is the tendency to focus on road user behaviour when looking for solutions to the road safety problem. Within the Safe System, the road transportation system is viewed as a whole, and so solutions are drawn from the entire system. Even today, we still have a tendency to view the system as discrete parts, and so the future direction of road safety will rely more and more heavily on drawing solutions from across the broad range of disciplines that manage the system.

Slide 14

So how does the Safe System differ from historical practice? In summary, the Safe System offers a system focus with a system-based approach to finding problems and seeking solutions. Road users are expected to make mistakes and so harm is viewed as a failure of the system, rather than a failure of the road user. Solutions are then sought from all aspects of the system, with redundancy built into the system by providing solutions from multiple aspects of the system. As we expect harm to occur as a result of system failure, rather than road user failure, data and information is collected from all parts of the system. By doing this, a more complete picture can be formed and better informed decisions can be made, resulting in management that undertakes to resolve issues across the whole system. It is only by doing this that we can hope to reach the Safe System goal of zero harm.

Slide 15

(No transcript)

Appendix B6. Module 2, Snippet 6 transcript

Slide 1

Welcome to Module 2, Snippet 6 of Safe System for Universities. In this snippet, we will look at the aspects of road design and operation that supports a Safe System. We will introduce some of the concepts that will feed into Module 3 of Safe System for Universities, where we will take a closer look at the practical design of safe roads.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, we will look at what it will take to achieve zero harm within our road transportation system.

Slide 5

The design and operation of our road transport system is a key element in the quest for eliminating fatal and serious injuries. Designing and operating the road transport system in a manner that supports harm elimination is a key responsibility of those who manage the system. Primarily, this will mean the direct design and operation of the road network. However, this can also mean decision making and influence in other sectors such as through the vehicle industry, where the implementation of vehicle safety technology has had a substantial influence on road safety. Design and operation that supports harm elimination can be categorised into three general elements. Certain design and operation may fall into one or more of these elements, and the definitions of each element can somewhat overlap. The importance of this categorisation is to help consider how harm elimination is affected and what is needed for it to be achieved.

The first element is exposure. This means removing people from situations where harm can occur. This can mean reducing absolute exposure, such as reducing the volume of traffic moving through an unprotected area of the road network, or by removing the need for higher risk activities. Grade separation is an obvious example, as it reduces exposure to intersection type interactions by removing the need for traffic streams to intersect. Exposure can also be relative, such as by increasing the relative proportion of the light vehicle traffic fleet that has a higher Ancap star rating.

The second element is likelihood. Historically, this has been the mainstay of most road safety activities. While a crucial part of road safety, like all elements it is important to recognise its place and limitation in the context of harm elimination. Reducing likelihood takes the form of design and operation that reduces the chances that road users will be involved in a crash. Road design that reduces likelihood can include such treatments as the sealing of shoulders on rural roads and the signalisation of intersections. Likelihood can also be affected outside of road design and operation, such as through mandating vehicle technology that reduces crash likelihood.

The third element of harm elimination is severity. Historically, our influence on crash severity has been limited. However, our ability to achieve harm elimination will be dependent on our ability to control crash outcomes. Reducing severity means reducing the impact of crashes on the human body to the extent where the human biomechanical tolerance to harm is not exceeded. This can mean reducing the energy of crashes, such as through lower speeds, using energy absorbing roadside safety barriers and removing non-frangible roadside objects. It can also mean reducing the transfer of energy to the human body, such as through the use of airbags and seatbelts in vehicles.

Slide 6

As each treatment can affect a different element of harm elimination, the level to which each treatment can affect harm elimination can also be different. For this reason, road safety treatments are also categorised according to their ability to eliminate harm. Under the Safe System, these categories are known as primary, step-towards and supporting treatments. A further category, known as other considerations, are elements that lie outside of road network management, such as speed enforcement, or that have an indirect contribution to road safety, such as line marking consistent with autonomous vehicle technology. The Austroads Safe System Assessment Framework research report provides lists of primary, step-toward and supporting treatments for major crash types.

Primary treatments are named as such because they should be the primary consideration for road design and operation. Primary treatments are those that are known to produce near-fatal and serious injury elimination outcomes. While we must acknowledge that no road infrastructure treatment alone will achieve zero harm, the combination of primary treatments and actions within the other Safe System pillars represent our best opportunity to achieve zero harm. Most primary treatments achieve harm elimination through a reduction in crash severity, a reduction in exposure, or a combination or reduced severity and reduced likelihood. At this stage, few true primary treatments have been identified.

Supporting treatments are those that should be considered once the option for primary treatments has been exhausted. Step-toward treatments are the most desirable of the supporting treatments. They are so named because they provide a stepping stone towards the implementation of primary solutions and harm elimination, with minimal redundancy of investment. A classic example of a step-toward treatment is the use of wide centrelines along undivided rural roads, which provide enough space for flexible centreline barriers to be retrofitted at a later date.

Non-step-toward supporting treatments are those that support harm reduction but do not provide a direct pathway towards harm elimination. Because of their reduced ability to support harm elimination, these supporting treatments should only be considered when primary and step-toward solutions cannot be sought. Many supporting treatments work by limiting the likelihood of crashes, but do not deal with the severity of crashes when they occur. Some common examples of support treatments are full signalisation at intersections, rigid safety barriers, audio tactile line marking and sealed shoulders on rural roads, and speed reduction to non-Safe System speeds.

Slide 7

Now, let’s look at some concepts behind road design and operation that supports harm elimination.

Slide 8

Speed is a key decider in the ability for harm to occur. As speed increases, the likelihood of a crash occurring also increases, as does the severity of the crash when one occurs. Appropriate speed management is one of the most effective tools that we have for eliminating harm. Safe System speeds, which is a fancy term for speeds at which fatal and serious outcomes and very unlikely to occur, should guide road designers and operators in their decision making processes. While the exactness of these speeds is still widely debated, there is little objection that currently the majority of speed management and speed limits across our road network are well above what is deemed to be safe.

Beside speed, the impact angles between colliding vehicles is another important factor in determining crash severity. Head-on and right angle crashes are more likely to result in high severity outcomes that rear-end orientated collisions. This is because the relative speed of the colliding vehicles is much higher and, especially in the case of right angle crashes, the ability for the vehicle to protect its occupants is limited.

Slide 9

Along with other vehicles, roadsides are one of the most hazardous aspects of the road transportation system. This is because vehicles can depart the roadway and collide into hazardous objects. It is highly preferable that any roadside objects able to be reached by errant vehicles be made frangible. This means that they will bend or break on impact with very little force on the colliding vehicle. Of course, this is not always possible and, as will be discussed in the next module, vehicles are able to reach object located a surprisingly far distance from the roadway. As such, there is often a need to protect the occupants of errant vehicles through energy absorbing infrastructure, such as road safety barriers. Another benefit of these devices is to protect errant vehicles from one another.

Slide 10

Rollovers are often the unconsidered part of lane departures. While vehicle occupants can be protected from collisions with hazardous objects by removing these objects, this does nothing to protect from the risk of a rollover. Even relatively smooth, level roadsides can induce a rollover as vehicle snag on soft ground and unseen hazards such as spoon drains. Few infrastructure solutions are available for eliminating rollovers. The most promising are roadside barriers that are able to capture errant vehicles and slow them down progressively, rather than redirecting them or themselves inducing a rollover.

Slide 11

Next, we'll look at two examples of harm elimination in practice, and how these examples differ from common practices that will not achieve the elimination of fatal and serious injuries.

Slide 12

Intersections pose some of the greatest locations of risk for road users. Crashes at intersections often occur at high speeds and at crash angles that limit a vehicle's ability to protect their occupants. Intersection along rural roads present a particularly high risk due to the high speeds at which these road are operated. Many intersection designs are reliant on reducing the potential for errors to be made. They however do nothing to limit the severity of crashes when they occur.

Roundabouts have been used in limited numbers since the early days of motoring. It is more recently that we have realised the safety benefits of roundabouts. Appropriately designed, roundabouts can limit vehicle speeds and impact angles to the point where severe injury outcomes are all but impossible. This is achieved because the design of roundabouts ensures all vehicles entering the intersection do so at a speed that is appropriate for the type of interactions that can occur.

Slide 13

Head-on crashes are a common cause of fatal and serious injuries along rural roads. The risk of head-on crashes is particularly high along undivided roads where there is very little space separating vehicles that are travelling in opposing directions. The relative speed of head-on crashes, particularly along high speed roads, ensures the high risk of severe injury outcomes.

The provision of more space between passing vehicles can help to reduce harm by reducing the likelihood that head-on crashes will occur. If a driver drifts out of their lane and towards the oncoming lane, a wide centreline provides them with more time to correct their vehicle's path of travel before a head-on crash can occur. Working in this way, the wide centreline reduces the likelihood that a head-on crash will occur. However, a proportion of errant vehicles will still traverse into the oncoming lane. For these cases, any resulting head-on crash will generally be as severe with the wide centreline, as it would have been without the wide centreline.

However, if we implement a road safety barrier into the wide centreline, errant vehicles are now captured by the barrier and the possibility of head-on crashes is practically eliminated. Now, lane departures can occur and vehicles can cross the road centreline, but the barrier prevents these events from resulting in head-on crashes. While a crash with the barrier may occur, these crashes are likely to be far less severe than a crash with an oncoming vehicle. Hence, the harm that corresponds to head-on crashes is substantially reduced and may even be eliminated.

Slide 14

Finally, let's look at the core concepts of safe road design, and how to identify design and operation that will bring us closer to achieving a Safe System.

Slide 15

Exposure can often be overlooked in the design and operation of roads, as the decisions that affect exposure can be made at very early stages in their development. It is important that one of the first questions being ask is whether road users need to be exposed. Does a new intersection need to exist or can traffic be diverted to another, higher quality intersection? Do cyclists need to use a roadway or can they be diverted to a bicycle path? Do heavy vehicles need to access an area or are their alternative ways or times when goods can be delivered? These are just some of the questions that can be asked.

Eliminating points of exposure is the best way to ensure safe outcomes. Often though, full elimination of exposure is not possible. The next best alternative is to eliminate as much exposure as possible. This could mean removing a proportion of the possible conflict locations, or reducing the volume of traffic using a road. The remaining exposure can then be dealt with through reduction in the likelihood and severity of crashes.

Remember, exposure can occur in time as well as in space. A great example of exposure in time occurs around shopping centres. While alternatives to large heavy vehicle deliveries should be explored, another option could be to reschedule deliveries for times when pedestrians are not active around the shopping centre. Another example is the common practice of undertaking roadworks at night, when traffic volumes are low.

Slide 16

Design and operation needs to consider human vulnerability. Whenever there is a risk that crashes can occur, we need to be mindful of the crash outcomes and ensure they are survivable for those involved. And remember, more vulnerable members of society, such as young children and the elderly, will be even more susceptible to harm in the event of a crash.

Considering human vulnerability means we need to think about more than just the likelihood of crashes. We also need to consider the outcomes when a crash occurs. This means considering the possible severity of a crash. Solutions best aligned to Safe System principles will deal with the severity of crashes, as well as their likelihood.

Slide 17

Speed is one of the most important factors in determining the risk of harm. While in certain situations speed in not the dominant factor, such as crashes between heavy vehicles and pedestrians, speed is generally a very good determinant of injury outcome. This means that managing speed is a critical component to a safe road transportation system. Generally, there are two ways to achieve appropriate speed: speed management through road design and operation, and vehicle technology; and speed compliance through speed limits and enforcement. Both ways have their place in a Safe System.

While numerous studies have looked at the relationship between fatal and serous injury risk and speed, there is currently no definitive answer to what speeds are safe. As a rule of thumb, the following speeds should not be exceeded: 30 km/h where vulnerable road user are not protected from motor vehicles; 50 km/h where right angle crashes between motor vehicles and possible; and 70 km/h where head-on crashes can occur. Remember, these speeds are a general guide and do not take into account all circumstances. Some circumstances, such as for motorcycles and interactions between vulnerable road users and heavy vehicles do not have an easy safe speed answer.

Slide 18

(No transcript)

Appendix C. Module 3 transcript

The following transcripts are from snippets 1 to 6 of Module 3.

Appendix C1. Module 3, Snippet 1 transcript

Slide 1

Welcome to Module 3, Snippet 1 of Safe Systems for Universities. In this module, we will consider the practical responses to harm – the tangible solutions that will ultimately lead us to a road transportation system free from death and serious injury. Firstly, in Snippet 1 we will consider the problem of harm through the lens of kinetic energy and the problem of harm as one of energy management.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let us briefly explore our historical approach to road safety.

Slide 5

In the 1970s and 1980s, Australia and New Zealand saw the peak of deaths on our road networks. Since this time, we have steadily progressed road safety to a point where death is a comparatively rare occurrence. Think of the last time you saw a car crash. Most of us would barely witness one each year, let alone be involved in one.

We have inherited a myriad of road design that has reduced the likelihood of crashes to a point where they are extremely rare on an individual level. Despite this extreme rarity of crashes, they do occur and the sheer volumes of traffic on our roads means that an appreciable number of fatal and serious injury crashes do occur.

While efforts to reduce the likelihood of crashes have achieved great success, these efforts are alone incompatible with a vision of zero death and serious injury. This is evidenced by our recent trend of plateauing of annual deaths on our roads. In order to achieve a vision of zero harm, consideration must also be given to the consequences of crashes. Put simply, we must look to reduce the severity of crashes when they do occur, as well as reducing the likelihood that crashes will occur in the first place.

Slide 6

The risk triangle is an often used model of risk and its elements. Applied to road safety, it shows the elements that affect the risk of death and serious injury. These are the level of exposure to a possible crash event, the likelihood that exposure will result in a crash, and the consequence of a crash when it occurs.

Historically, we have been very good at reducing the likelihood of crashes. As demonstrated through the risk triangle, reducing the likelihood of a crash has reduced the risk of death and serious injury. However, while people are admitted into the road transportation system, error will continue to occur and crashes will continue to result.

In order to further progress to the vision of zero death and serious injury, we need to start dealing with the consequences of crashes, rather than the likelihood alone. This means applying road design and operating our roads in a manner that does not foreseeably allow errors and crashes to result in harm.

Slide 7

Next, we will consider the elements of risk as mechanisms leading to harm.

Slide 8

At the core of serious injury and death is the human body's biomechanical tolerance to harm. This is the limit at which the human body will sustain harm. Given exposure to enough force or acceleration, serious injury or death may result. The exact limit of tolerance before death or serious injury will depend on the situation and the type of exposure. A rough approximation of 100 kilojoules has previously been used. A change in kinetic energy above this limit has the potential to result in death or serious injury

Achieving a level of kinetic energy above the human biomechanical tolerance is relatively easy to achieve. For example, an average passenger vehicle contains enough kinetic energy to kill a pedestrian when travelling at only thirty kilometres per hour. Across our road network, there are very few situations where kinetic energy below the human biomechanical tolerance to harm can be guaranteed.

The result of this is seen across our road network with the number of fatal and serious injury crashes that occur. Higher than tolerable kinetic energy levels do not guarantee a crash will result in a serious or fatal injury, but every increase in energy increases the probability that a fatal or serious injury outcome will result

Slide 9

The kinetic energy management model is a conceptual representation of the mechanisms that lead to death or serious injury on our road network. At the centre of the model is the human body.

The kinetic energy management model is made of five layers, each representing a step along the pathway to harm. The five layers are the exposure to potential crash situations; crash likelihood per exposure; the kinetic energy per crash; the transfer of kinetic energy to the human; and the human biomechanical tolerance to harm.

As each layer of the conceptual model represents a step towards harm, each layer also represents a potential barrier to harm occurring. The two outer layers represent exposure and likelihood, the latter a mechanism that we have historically been good at mitigating. The three inner layers represent consequence. While we cannot do much to improve the biomechanical tolerance of humans, we can affect the transfer of kinetic energy and the kinetic energy per crash through road design and operational practices.

Slide 10

Now that we understand the mechanisms of harm, let us consider what a focus on consequence can achieve.

Slide 11

As the saying goes, “it’s not the fall that will kill you, it’s the sudden stop at the end”. People are very good at recognising this risk when it is staring us in the face, such as when looking over the side of a balcony several storeys up the side of a building. However, we are not so good at recognising the same risk when applied to a road transportation context.

As with a fall from a building, a key factor in the survivability of a crash is the speed at which you are going when the crash occurs. Besides the setting of speed limits, road design has a direct effect on the speed at which people travel. The way we design and operate our roads has a direct effect on not only the likelihood that crashes will occur, but the survivability of those crashes when they do occur.

A key philosophy of the Safe System is that it is the responsibility of the system managers to ensure road users are not exposed to the risk of death or serious injury. To achieve this, designers and operators need to ensure that roads are designed and operated at speeds which do not exceed the human biomechanical tolerance to harm. Where this cannot be achieved with road design alone, speed limits need to be corrected so that harmful consequences cannot prevail within the current road environment.

Slide 12

In collisions between two vehicles, the angle at which the impact occurs has a direct consequence on the probability of severe outcomes. As a rule of thumb, the greater the impact angle from a rear end collision orientation, the greater the probability of death or serious injury. For this reason, situations where vehicles are exposed high approach angles at intersections are particularly hazardous.

The main effect of an increased impact angle is a greater difference between the directional velocities of both vehicles. As impact angle increases, the change in velocity and therefore the acceleration experienced by each vehicle increases. As can be seen here, an impact at a right angle results in a far greater change in velocity compared to a low angle impact.

A further issue of impact angle is the near right angle impact experienced at most intersections. While modern passenger vehicles are very good at protecting their occupants with crumple zones at the front and rear of the vehicle, they offer relatively little protection in side impact situations.

Slide 13

When two objects, such as two vehicles, with equal mass collide with one another, the acceleration enacted on each object is equal. When there exists a mass inequality, the less massive object will undergo greater acceleration. This greater acceleration increases the likelihood of severe outcomes. Whenever there is a mass inequality between colliding vehicles or road users, there will be a greater likelihood of harm.

The two most consequential situations of mass inequality are collisions between heavy vehicles and lighter vehicles; and collisions between vulnerable road users such as pedestrians and cyclists, and other vehicles. Some of the most dangerous situations are conflicts between vulnerable road users and heavy vehicles, for which we have very few solutions to mitigate the possibility of severe outcomes.

Though not often considered as a mass inequality, an impact between a vehicle and a rigid object is essentially a mass inequality of infinite scope. In these crashes, such as when a vehicle collides with a fixed pole or a large tree, the vehicle undergoes practically all acceleration.

Slide 14

Finally, let us look at what Safe System means In practice, as a design problem leading to practical solutions.

Slide 15

Many mechanisms of harm, whether related to exposure, likelihood of a crash or the severity of the crash once it occurs, can be affected by design. Often, the way we design and operate the road network can have a greater effect than changes in road user behaviour or even vehicle design.

The Safe System calls for a system approach to road safety. In other words, we need to consider all components of the system to create the most favourable conditions for eliminating harm on our roads. Road design and operation is an integral part of this system. It is the responsibility of those who manage this component of the system to ensure safety is optimised within its domain.

This means that those who manage the road transportation system, the designers and operators of the system, have a responsibility to ensure harm does not occur. When a part of the network is recognised as not performing to this standard, responsibility rests on these system managers to identify the problem and rectify it before further harm can occur. The Safe System recognises that this responsibility is irrespective of whether other components of the system, such as road user behaviour, are performing to an acceptable standard.

Slide 16

A core principle behind the Safe System is incorporating the consideration of human biomechanical tolerances into the everyday domain of design and operation. This has been a primary failing of the historical approach to road safety and without such consideration, design and operation of the system is not aligned to understanding and mitigating the consequences of crashes when they do occur.

Historical approaches to road safety have resulted in vast improvements to our road network by managing the likelihood of crashes, but ultimately fall short of eliminating death and serious injury. This can been seen in the plateauing of current fatality and serious injury trends. The next step in the evolution of road safety is to consider and ultimately manage the quantum of kinetic energy required to reside within the tolerances of the human body.

In Module 3 of the Safe System for universities, we will explore the practicalities of dealing with human error and ensuring when error occurs, it will not result in serious injury or death. You will learn innovative solutions to improve survivability on our roads, and learn to distinguish between practices that make our roads less dangerous and those that make them safe.

Slide 17

(No transcript)

Appendix C2. Module 3, Snippet 2 transcript

Slide 1

Welcome to Module 3, Snippet 2 of Safe System for Universities. In this snippet, we will be talking about the harm of intersection crashes and the interventions available to eliminate harm at intersections.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let’s take a look at the mechanisms of harm associated with intersection crashes.

Slide 5

In the image on the left, we can see a map of right angle injury crashes that occurred between 2009 and 2018, in the inner southern suburbs of Adelaide, South Australia. In an urban environment such as this, signalised intersections tend to dominate the locations of intersection crashes. Despite the greater level of control and reduced likelihood of crashes at signalised intersections, the very high volumes of traffic using these intersections mean that they tend to experience more crashes than at intersections with lower levels of exposure. Unsignalised intersections along arterial roads also tend to experience a large number of crashes. This is due to the high exposure along arterial roads combined with the lack of control for traffic entering from side roads.

Like urban intersection crashes, rural intersection crashes tend to occur more at intersections with high volumes of traffic. Unlike in urban areas, rural intersection crashes are spread out over a vast area, with often much lower levels of exposure, meaning the random nature of these crashes can be more easily appreciated. In the image on the right, we can see a map of right angle injury crashes that have occurred over an area of nearly 3,000 square kilometres between Clare and Crystal Brook in South Australia. Due to the relatively high levels of exposure, most crashes have occurred in and around the townships, while those crashes occurring at intersections along the higher speed roads are less frequent but often more severe, due to the very high energy nature of these crashes.

Slide 6

Generally, the risk of crashes occurring at an intersection are dictated by two factors – exposure, or the volume of traffic using the intersection, and likelihood, which is closely tied to the level of control maintained over road users traversing the intersection.

In urban areas, this means that the greatest number of crashes tend to occur at intersections with arterial and distributor roads that carry the vast majority of traffic. While signalised intersections maintain a high level of control, their placement at the highest volume intersections where arterial and distributor roads meet one another means a large number of crashes occur at these locations. Another frequent location of crashes is at the intersections of arterial or distributor roads and the local streets that join them – despite lower volumes of traffic entering the main traffic streams, a lack of control at these locations increases the risk that crashes will occur.

In rural areas, crashes tend to congregate around highly trafficked areas such as near and within townships. Crashes outside of these areas tend to be less frequent, but often much more serious due to the high speed nature of the roads along which they occur.

Poor intersection design, such as confusing intersection layouts, confusion regarding who is required to give way, poor visibility along intersecting roads or poor visibility of the intersection from the approach, can also contribute to a higher risk of crashes.

Slide 7

Generally speaking, there are three levels of control used to operate intersections. At minor T-junction intersections, no control can be employed. These are termed as uncontrolled intersections and require road users to revert to the road rules to understand who gives way to who.

The next level of control is by the use of regulatory control – which means using either stop and give way control. These intersections, termed as controlled intersections, define which roads are required to give way, and which are not. However, they still leave it to the road users to judge the situation and decide when it is safe to proceed through the intersection – a task that is often prone to error.

The greatest level of control, known as signalisation, is afforded to only the highest volume intersections. Termed signalised intersections, they are most commonly seen at the intersection of arterial and distributor roads. Generally, crashes occur at intersection when a road user, either purposely or through error, runs a red light, or with movements that are not fully controlled. At signalised intersections where filter right turns operate, which require right turning drivers to judge gaps in oncoming traffic, around half of all injury crashes can be associated with this movement.

Slide 8

Despite the level of control that may be employed, crashes are possible and when they do occur, the design of the intersection largely dictates the level of harm that can occur.

Most intersections occur at right angles. While good for visibility and improving the likelihood that a driver will see another vehicle approaching from the intersecting road, right angle collisions can be severe, due to the relative lack of protection afforded by a vehicle's design. Unlike front and rear impacts, the side of a vehicle has very little room to absorb the energy of an impact before the occupant compartment is compromised.

Appropriate speed management is also lacking at many intersections, with vehicle speeds similar to those obtained between intersections, where the risk of a right angle collision is much lower. Speed management at intersections is generally limited to observation of the posted speed limit, or control from the minor road approach, where a vehicle may be required to stop or slow down and give way before entering the intersection. There is usually opportunity for vehicles on at least one of the approaches to traverse the intersection at speed.

The potential for high speed collisions at right angle orientations mean that kinetic energy levels of a crash can be well in excess of the human biomechanical tolerance to harm. As mentioned, the relative lack of protection afforded by a vehicle when collided with on its side means that considerable potential exists for this energy to be transferred to the vehicle occupants.

Slide 9

In addition to the roles of speed and impact angle, the difference in mass between colliding vehicles, known as the mass inequality, can play a substantial role in the outcomes of a crash. When a heavier vehicle collides with a lighter vehicle, the mass inequality means that the lighter vehicle will undergo greater acceleration, increasing force on the vehicle and in turn increasing the chance of severe injury outcomes to its occupants.

The issue of mass inequality is most recognisable with heavy vehicles. When a light vehicle collides with a heavy vehicle, the effect that the difference in the vehicle's mass has on the crash outcomes are obvious. The lighter vehicle will undergo much greater deformation than if it collided with a vehicle of similar mass. In addition to the greater force felt by its occupants, the occupant compartment can be compromised to a much greater extent, increasing the risk of crushing injuries.

As well as with heavy vehicles, mass inequality can greatly disadvantage vulnerable road users, which are generally much lighter than the vehicle with which they collide. The much greater force felt by a cyclist, pedestrian or motorcyclist in a crash with a light vehicle compounds the effects of the lack of protective structure.

Slide 10

Now, knowing how harm can occur at intersections, let's take a look at what mechanisms are available for eliminating this harm.

Slide 11

Reducing the likelihood of a crash is often a primary consideration of many intersection designs. Most engineering features implemented at intersections are focussed on improving the level of control, increasing guidance and conspicuity, and reducing the possibility of confusion and error. This focus on likelihood has served us well, with many intersections providing efficient mobility to high volumes of road users. However, as it attested in crash history Australia wide, errors still occur and these errors sometimes lead to severe injury outcomes. And as such, a focus on likelihood alone will not achieve zero harm.

When a crash does occur, the best chance to avoid a severe injury outcome is to reduce the kinetic energy of the collision to below the threshold of the human body's biomechanical tolerance to harm. In practice, this means reducing speed and impact angles to the level where the kinetic energy imparted upon vehicle occupants involved in the crash is not enough to cause harm. To do this, the design of intersections needs to be reimagined to one where both likelihood and consequence are a part of the design brief, instead of likelihood alone.

There is also a third part to the equation – exposure is a key mechanism of harm and therefore can also be used to our advantage. Some movements, such as right turns and through movements, are more prone to high severity outcomes than others. Banning certain movements and redirecting traffic to safer intersections can also be a powerful tool in the effort to eliminate harm. The example you can see here was implemented along Greenhill Road, a centrally located arterial road in Adelaide. The works focussed in preventing right turns from intersecting local roads, instead redirecting traffic to U-turn facilities that reduced exposure to right angle conflicts.

Slide 12

Next, let us discuss the primary treatments – those best aligned to the Safe System objective of eliminating fatal and serious injuries.

Slide 13

Grade separation is one of the best options we have for eliminating harm at intersections, as it largely eliminates the intersection of traffic streams by allowing them to cross over or under one-another. The only points of collision that remain are where traffic enters or exits the traffic streams through slip lanes. When an intersection is grade separated, right angle and right turn crashes, which often represent the majority of harm at intersections, are eliminated as the associated movements no longer exist. Rear end crashes, which can contribute to harm, are also greatly reduced as there is no longer a need for traffic to slow or stop before traversing the intersecting traffic stream.

Grade separation involves a substantial amount of work and generally more land than an at-grade intersection. The costs associated with the physical construction work and the acquisition of land, especially at already constricted locations such as in urban areas, means that their use is limited.

The large financial costs involved in grade separating intersections, as well as their expansive footprints mean that they are generally reserved for use along high-speed, high-volume restricted access roads, such as freeways and expressways. Partial grade separation is used to a limited extent in urban environments, where major arterial roads cross one-another – the benefits of such partial grade separation are not as great as with full grade separation, as right turns are generally still required and dealt with through signalisation.

Slide 14

Roundabouts have been used for many decades, though their safety benefits have only more recently been understood. They represent one of the best at-grade solutions that we currently possess.

The geometric design of roundabouts means that all vehicles are required to slow down before proceeding through the intersection, ensuring the kinetic energy of a crash will be far lower than at traditional right angle intersections. Additionally, the reduced impact angle between vehicles at locations of conflict mean that the relative velocity and therefore acceleration and force undergone during a crash will also be reduced.

The safety benefits of roundabouts are due in a large part to their ability to manage speed through their design. This means that the design of a roundabout can greatly affect its ability to reduce or eliminate harm. Larger roundabouts, especially along multi-lane roads, are often less capable of achieving safe intersection speeds between vehicles. Access requirements for larger vehicles, such as trucks and buses, can also compromise the ability to reduce light vehicle speeds, though design details such as roll-over aprons can help avoid such tradeoffs.

Slide 15

In some circumstances, roundabouts can have reduced capacity compared to signalised intersections. More recently, large capacity signalised roundabouts have been used to combine the capacity benefits of a signalised intersection with the safety benefits of a roundabout. Signalised roundabouts work by coordinating vehicle movements onto or around the circulating area of the roundabout. Partial signalisation has also been used on roundabouts where unequal flows and tidal flows on commuter routes can cause delays to traffic on the lower-volume approaches.

Over recent years, a number of other innovative roundabout designs have appeared. Mini roundabouts have become popular in Europe and some applications have been seen in Australia. The small footprints of mini roundabouts, which can be no larger than that of a traditional intersection, make them an attractive solution at small local road intersections. Larger designs such as the hamburger or cut-through roundabout, the flower roundabout and the turbo roundabout are largely designed to improve the capacity of multilane roundabouts. Turbo roundabouts, such as the one shown here also have a demonstrated safety benefit over traditional multilane roundabouts.

Another innovative solution is the compact rural roundabout. Rural roundabouts, placed at the intersection of high speed rural roads, have been designed with very large circulating radii to handle the generally high speed of vehicles approaching the intersections. This in-turn has limited their usefulness at sites with constricted space. The compact roundabout uses vertical deflection on approach to the roundabout to better manage approach speeds, and a smaller circulating radii requiring less space than a traditional design. This makes the compact rural roundabout a promising solution at sites where traditional roundabout designs would have been rejected due to their large size.

Slide 16

Raised safety platforms are a recent innovation on a relatively old form of traffic management – the speed hump. Like the speed hump, raised safety platforms rely on vertical deflection to slow vehicles as they traverse the treatment. Unlike speed humps, raised safety platforms have been developed with intersection applications in mind.

Raised safety platforms reduce risk by reducing vehicle speeds at the location of the treatment. When applied at intersections, they can reduce the speeds of all vehicles as they traverse the intersection. The speed reducing properties of raised safety platforms are dependent on their design, meaning vehicle speeds can be managed to desirable levels dependent on the application.

A variation on the raised safety platform concept is the raised intersection, where the entire intersection forms a raised platform. While raised safety platforms are successfully used on low volume, low speed roads, they have also been developed with higher speed, higher volume road applications in mind. So far, several raised safety platform solutions have been applied along arterial roads in Australia.

An example is the intersection of the Surf Coast Highway and Kidman Avenue in Belmont, Victoria. The speed limit along the Surf Coast Highway is 70 km/h, while the raised safety platform slows vehicles through the intersection to a safer 50 km/h.

Slide 17

Next, we will discuss some of the supporting treatments available to practitioners.

Slide 18

While roundabouts and raised safety platforms aim to reduce speeds to survivable levels, any reduction in speed through intersections is beneficial for reducing both the likelihood and severity of crashes. Reducing speed limits is an inexpensive means for reducing speed. While adherence to reduced speed limits, especially over short distances such as through intersections, can be an issue, it is important to remember that speed reduction, and not speed limit adherence, is the primary concern when prioritising harm reduction.

An issue with this approach is, however, the inability to ensure lower speeds are adhered to. Compliance to reduced speed limits over such short lengths of roadway and at regular intervals could be difficult to achieve. Speed enforcement, such as the use of speed cameras, may not be possible due to the close proximity of camera and speed limit signage locations.

Though tempting due to its low cost, speed limit reductions alone are likely to be only moderately successful at best. Better results may be obtained by road design that reinforces the lower speed environment. Such road design may also be successful in isolation.

Slide 19

Full signalisation, including the full-time control of right turns, can substantially reduce the likelihood of crashes at an intersection as uncontrolled turning movements commonly represent a high proportion of injury crashes at intersections where they are employed.

Uncontrolled right turn movements are especially hazardous at signalised intersections where they are employed. They require a driver to judge gaps within oncoming traffic, commonly comprising two or more oncoming lanes. Uncontrolled right turns are particularly hazardous for pedestrians and cyclists, as drivers making uncontrolled right turns may be focussed on judging gaps within oncoming vehicular traffic, rather than looking for these vulnerable road users.

While full signalisation can benefit a reduced likelihood in crashes, in isolation, signalisation does not deal with the consequence of crashes as speed is not managed in consideration with the types of interactions to which road users are exposed. Another complicating factor is that signalisation is commonly applied to high exposure intersections and intersections where rising demand dictates its need, thereby increasing exposure and therefore the risk of crashes. While signalisation alone will not achieve Safe System outcomes, combining signalisation with speed reducing treatments, such as raised safety platforms, may achieve near Safe System levels of performance.

Slide 20

Another way to reduce harm at intersections is to remove exposure to the more severe types of conflicts.

An example well-aligned to Safe System objectives is the left-in, left-out intersection, where all cross-road and right turn movements are redirected to U-turn facilities on the major road. While crashes are still possible through the left turn and U-turn movements, their severities are likely to be less severe than that of a right angle or right turn crash.

An added benefit of this type of treatment is the simplification of the intersection. Less movements are possible, meaning the driver’s task is simplified and errors are less likely to be made. Such simplification may also provide additional ability to safely deal with pedestrians and cyclists.

Slide 21

Though not well aligned to a system’s perspective of road safety, improved signage can nevertheless help reduce harm by reducing the likelihood of error by road users. Improving signage can be particularly effective at locations where signage is below acceptable standards, or where there is a known, related safety issue.

More recently, technological innovations have led to electronic signage that can be activated by a vehicle’s presence. This brings the benefit of only displaying a warning or message when it is needed and can be related to an observable risk, so that its effectiveness is better retained.

One example is the rural intersection activated warning sign. When triggered by a vehicle exiting from a side road, the sign acts to provide warning or reduce the speed limit along the main road, with the aim of alerting passing vehicles and reducing their speed in the presence of the entering vehicle.

Slide 22

A proportion of crashes can be traced back to intersection or control conspicuity, where the driver was either unaware of the intersection or the need to give way to other traffic. A lack of intersection awareness is particularly problematic in rural areas, where infrastructure can be minimal.

A standard response is to increase and improve signage on the minor road approaches to the intersection. This may involve the installation of duplicate signage and advanced warning signs. Channelisation can also be used to improve intersection conspicuity by drawing attention to a change in the road environment.

The staggered T-junction design has been a standard response to improve rural intersection safety. Part of this design's benefit is to highlight the intersection through termination of the minor roads. However, the use of staggered T-junctions has become unfavourable due to their high cost for minimal gain. Superior designs, such as roundabouts, can be implemented for similar cost.

Slide 23

Channelised and auxiliary turning lanes are often used to remove turning movements from through lanes and provide some separation from intersecting movements. This response can reduce rear end crashes when traffic waiting to turn does not queue back into the through lanes.

Such treatments may also simplify the driving task by separating and channelling individual tasks. For example, channelising uncontrolled right turns may reduce pressure to expedite the turn and therefore the risk of error by selecting inappropriately sized gaps in oncoming traffic.

Channelisation can also lead to potential safety issues. A prime example is the channelization of left turns at signalised intersections. Channelisation of the left turn can give an impression of priority for vehicle drivers, increasing the risk of conflict with crossing pedestrians.

Slide 24

Other general design improvements can benefit safety, especially where such design features are lacking. Adequate street lighting can improve the conspicuity of road users at night, reducing the risk that approaching drivers will miss detecting conflicts. Street lighting is especially important where pedestrians are expected, as they can be particularly difficult to see when dark.

Inadequate skid resistance can lead to serous safety issues, due to the increased braking distances that result. Improving already adequate skid resistance can help to improve safety, especially where there is a substantial risk of encountering conflicting movements at speed, such as along the major road approaches to intersections.

Sight distance is another design feature that may compromise safety when inadequately provided for. In addition to the regular consideration of static sight obstructions, such as vegetation and road furniture, consideration should also be given to dynamic visual obstructions. An example as shown here is dynamic visual obstruction from left turning vehicles on the major road, which can mask the presence of through vehicles from the perspective of a driver turning from the minor road.

Slide 25

A complete rethink of the way we design intersections is required if we are to achieve the elimination of death and serious injury on our road network. However, despite some promising solutions, we cannot achieve elimination through road design alone. Enforcement has presented some improvement in safety at intersections, especially at signalised intersections where the widespread use of combined red light and speed cameras had somewhat reduced intentional red light running and speeding.

Autonomous vehicle technology represents substantial possible gains in safety at intersections. Currently, autonomous braking technology is able to detect possible rear end collisions and reduce impact severity or completely avoid a crash. Upcoming technology should assist in avoiding other crash scenarios that are currently difficult to detect, such as right angle crashes.

Connected autonomous vehicles, or CAVs, are able to communicate with each other and smart infrastructure, such as connected traffic signals. While still some time from becoming mainstream, CAVs represent a promising solution to much of the harm that occurs at intersections. For example, CAVs technology may be able to completely avoid crashes resulting from red light running by stopping a vehicle before it traverses the red light.

Slide 26

(No transcript)

Appendix C3. Module 3, Snippet 3 transcript

Slide 1

Welcome to Module 3, Snippet 3 of Safe System for Universities. In this snippet, we will be talking about harm due to lane departures and interventions for minimising this harm.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let’s take a look at how harm from lane departures occurs.

Slide 5

Road departure crashes are a substantial problem and one of the main contributors to harm on our roads. Road departures occur when a vehicles leaves its lane and collides with a vehicle in another lane, an object on the roadside, or rolls over as it departs the lane.

Fuelled by high speeds and long travel distances, road departures represent the majority of fatal and serious injury crashes in rural and remote areas. Exposure plays a large role in dictating where these crashes will occur, with many situated on arterial highways carrying the majority of traffic. Here, we see an about 15 km section of both the Horrocks and Barrier Highways north of Adelaide, in South Australia, which together serve both as important tourist and freight links. Here we can see a number of hit fixed object crashes, resulting in both hospitalisation, represented by the dots in red, and fatalities, represented by the dots in black, that occurred in the ten-year period from 2009 to 2018.

Often overlooked, road departure crashes also represent a substantial part of the harm problem in urban areas. The answers for mitigating harm caused by road departures in urban areas are often less clear than the answers for rural and remote areas. In the right image, we can see a map of hit fixed object crashes over a 10 square kilometre area of Adelaide's inner western suburbs. Most of the injury crashes seen here have occurred on arterial and distributor roads, where speeds and traffic volumes are higher, with a mix of crashes at midblock and intersection locations.

Slide 6

Most road departures end with little seriousness with respect to the outcomes. Either the driver of the vehicle is able to recover the errant vehicle or the vehicle stops before any obstacles or other vehicles are hit.

Harm occurs when a driver is unable recover the errant vehicle, or is unable to do so in time. The first mechanism for harm is a head-on collision with another vehicle. This occurs when an errant vehicle crosses paths with another vehicle travelling in another lane, coming in the opposing direction. This can occur even when the road is divided by a median. Head-on crashes can also occur when a vehicle is overtaking and is required to travel along the opposition direction lane to do so. The generally high severity of these crashes is due to the often very high relative speed of the colliding vehicles.

Harm can also occur when an errant vehicle leaves the road and strikes a roadside object. Non-frangible objects, those that for all intents and purposes do not move when struck, are the most likely to cause severe outcomes.

When a vehicle leaves the road, harm can occur even when an object is not struck. Roll overs occur when a vehicle "trips" and rolls onto its side or roof. A tripping mechanism can be anything from the road surface to a curb to uneven roadside ground. Vehicles with higher centres of gravity are more prone to rolling over. Heavy vehicles can even roll over without loosing control – the forces exerted on a heavy vehicle when cornering can be enough to cause it to tip.

Rear-end crashes, though not normally due to lane departures, are another mechanism for harm prevalent in urban areas. While most rear end crashes result in low severity outcomes, the sheer number of these crashes has led them to contribute meaningfully to the number of deaths and serious injuries on our roads.

Slide 7

The mechanisms for lane departures can differ between situations. In general, they either can occur as a drift-off, where the vehicle departs the lane in a controlled manner, or as a yaw, where the vehicle quickly becomes uncontrolled and acts largely free of the driver's inputs.

The first scenario, a drift-off, occurs when the driver is in some way distracted and allows the vehicle to depart the lane. At this stage, the vehicle is still controllable but the driver is not using this control to keep the vehicle within its lane. Compared to a yaw, a drift-off scenario still provides scope for the driver to retain control and correct the vehicle's path. Generally, successful regain of control will require progressive brake and steering inputs. If this is done before colliding with another object, such as a roadside hazard or another vehicle, a crash can be avoided.

The second scenario is a yaw. A yaw occurs when the driver has lost control of the vehicle and it begins to spin around its vertical axis. Yaw scenarios can result from unsuccessful recovery of a drift-off scenario or from an evasive manoeuvre, such as to avoid an animal on the roadway or another vehicle that has entered the vehicle's lane. Yaw scenarios are generally not recoverable by a driver, but may be prevented by electronic stability control if fitted to the vehicle.

Both drift-off and yaw scenarios can result in either a head on crash with another vehicle or a run off road crash that results in a roll over or collision with a hazardous object. While the risk of a lane departure may seem more prevalent around horizontal curves, they are also likely to occur on straight sections of road, where a lack of concentration for only a few seconds can lead to a drift off scenario. It is important to remember that once a yaw occurs, a vehicle is likely to traverse the centre line of an undivided roadway, even if the final crash occurs on the left side of the road. This scenario is referred to as a double yaw and is a common mechanism for run off road crashes to the left side of the roadway.

Slide 8

As we have discussed, lane departures can lead to either head on or run off road type crashes. Whether a lane departure results in a head on or run off road crash is dependent on whether a vehicle travelling in the opposing direction is present or not at the time of the loss of control. For this reason, the relative risk of either a head on or run off road outcome is highly dependent on the volume of traffic using the road. A New Zealand study found that while the rate of head on crashes per kilometre of roadway increased in a linear relationship with traffic volume, the rate of run off road crashes increased in a logarithmic relationship, so that the relative likelihood of a head on crash was greater once a threshold volume was reached.

The relationship between traffic volume and the rate of head on crashes means that they can become a substantial issue as traffic volume increases. The need for centreline protection is exacerbated by the fact that most run off road crashes involve a centreline incursion. All run off road to the right crashes involve a vehicle crossing the centreline, as do a substantial proportion of run off road to the left crashes. This is because a key mechanism for run off road to the left crashes is the double yaw, where a vehicle crossed the centreline before departing the roadway to the left.

Unfortunately, most rural roads in Australia and New Zealand are poorly designed to cope with crashes that involve a centreline incursion. At best, most roads involve some type of roadside barrier to help mitigate run off road impacts. In comparison, centreline protection would enable mitigation of almost all head on and run off road to the right crashes, as well as a substantial proportion of run off road to the left crashes. This is achieved by a centreline barrier that can capture a vehicle before it yaws off to the left and departs the roadway.

Slide 9

Now that we understand the core mechanisms of lane departure crashes, let's look at the two main ways of treatment, road safety barriers and clear zones.

Slide 10

Clear zones are flat areas of ground, free from obstacles, that flank the side of a roadway. They provide space for an errant vehicle to slow down and stop before colliding with any hazardous objects, thereby averting a potentially severe run off road crash and instead resulting in a loss of control incident from which a driver may potentially be able to drive away. In Australia and New Zealand, Austroads guidance recommends clear zone widths dependent on adjacent roadway's design speed, traffic volume and the lateral slope of the clear zone.

In practice, clear zones rarely conform to ideal standards. In all but the best maintained motorway and arterial rural road environments, roadsides are often maintained well below the recommended clear zone standards. Common issues are reduced clear zone width, hazardous obstacles within the clear zone and low quality ground preparation. Maintaining these facilities to recommended levels can be prohibitively expensive and can require land acquisition and clearing intruding into adjacent private land or within the roadside vegetated roadside reserve that, in agricultural areas, can form a substantial part of the habitable environment for wild animals.

Poor ground quality can be a core issue with clear zones and may lead to high severity roll over crashes. Soft ground material, ruts and low lying obstacles such as drainage pits can all lead to tripping hazards that may result in a roll over. The quality of clear zone required to prevent a roll over can be underestimated and seemingly well maintained clear zones, such as the one pictured here, can initiate roll overs.

Slide 11

Critically, recent evidence has shown that the severe crashes that are meant to be treated by clear zones are not completely eliminated, irrespective of how wide the clear zone is. While clear zones are effective at eliminating a proportion of these crashes, their effectiveness is subject to a diminishing rate of return to the point where adding to the width of substantially wide clear zones will have little affect on the rate of severe crashes.

In other words, there is a residual of run off road crashes that are not affected by clear zone width. This residual is enough to ensure that a substantial proportion of the lane departure problem will remain, even when clear zones designed beyond current recommendations are employed. For this reason, the most recent editions of Austroads Guides to Road Design and Road Safety rely less on the use of clear zones as a primary way to treat lane departure crashes on high speed rural roads.

Slide 12

A study performed in 2011 by the Centre for Automotive Safety Research at the University of Adelaide looked at the simulated outcomes of lane departures, based on real crashes that were investigated by the centre. The reconstruction of vehicle speed and movement was used to recreate conditions of the crash, which were then exposed to a scenario where the vehicle was able to slow to a stop without colliding with roadside objects. This process was used to estimate the lateral displacement of the vehicle from its initial travel lane.

The results of this study showed that vehicles regularly depart roads with enough speed to result in a severe outcome in the event of a collision with a roadside object, even when the vehicle has reached the extent of current clear zone widths. The findings of this study also suggest that clear zones would need to be unrealistically wide if serious crashes with roadside objects are to be eliminated.

Slide 13

Road safety barriers are becoming the primary treatment for harm caused by lane departures. They are in most situations considered as leading practice and, depending on their design, can achieve near Safe System levels of performance. The fundamental principle behind the operation of road safety barriers is to capture a lane departed vehicle before it collides with a more hazardous object.

Historical thinking led road safety barriers to be considered as hazards in their own right and therefore their use to be avoided unless necessary. Knowledge of their benefits has since moved forward to a point where road safety barriers are considered as preferential to the provision of clear zones. While a collision with a road safety barrier comes with the risk of injury, this risk is substantially lower than if the vehicle in question is allowed to continue its lane departure and roll over, or collide with a hazardous object or another vehicle.

While clear zones are idealistically meant to prevent crashes altogether, barriers do not prevent lane departure crashes but instead reduce their severity. This is achieved by capturing and controlling the departure of vehicles. Barriers can therefore be viewed as a liability, as they become a maintenance issue whenever they are struck. This is particularly true of flexible barriers, which require maintenance after even minor hits. However, another perspective on the maintenance issue is that every collision with a barrier is a potential severe injury crash that has been avoided.

The provision or road safety barriers can result in an increase in lane departure crashes, when compared to the use of clear zones. However, the benefit of road safety barriers is that these crashes are generally of a reduced severity. The result is a reduction in serious injury crashes, compared to where clear zones are employed.

Slide 14

Road safety barrier performance, or their ability to reduce the severity of crashes, is largely dependent on their design. Road safety barriers are general split into three categories: rigid, semi-rigid and flexible barriers. Rigid barriers, generally made of concrete or steel, often result in the most severe outcomes. Semi-rigid barriers are able to deflect on collision and often result in less severe outcomes, due to the reduced acceleration on colliding vehicles. Most semi-rigid barriers in Australia and New Zealand are of a steel w-beam design. Flexible barriers provide the greatest level of deflection and therefore the lowest acceleration colliding vehicles and their occupants, which often leads to the least severe outcomes. Wire rope safety barriers are the most common type of flexible barriers.

It is important to consider the context of application when selecting the desirable type of barrier. While flexible barriers are best for most applications where light vehicle crashes are concerned, they may not be appropriate for containing heavy vehicles and therefore the use of stronger, more rigid barrier designs may be required. The deflection of barriers also needs to be considered. Where hazardous objects are very close to the roadside, the use of more flexible barriers may still lead to a collision with the hazard behind the barrier.

Road safety barriers also present as substantial hazards some road user types. Motorcyclists, and to a lesser extend bicyclists, may be severely injured in a collision with a barrier. The common mechanisms of injury are collisions with the barriers support posts in a sliding position, and slicing and snagging from sharp points along the barrier when still mounted on the motorcycle or bicycle. W-beam barriers are substantially hazardous when the top edge of the barriers and support posts are left exposed, and the support posts are left unprotected.

Slide 15

As we have discussed, clear zones have historically been employed as a primary treatment.

Clear zone surfaces have idealistically been flat or with a limited slope, and obstacle-free. While high standards are able to be maintained along the highest priority roads, such as freeways and motorways, clear zones along many other roads have either been designed or maintained below Austroads guidelines.

Along dual carriageway roads, clear zones have also been employed to separate opposing direction lanes. Along many of these roads, median barriers are now being retrofitted as the performance issues of clear zone-based design has been acknowledged.

However, the use of road safety barriers has historically been reserved for spot treatment when hazardous obstacles and non-traversable roadsides were unable to be removed or corrected.

Slide 16

Today, the treatment of lane departure crashes is being aligned to Safe System principles by prioritising full length, flexible barrier installations over clear zones. Other less forgiving barrier types, such as semi-rigid and rigid barriers, are employed where flexibles barriers are not feasible, such as where large roadside drops are present or where barrier deflection cannot be safely contained.

In order to achieve near Safe System performance, flexible barriers are being employed along both the roadside and centreline for the full length of the roadway. This ensures that any vehicle departure will be captured by the barrier.

Counter to historical practice, well maintained, wide and flat run out areas are utilised only at locations where barrier installation is not feasible.

Slide 17

Now, we will take a look at barrier design in the context of a primary Safe System treatment.

Slide 18

An example of primary Safe System design is being standardised by Regional Roads Victoria to guide their high speed road design now and into the future. These standardised designs are based on the context of achieving a fatal and serious injury-free network by 2050, and are based on certain assumptions such as the safety performance of vehicles across the network in 2050. These designs have been created with the recognition that while Safe System performance will take time to achieve, we need to set a tangible target date if it is ever to be achieved.

Primary designs are context sensitive, and are based on assumptions of the role and strategic importance of roads now and into the future. Roads of greater importance, such as very high-volume roads and strategic freight routes may receive high levels of infrastructure funding. For roads of lesser importance, infrastructure funding is likely to be scarce and Safe System performance will need to be achieved in other ways.

Travel mode is an important consideration that may dictate changes to standardised design. For example, heavy vehicle routes may require altered barrier design to ensure heavy vehicles departures are contained. Achieving Safe System performance for other modes, such as motorcycles, may not be possible with current knowledge and may require alternative design as this knowledge improves.

Slide 19

Transformative works that see route-level implementation of Safe System aligned infrastructure improvements will only be possible for a small proportion of the network. Along these roads, current extra-urban speed limit setting can be upheld to prioritise faster travel times for the high volumes of traffic using these roads. Currently, some strategically important roadways, including the expressways and freeways that carry traffic into and between urban centres and other important locations, are built to such standards.

A high level of design means that flexible barriers will be employed along both the roadside and median to contain all errant vehicles before more severe collisions can occur. Where flexible barriers are not permissible, other barrier types may be used. Hybrid installations, such as using rigid barriers behind flexible barriers to ensure heavy vehicle containment while still providing the most forgiving design for the majority light vehicle users, may also be employed.

One concept of such a roadway has been envisaged through Victoria’s development of a zero death and serious injury strategy. This concept calls for all high-speed multi-lane roadways to be continuously barrier lined, with sealed shoulders and breakdown lanes to reduce the likelihood of lane departures and provide for safe emergency stopping areas outside of travel lanes.

Slide 20

A high level of infrastructure design may also be possible along strategically important single-lane regional and rural arterial highways. Where an appropriate level of funding is available, infrastructure improvements can be used to ensure safe travel at high speeds in line with current extra-urban speed limit setting.

Along these roads, roadside and centreline road safety barriers are employed to contain all road departures. Like with higher order roads, flexible barriers are preferred but may be replaced by other barrier types in locations where they are not suitable.

To facilitate passing without placing road users at risk of head-on collisions, passing lanes need to be provided at regular intervals. An example of this concept in practice can be seen with Sweden's "two plus one" roads, along which passing lanes are continuously provided along alternating directions of the roadway. Regular but not continuous passing lanes may be used where such a high level of provision is not feasible.

Slide 21

While the scale of transformation required is immense, the scale of road network is even larger and so we will inevitably face the question of in which roads we will choose to invest. Where high levels of financial investment are justified, such as for reasons of traffic volumes, strategic importance of a road, community value or the needs of specific road users, transformative works will be undertaken. For the rest of the network, we must find an alternative solution to providing safe mobility.

For the vast majority of our rural and remote road network, this will mean a reliance on speed management through lower speed limits, enforcement and infrastructure improvements at high risk locations, such as the use of targeted barrier installations. Currently, there remains a large gap between current rural and remote road speeds, and what is safe given the infrastructure and vehicle technologies at our disposal. Public and political attitudes to lowering speed limits, especially where travel distances are great, often mean that speed limit reductions are unpalatable.

However, in the near future, as targeted infrastructure investment continues and vehicle technology improves, achieving safe speeds will become increasingly possible. As an example, through its development of a zero death and serious injury strategy, Victoria has estimated that, by the year 2050, speeds of up to 80 km/h will be safe where head on collisions between passenger vehicles are possible.

Slide 22

Whatever specific design approach is taken, a socially and politically driven conflict between safety and mobility is likely to endure. Envisioning what constitutes a safe road design is ultimately much easier than finding a solution that satisfies both the desired safety and mobility capacities set by our society.

One avenue for settling this conflict is to employ a practice of safe mobility. This means that mobility becomes a function of safety to ensure that safe road access is always provided. The conflict then becomes one between mobility and financial expenditure.

On high order road where financial outlay can be justified, transformative infrastructure works can be used to maintain safe mobility at higher speeds, such as those in-line with current extra-urban speed limit setting. On low order roads where traffic volumes are limited and costly infrastructure improvements are unable to be funded, speed management must be used to provide safe mobility. This ultimately means lowering speed limits and managing new speed limits in-line with what is survivable in environments where lane departure crashes are permissible.

The most difficult decisions will likely be those along high volume but lower priority routes that do not form a key part of the network strategy. The hard decision of whether to design up in order to allow higher speeds, or reduce speed to ensure safe mobility without extensive infrastructure investment, then becomes a question of social priority where a choice must be made between improving mobility or redirecting funding to other more critical social investments.

Slide 23

An example implementation of Safe System aligned roadway design comes in the form of the infrastructure improvements rolled out along a section of the Princes Highway between Longwarry and Traralgon in eastern Victoria. In this case, a transformative approach was taken to secure Safe System performance with regard to lane departure risk while maintaining the mobility expected of such a strategically important roadway.

The works implemented along this route constitute a step change towards harm elimination. Rather than focussing on only the highest risk locations of the route, the entire road environment was transformed to bring safety performance up to Safe System levels.

At the core of this approach was the mass installation of full length roadside and median barriers. Flexible barriers were prioritised and other barriers types where utilised only where flexible barriers were not permissible.

Slide 24

Starting in the early 2000, full-length road safety barrier investment was prioritised along the route under the Safe System Road Infrastructure Program, or SSRIP. The progress of barrier installation was modest until funding was attained through the Towards Zero Action Plan in 2017. By 2019, road safety barrier installation should be completed along the vast majority of the route.

In combination with vehicle safety technology improvements and ongoing speed management, it is projected that this section of roadway will be free of fatality and serious injuries by the year 2050 or before.

Slide 25

While full length barrier installation and speed management constitute the primary approach to achieving Safe System performance, other treatments are available that, while not achieving harm elimination alone, can support the journey towards this goal.

Slide 26

Sealed shoulders are one of the most commonly used lane departure treatments across Australian and New Zealand roads. Sealed shoulders provide drivers with room to recover from some lane departures and can therefore reduce the likelihood of lane departure crashes. They are especially effective when combined with driver warning mechanisms such audio tactile line marking.

Centreline audio tactile line markings are another regularly used treatment for reducing the likelihood of lane departures across the centreline of an undivided roadway. These can be combined with wide centrelines to further reduce crash likelihood. Like sealed shoulders, wide centrelines increase the amount of space that a driver has to recover from a lane departure before venturing into the path of obstacles, which in this case are oncoming vehicles. An additional benefit of wide centrelines is that they provide space for centreline barriers to be retrofitted at a later stage.

Where barriers cannot be employed, high quality, well maintained run off areas reduce the likelihood that lane departures will result in severe outcomes through rolling over or collisions with hazardous objects. Such run out areas also allow sufficient space for barriers to be installed at a later stage.

Slide 27

There are many other treatments that can help reduce the risk of crashes. It is important to remember that most of these work on reducing likelihood but do not affect the consequences of crashes when they occur. Most good road design practices will to some extent benefit road safety, but will not lead to the elimination of fatal and serious injuries. Good road design is about achieving at least a minimum standard across the entire network and treating sub-standard locations that pose a heightened risk to those traversing their locations. However, to achieve Safe System performance, we will need to look past these historical practices as the only form of intervention.

Beyond conventional practices, a number of technologically-based solutions are coming to market and may prove to be viable supporting treatments. Vehicle activated signs are becoming more prevalent as a cost-efficient treatment at high-risk locations such as rural intersections and out of context curves on high speed roads. One such device first implemented in New Zealand and known as the rural intersection active warning system, or RIAWS, is activated by side road traffic and warns drivers along the main road that a vehicle is about to enter the roadway. A modified version reduces the speed limit along the main road when side road traffic triggers the system. This technology is being trialled in Victoria and South Australia, and has shown promising results for reducing vehicle speeds through intersections when side road traffic is present.

Slide 28

Considerations outside of the infrastructure realm offer varying degrees of promise for reducing the harm that is being created on our roads. Speed enforcement is likely to remain a key tool for maintaining safe mobility. The role of speed enforcement will need to be carefully considered as it will not alone solve the problem. Speed enforcement is likely to be of greatest benefit where it can help maintain speeds within a reasonable envelope and reinforce the setting of speed limits. A key improvement to speed enforcement could be the use of mobile point-to-point speed cameras, which may help fill the gap of enforcement along lower order regional and rural roads.

Autonomous vehicle technology is fast gaining pace. A key limitation of autonomous vehicles is looking to be the road environment along which they are travelling. Autonomous technology requires consistent and easy to read road environments to be effective. A key challenge for road system managers will be to implement and maintain delineation, signage and overall road environment design that is compatible with autonomous vehicles.

A key part of the Safe System is acknowledging the limitations of humans and designing a road transportation system that considers these limitations. Further consideration of human needs and limitations will play a part in a Safe System. As well as design that is accepting of human error, which play a core role of Safe System-aligned design, is design that helps to reduce human error. An example of this type of design is regularly spaced rest areas along long distance rural routes to help alleviate the effects of driver fatigue.

Slide 29

(No transcript)

Appendix C4. Module 3, Snippet 4 transcript

Slide 1

Welcome to Module 3, Snippet 4 of Safe System for Universities. In the last two snippets, we have discussed ways in which harm can be eliminated for motor vehicle users. Now, we will look at how to eliminate harm for vulnerable road users.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let’s take a look at what a vulnerable road user is and how they can be harmed.

Slide 5

A vulnerable road user, or VRU for short, is any road user mode that is especially susceptible to harm. This is generally because of a lack of protection normally afforded by being an occupant of a motor vehicle. Pedestrians, bicyclists and motorcyclists are the most common forms of vulnerable road users, although this category also includes the likes of skateboarders, mobility scooter users and others.

While pedestrians and bicyclists are often talked about in the same conversation, motorcyclists are generally discussed separately due to their individual problems and needs. In this snippet, we will focus on pedestrians and bicyclists. Motorcyclists will be discussed in next Snippet.

Slide 6

Vulnerable road users are particularly susceptible to harm. This is due to a combination of fragility, speed and mass.

The human body is fragile. Compared to the structure of a motor vehicle, it is particularly susceptible to damage. Occupants of most modern motor vehicles are protected from harm by the surrounding structure of the vehicle. When a crash occurs, the vehicle's protective structure absorbs most of the crash energy, reducing the potential for harm to occur to its occupants. Vulnerable road users are generally afforded no protection by their particular mode. When a crash occurs, all of the crash energy is absorbed by the human body.

Speed is also a major contributor to harm. The human body evolved to survive low speed impacts, such as running into a solid object or falling from a low height. The human body was never designed to cope with the forces of a crash with a high speed motor vehicle.

Mass is the other contributor to the harm endured by vulnerable road users. When two objects of equal mass collide, they both undergo the same acceleration. As one of the objects decreases in mass relative to the other, its acceleration becomes greater. This is Newton's three laws of motion in practice. Vulnerable road users tend to be much less massive than the objects they collide with. It results that in a crash, most of the acceleration is undergone by the vulnerable road user and not the other object with which the vulnerable road users collides.

Slide 7

Generally speaking, there is a speed at which pedestrians and cyclists can safely interact with motorised traffic. Above this speed, a risk of fatal or serious injury outcomes exists and it no longer becomes acceptable for interactions to occur. This speed is often cited as being 30 km/h to prevent fatal outcomes, though it could be as low as 20 km/h if serious injuries are also to be prevented.

The speed at which interaction is safe is also going to be dependent on the road users themselves. For example, children and the elderly are more susceptible to injury and so the safe interaction speed is likely to be lower.

For some interactions, there may be no safe speed, such as between pedestrians, cyclists and heavy vehicles. Interactions like these are unsafe regardless of speed and must be dealt with in other ways.

Slide 8

Currently, our road networks generally do not cater well for vulnerable road users. In urban areas, space is often at a premium, meaning within the carriageway there is competition between the use of space for different modes. Our consideration of the road network function largely follows a motor vehicle-oriented perspective. While walking and cycling can be well catered for where space and a well-conceptualised demand exits, the needs for these modes are generally underserviced in order to cater for the larger demand for motor vehicle access.

In the context of a road transportation system, pedestrians and cyclists are viewed as another mode of transportation alongside motorised forms. This has produced a legacy whereby pedestrians and cyclists are required to fit the system laid out in this context. As a result, pedestrians and cyclists are often required to interact with motorised modes without much consideration for their specific needs. In other words, access to the system is granted without consideration of their extreme vulnerability.

As an example, consider an standard signalised intersection. Pedestrians may have their own phase and cyclists are often required to use the same phase as motor vehicles. However, both are required to intersect with motor vehicle streams, which at these locations operate under speed conditions that do not take into account the extreme vulnerability of the pedestrians and cyclists with which they interact.

Slide 9

While cyclists and pedestrians are well-catered for in some discrete sections of the road network, route level access can have many gaps. A common gap is accessibility across heavily-trafficked roads, where priority is given to the larger volumes of motor vehicles and often requires people to judge gaps in traffic in order to cross.

When space becomes a premium, pedestrian and cyclist are often the first to lose accessibility. Examples are bicycle lanes running out before intersections, where additional space is required for turning lanes; and narrow footpaths alongside multi-lane roads.

Pedestrian and cyclist facilities are often required to perform several functions. For instance, bicycle lanes often revert to on-road parking outside of peak traffic times. Footpath space is generally required for multiple functions, such as space for utilities and roadside furniture; and uses common to the adjacent land, such as dining facilities outside of restaurants.

Where space is provided, the comfort and vulnerability to harm of pedestrians and cyclists is often not well-considered. Footpaths can run alongside roads without any perceived or real protection from errant vehicles or those simply accessing adjacent land. Bicycle facilities often reside on the roadway itself, with little room between cyclists and high speed traffic, let alone any form of physical separation able to protect cyclists from vehicles or cyclists straying out of their lanes.

Slide 10

Next, we will take a look at the primary Safe System aligned treatments available to help eliminate harm to pedestrians and cyclists.

Slide 11

Primary treatments for eliminating harm are essentially similar for both pedestrians and cyclists. They must be separated from motorised traffic or traffic speeds must be managed to safe interaction speeds. For pedestrians, this means providing separation between footpaths and roads where traffic speeds are above the safe interaction speed.

In some locations, physical separation may not be desirable from an amenable or aesthetic perspective. At moderate urban speeds, spatial separation such as through the use of vegetation strips may be considered as adequate, though this in itself may not always guarantee a safe outcome.

Where motorised vehicle speeds can be managed to acceptable levels, there can be minimal separation between them and vulnerable road users. With careful design, mixing these road users modes can itself help to manage motor vehicle speeds as the road environment becomes ambiguous and motor vehicle priority is no longer perceived.

Slide 12

Where pedestrians cross roads, they must be separated from motorised traffic when safe interaction speeds cannot be maintained. This is a particular challenge in the urban environment, as spatial constraints and amenity issues mean that grade separated crossings are often undesirable or not feasible.

For most urban locations, speeds will need to be managed in order to maintain safe interactions where pedestrians cross traffic streams. Physical treatments such as raised platforms at intersections and vertical deflection at pedestrian crossings may be sufficient to achieve safe interaction speeds.

Pedestrian access across arterial urban roads are a considerable challenge and will require a complete rethink about how we prioritise traffic along these roads.

Slide 13

Facilities well-aligned to Safe System outcomes are already available for cyclists in many locations around Australia. There exists a growing network of dedicated bikeways and shared-use pathways that link with the greater road network. Along these paths, interactions with motorised traffic needs only to be managed where they join or cross the road network.

Along roads with moderate speeds and vehicle traffic volumes, separated bicycle lanes are necessary. Physical separation can be achieved through the use of barriers, non-mountable curbs or in combination with on road parking facilities, where parked vehicles provide a level of physical protection between cyclists and vehicles.

Where safe interaction speeds can be managed, mixing of bicycle and vehicle traffic can be encouraged. For our current network, this is generally limited to local roads with little vehicle traffic. As perceptions of appropriate speeds broaden, managed interactions may become possible over other parts of the network. Where heavy vehicles are present, mixing is likely to be unmanageable, irrespective of speed.

Slide 14

Now, let’s look at some supporting treatments that can help to reduce harm to pedestrians and cyclists.

Slide 15

While speeds above a safe interaction speed may be undesirable from a safety perspective, they are often considered as beneficial from a mobility perspective. For the time being, this tension is unlikely to be solved and so speeds will likely remain higher than is desirable. In such circumstances, lowering speeds by any amount may not fully eliminate harm, but it will be helpful in reducing harm. Such outcomes are already being seen across wide areas of the local road network, with many local governments opting for 40 km/h speed limits along their road networks, and backing these speed limits with physical measures to manage speed.

Reducing motorised traffic volumes will undoubtedly benefit vulnerable road user safety. Although any motorised traffic still poses a threat of harm, reduced volumes reduce exposure to possibly harmful events. Where motorised traffic capacity is considered as strategically important, reducing exposure to motorised traffic could also be achieved by moving key pedestrian routes away from these high volume roads.

Along midblock locations, both formal signalised and non signalised crossings, and informal pedestrian crossings such as pedestrian refuge islands, can be used to guide pedestrians to cross at safer locations along the roadway. Ideally, safe crossing at these locations would be reinforced by speed management to lower interaction speeds.

At intersections, signalised crossings can be used to provide priority to pedestrians crossing the road. Uncontrolled vehicle movements across pedestrian crossings, such as filter right turning movements, should be avoided. Especially at high pedestrian volume locations, separate pedestrian phases can be used to stop all motor vehicle movements when pedestrians are crossing.

Slide 16

A substantial proportion of fatal pedestrian crashes involve pedestrian intoxication. Intoxication is especially problematic around night entertainment areas. Especially in such locations, pedestrian safety measures need to be formulated with consideration of the intoxicated pedestrian issue.

Intoxication brings an increased likelihood that pedestrians will fail to see and give way to motorised vehicles. It is therefore even more important at these locations that treatments deal with the consequences of crashes. Traffic calming and treatments that prioritise pedestrian movements should be prioritised. Variable speed limits are a relatively new concept that can be used to calm traffic during high pedestrian volume hours, while still conceding to motor vehicle mobility demands during other times.

Rest on red signal phasing is an especially promising treatment for high pedestrian volume and intoxicated pedestrian areas. At signalised intersections, all approaches default to a red signal and the ability to traverse the intersection is only allowed once a vehicle stops at the intersection control line, thereby activating the green signal.

Other more general improvements can be made that will benefit the intoxicated pedestrian issue. Increased pedestrian conspicuity can be used to reduce the likelihood that drivers will fail to see a pedestrian on the road. Increasing night-time conspicuity is especially important for pedestrians as they carry no lights or other forms of illumination that can be used by others to detect their presence.

Slide 17

Like for pedestrians, eliminating harm for cyclists means either separating them from motorised traffic, or reducing speeds to those survivable in the event of a crash. While these measures may not be feasible across the broader network now, there are measures that can be taken to reduce the harm occurring to cyclists. Most forms of separation can be beneficial cyclists, including commonly provided bicycle lanes.

As with pedestrians, either reducing motorised vehicle volumes or re-routing cyclists along lower motorised vehicle volume routes will be beneficial. This can be achieve by providing bicycle lanes and other facilities away from arterial and other heavily trafficked route, and by filling gaps and removing blockage points along bicycle routes that utilise the local and distributor road networks.

While encouraging cyclist use of the local and distributor road network is beneficial from the perspective of reducing exposure to high motor vehicle volumes, it is often necessary to access some part of the arterial road network. Providing prioritisation to cyclists, such as through separate cyclist phases at signalised intersections, can help to calm motorised traffic at locations where cyclists are present.

Slide 18

Historically, cyclists have been catered for by providing facilities along arterial roads. While this may benefit dedicated commuter cyclists desiring the most direct links to travel upon, it has come at the detriment to safety by increasing crash consequences through higher speeds and increasing exposure through higher motorised traffic volumes. This approach is also an issue from an amenity perspective and is arguably one of the barriers preventing more people from pursuing cycling as a viable alternative travel mode.

More recently, the thinking behind catering for cyclists has shifted. Safety and amenity have come to the fore and this has informed the way cycling routes are now being planned. Local and distributor roads are now becoming the primary locations for strategic bicycle routes, moving cyclists away from highly competitive space and onto roads where other functions are less highly prioritised.

The key benefits of this movement is it allows cyclist to use the space with little competition from other travel modes and provides a safer, more amenable space for cyclists to use. This change is bringing more people to cycling, which will ultimately help to reduce motorised congestion and improve cycling visiblity and priority on parts of the road network where they can not only be catered for, but can be prioritised without detriment to other road users.

Slide 19

(No transcript)

Appendix C5. Module 3, Snippet 5 transcript

Slide 1

Welcome to Module 3, Snippet 5 of Safe System for Universities. In this snippet, we will be discussing the gap that exists between current practice and a road transportation system where death and serious injury is eliminated.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, we will look at the role of infrastructure and the gap which infrastructure investment alone cannot fill.

Slide 5

In 2018, the Australian Road Research Board undertook a study of eighty-five VicRoads road design projects completed in Victoria for which Safe System Assessments were undertaken. They found that "normal design", or the level of design normally undertaken by VicRoads or its design contractors, had the potential to reduce fatal and serious injury crashes by nearly 20%. While this shows that business as usual design is having a positive impact on safety, it also highlights the design gap that is left to fill if we are ever to achieve a harm elimination outcome.

Next, business case design, or design where general Safe System alignment is introduced at the business case stage, was assessed. Business case design had the potential to reduce fatal and serious injury crashes by a further 10%. The leftover gap, referred to here as the application gap, represents the gap in outcomes that could be filled by pushing Safe System alignment as far as is practically possible.

When high Safe System alignment, which represents the full realisation of Safe System outcomes as far as is practically possible, was analysed, it showed that infrastructure investment alone has the potential to reduce fatal and serious injury crashes by up to 60%. The leftover gap of 40% represents a gap in harm elimination that cannot be achieved by infrastructure investment alone. This gap is known as the system gap, and represents the gap that needs to be filled by the other pillars of the Safe System.

Slide 6

Knowledge that such a system gap exists is a powerful concept for system managers to embrace. It shows us that we cannot build our way out of the legacy of harm that we have inherited. It also shows us that far greater results can be obtained compared to the business as usual processes that are currently employed, if we chose to prioritise safety and maximise the benefit of each investment.

The question then remains, even if we push infrastructure to its greatest potential for harm reduction, how will harm elimination be achieved? The answer will come from the other pillars of the Safe System. A key recognition of the Safe System is that a system's approach must be embraced if harm elimination is to be achieved. Through the rest of this snippet, we will discuss what a system's approach may look like and what changes need to be made in order to achieve harm elimination.

Slide 7

Now, let’s discuss how a system’s approach will help to fill the harm elimination gap that is not dealt with by infrastructure alone.

Slide 8

Speed management is likely to be one of the most effective and least costly ways to fill the system gap. Speed management will need to encompass more than just speed limit setting, due to the often negative political and community reception to reducing speed limits, especially when this is done without any visible investment in other parts of the system. Speed management will likely continue to encompass the other pillars of the Safe System, such as through appropriate infrastructure design that encourages appropriate speeds, education and enforcement to discourage non-conformation, and vehicle technology that sets to limit the speeds obtainable on our network.

While vehicle technology has the opportunity to support better speed management, it has also become one of the greatest allies in reducing harm that we have seen so far. The introduction of passive technologies, such as seatbelts and airbags that limit the severity of injuries in a crash, and active technologies, like autonomous emergency braking that can help prevent a crash, have played a vital role in the reduction in harm that we have seen over the last few decades. With the introduction of greater autonomous vehicle technologies now and into the near future, it is likely that vehicle technology will continue to play a critical role.

Enforcement is an often unappreciated but necessary component of the system. Unlike its reputation, enforcement is not about raising government revenue and it must also not become our only response to the road safety issue at hand. Enforcement can help to correct non-compliance, but it does not make compliant behaviour safe. Nonetheless, the role of enforcement will likely increase as we transition towards a system centred around appropriate speeds for safe road user interactions. The role of enforcement in this context will need to be one of setting an upper boundary to the amount and magnitude of non-compliance that is allowed to occur within the system.

Slide 9

The system gap that is left to fill is likely to be different for different parts of our road network. Higher mobility and strategically important roads that can attract substantial infrastructure investment may be able to push infrastructure improvements to their logical conclusion with regard to safety. However, lower mobility roads where infrastructure funding is not a priority and such substantial investment is not justifiable will sustain a much larger system gap.

The question is then how will the responses to these different gaps be addressed, and what will make up the difference that cannot be addressed by infrastructure investment on lower mobility roads?

Slide 10

As the level of vehicle technology is largely independent of the road transportation industry, being serviced by the largely privately run vehicle manufacturing industry, any balance in the gap will need to be supported by speed management and enforcement. While enforcement agencies hold close ties to the road transportation industry, their governance is run independently of the road transportation system managers, limiting the amount of influence that can be had on the availability of enforcement. This leaves speed management as the key support for balancing any deficiencies in the system gap.

Slide 11

In snippet three, we discussed the concept of safe mobility as a answer to the current trade-off that occurs between safety and mobility. Safe mobility means that mobility becomes a function of safety to ensure that safe road access is always provided. Safety becomes regarded as the limiting factor. In other words, a certain level of safety is expected and becomes the dominant factor for designing and operating the system. The conflict then becomes one between mobility and financial expenditure.

An outcome of this concept is that high speeds supporting the desired level of mobility are afforded by greater levels of investment in the design and operation of the road system. However, due to the inevitable limit on investment spending that is permissible, this will only be possible on a small proportion of the road network. For the rest of the road network, the choice will either become an easier one where mobility needs are low and high levels of investment are therefore irrelevant, such as on low volume local roads, or will become the harder question of choosing between the conflicting demands of mobility and financial investment.

Slide 12

Along higher mobility roads, the high speeds encompassed within our current speed limit setting strategies may be preserved by the high level of infrastructure investment that can be afforded along these sections of the road network. In other words, a high level of protection from infrastructure will afford safe road use even when speeds remain high.

Along lower mobility roads, the level of infrastructure investment is unlikely to allow for such high speeds and the question then needs to be asked: what is the community willing to pay in order achieve the level of mobility it desires? Competition for investment in all other aspects of our communities means that the amount of investment will likely remain low, and so the system gap will then need to be filled to a greater extent by speed management. In other words, speeds will need to decrease to allow foreseeable crash types to remain survivable.

Slide 13

While the answers are somewhat clear for a large part of the road transportation system, there remain some areas of the system where we know that our current level of knowledge is not sufficient to prevent harm. These are the known unknowns. Now, we will discuss the two most prominent known unknowns

Slide 14

Motorcyclists are the first known unknown. We know motorcyclists are extremely vulnerable to harm and that the speeds attainable by motorcyclists are incompatible with survival in the case of a crash. Motorcycles are also utilised much more often for recreational purposes than with other forms of motorised transportation. This means that speed management and risk taking are relevant issues that heighten the risk of harm. Currently, there are no clear methods for providing safe access to motorcyclists.

Slide 15

Most treatments that can work well for other modes of motorised transportation do not generally perform to acceptable levels for motorcyclists. Road safety barriers are a key example. While some barrier designs can lead to the near elimination of fatal and serious injury outcomes for light vehicle users, there are currently types of barriers that can work even nearly as well for motorcyclists. Often, the outcomes for motorcyclists can be just as severe as if no barrier was present in the first place.

While some motorcycle specific treatments are available, these do not perform well in the context of eliminating harm. Motorcycle barrier protection, which prevents motorcyclists from colliding with the supporting posts of road safety barriers, can reduce the severity of impacts with barriers, but the magnitude of mitigation is likely to be low.

Overall, the level of solutions afforded by infrastructure is inadequate and we must therefore look to other areas for providing safe access. The level of vehicle safety technology seen in the car industry is unmatched in the motorcycle industry and so currently vehicle safety improvements do not appear to be able to provide the answer. While speed management and enforcement could possibly lead to harm elimination for motorcyclists, the extent of speed management required is unlikely to be accepted by the motorcycling or larger road user community.

Slide 16

Heavy vehicles are the other known unknown that we will explore here. A key issue for heavy vehicle is how to grant them access to the road transportation network in a manner that is safe for other road users. In the context of safe interactions, heavy vehicles are, most of the time, incompatible with other roads users.

This is especially true for vulnerable road users, where low speeds do not guarantee survivable outcomes when they collide with a heavy vehicle. This is due to the tendency for pedestrians, cyclists and even motorcyclists to become entrapped under heavy vehicles and suffer from crush injuries.

The other key issue with heavy vehicles is mass inequality, The extreme difference in the mass of heavy vehicles and light vehicles means that injury severity will likely increase for the light vehicle occupants when a collision occurs, compared to a collision between two light vehicles. This extreme mass inequality means that safe interaction speeds are likely to be substantially lower for crashes with heavy vehicle, compared to with light vehicles.

Slide 17

The only viable solutions for allowing safe access for heavy vehicles are not easy to achieve, given the road transportation network that we have inherited. For most of the network, heavy vehicles need to be segregated from other road users. This could occur in space, such as through the use of separate roads for heavy vehicles or physically separated heavy vehicle lanes. More realistically, heavy vehicles can be separated in time by either regulation or motivation so that they are accessing the network during times when the volume of other road users is low. Additionally, the use of smaller, last kilometre delivery vehicles may be useful for urban areas, to reduce the number of larger heavy vehicles that are access this part of the network.

Where segregation cannot be achieved, speed is the only other option that is likely to achieve anything near harm elimination. For interactions with heavy vehicles, this means that speeds will need to be substantially lower than that of the safe interaction speeds between light vehicles. Speeds that will ensure safe interactions between heavy and light vehicles, and heavy vehicle and roadside objects, remains largely unexplored.

Regardless of how heavy vehicles are granted access to the road network, complete separation from vulnerable road users must be obtained to ensure that no fatal or serious injury outcomes result. In addition to the severity of injuries that can occur at low speeds, the visibility of vulnerable road users to heavy vehicle drivers is a core reason why interactions cannot be allowed. In several fatal accidents between very low speed heavy vehicles and vulnerable road users that have been investigated in South Australia, the heavy vehicle driver was not aware of the vulnerable road user before the collision, as they were outside of the driver's field of vision.

Slide 18

(No transcript)

Appendix C6. Module 3, Snippet 6 transcript

Slide 1

Welcome to Module 3, Snippet 6 of Safe System for Universities. In this snippet, we will be looking at the range of tools available to assist road designers in achieving Safe System levels of performance.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, let's take a look at what tools are available to assess alignment with the principle of eliminating fatal and serious injuries.

Slide 5

Generally speaking, there are two types of tools employed in identifying and evaluating the safety of road design and operations: reactive and proactive tools. Historically, reactive tools have been employed as a mechanism for gaining road safety funding, such as through the Black Spot programs. More recently, proactive tools are being considered as a potentially better way to prioritise funding, though the mechanisms for sourcing such funding are still limited.

Reactive tools are based on crash data. While reactive tools provide a direct measurement of harm, they rely on harm having already occurred before it can be identified and treated. This means they can only be applied retrospectively, preventing their use on new or substantially altered roads.

On the other hand, proactive tools rely on the direct identification of road and traffic attributes to predict future harm. A benefit of this is that proactive tools can be applied before the road is even constructed and harm has had a chance to occur. However, proactive tools can be limited by their reliance on indirect measures, which may not always be a reliable indicator of future harm.

Slide 6

A notable issue with the reactive approach is a reliance on crash clustering to highlight problem hotspots, such as blackspots. While this approach has achieved considerable success over the past decades, severe crash numbers have decreased with continued treatment of blackspots, to a point where most severe crashes are occurring in locations with little or no recent crash history. As a result, reactive approaches are achieving diminishing returns with crash locations that are now largely scattered across the road network and not easily reducible to individual problematic locations. This is a particular issue on local government and other low volume roads, where exposure to crash risk is limited and crashes occur infrequently enough to make patterns in the data almost impossible to detect.

Slide 7

Proactive approaches are, on the other hand, better equipped to deal with the scattered existence of crashes across the network. Their focus on systematic problems allows for the identification of locations not necessarily associated with a recent crash history. This also makes them applicable to new as well as existing parts of the road network, allowing problems to be identified even at pre-construction stages, before crashes have had a chance to occur. While both proactive and reactive tools have their benefits and drawbacks, proactive tools are seen as more closely aligned to Safe System principles, as they do not rely on waiting form harm to occur before enabling system managers to act upon the risk of harm.

Slide 8

As we have discussed, most tools well aligned to Safe System principles are proactive in nature: they focus directly on identifying risk through known relationships with road and traffic attributes, instead of a retrospective reliance on harm that has already occurred.

At the core of most proactive approaches is their focus, in one form or another, on energy management. In other words, the approaches often allow for the identification and prioritisation of design and operational conditions that reduce the release of high kinetic energy onto road users, which is associated with severe crash outcomes.

Their general focus on road and traffic attributes can also allow some of these approaches to identify design and operational details that need to be remediated in order to reduce the risk of harm. For example, the identification of high-risk movements at an intersection, the benefits of conversion to roundabout control, or the need to separate oncoming traffic along high speed roads.

Slide 9

A number of tools well-aligned to Safe System principles are available for a range of applications, from strategic prioritisation of works to detailed design changes affecting elements of individual projects.

Strategic reviews are aimed at high level oversight and administration. While often not targeted only to road safety, their use can help alignment to the Safe System through strategies and procedures that prioritise safety outcomes and set defined performance criteria.

Road assessment programs aim to quantify safety performance of a road based on its physical and operational features. They are widely applicable from strategic prioritisation of road treatments and upgrades to route and project level assessments.

Crash reduction factors provide information about the safety performance of specific treatments and programs. Their generic nature means they are more applicable to larger scale works than individual design elements, where situational details may magnify inaccuracies. It is worth noting that crash reduction factors still rely on crash histories as they are generally based on crash studies.

The Safe System Assessment Framework is a recently developed tool useful for qualifying Safe System alignment of individual roads and road elements based on assessment with a focus on infrastructure. The scalability of the Safe System Assessment Framework means it can be applied to route, project and detailed design levels.

At the detailed design level, models such as the kinetic energy management model are useful for assessing the severe injury risk of different impact configurations and speeds. For example, when applied to intersections, such a tool is useful for identifying risk associated with geometric design details of the intersection, such as intersecting road angles, speed management devices and channelization.

Slide 10

Now that we’ve taken an overview of the types of tools available, let’s discuss some examples. Firstly, we’ll take a look at road assessment programs.

Slide 11

Road assessment programs, or RAPs, provide an easy to understand measure of the level of risk on our road network. Like the new car assessment programs that put stars onto cars to provide a quick and easy measure of a vehicle’s safety rating, road assessment programs put stars onto roads so that industry professionals and the public alike can better understand the safety ratings of the roads that they are using. RAPs are especially useful for road authorities, as they provide an easy to access forum for identifying risk on the road network.

Road assessment programs are undertaken in several countries around the world, with some falling under the international road assessment program organisation. In Australia and New Zealand, our programs are known respectively as AusRAP and KiwiRAP.

Slide 12

Road assessment programs score the safety risk of a road through a series of factors. Once evaluated, the scoring can be graphically presented on maps that show how the safety risk changes over the length of the road network. Some of the factors evaluated as part of the risk scoring including traffic speed and the speed limit, the geometric design of the road, the roadside environment including the provision of barriers, and exposure levels such as traffic volumes. Data for these factors is collected through a variety of means, including road surveys conducted by a specially equipped vehicle that traverses the length of the road network that is being assessed.

From the scoring system, a star rating is developed for each section of road to signify the broad level of safety risk. Star ratings range from one star, signifying a high risk of harm, to five stars, which signifies a low risk of harm. Each additional star represents a halving in the risk of fatal and serious injuries. Star ratings can be developed for both personal risk, which is the risk to each person traversing the roadway, or collective risk, which is analogous to the frequency of expected harm.

Slide 13

At a level of detail greater than the road assessment programs sits crash modification factors, which detail the level of benefit supported by each type of treatment.

Slide 14

Crash modification factors provide a quantitative estimate of the safety effect of a road safety treatment. They are generally aimed towards infrastructure treatments and are used to estimate the reduction or increase in harm that a treatment will produce. Crash modification factors, and the similar crash reduction factors, are based on empirical data analysis. Empirical studies from a sample of each treatment type are used to create a estimate of the general effect size of the treatment, which then becomes the crash modification factor. Crash modification factors may estimate the effect size on all crashes, injury crashes, or severe injury crashes.

As an example of a crash modification factor, converting an unsignalized intersection to signalisation may affect the likelihood of right turn and adjacent direction crashes. Crash modification factors can be used to estimate the effect on these crash types. In this example, two crash modification factors are involved and they each provide an estimate of the reduction in their respective crash types. Crash modification factors for various crash types are available in the Austroads Guide to Road Safety. A key limitation of crash modification factors is their generalisation of effect sizes that may be substantially effected by local factors, such as the local road environment, the traffic environment and they specific design of each treatment.

Slide 15

Safe System assessments are a recent development that aim to provide a Safe System perspective on the concept of road safety audits.

Slide 16

Like road safety audits, Safe System assessments aim to provide a qualitative appraisal of safety for specific locations within the road network. Safe System assessments however aim to bring a Safe System perspective to the assessment process, by considering the potential for harm elimination. Safe System assessments can be used to assess a range of project scopes, from single intersections to entire routes. They can also be employed at different stages of a project, from concept development to implementation and ongoing operations.

Safe System assessments provide a qualitative assessment of the harm elimination potential supported by the road design and operation. Like road safety audits, they are meant to provide more than just a check against the standards and guidelines used to design and operate roads. Instead, they are about highlighting the harm potential from the perspective of all road users by estimating risk associated with the exposure to crashes, the likelihood of crashes, and the consequences once a crash occurs. While they can be implemented at any stage during the life of a project, their benefits are generally greater when implemented at the earlier stages when more than just detailed design changes are still possible.

Safe System assessments were first formalised through the Austroads Safe System Assessment Framework research report, published in 2016. In this report, a broad categorisation of treatments is provided to help guide practitioners to use those treatments that are better aligned to Safe System outcomes. These treatments are categorised by their alignment to the Safe System. Safe System or primary treatments are those that promise near harm-elimination performance. Supporting treatments, which reduce harm but will not eliminate it, are separated into those that are compatible with the future implementation of Safe System treatments, and those that do not affect such future implementation. Other considerations lying within the speed, vehicle technology and road user behaviour pillars of the Safe System are also provided.

Slide 17

As an example application of the Safe System assessment, we can consider two design options proposed for the design of a rural multi-lane arterial highway. The first option incorporates a more historical design, with a wide footprint consisting of a dual carriageway separated by a grass median and lined by clear zones. The second option incorporates Safe System principles by utilising median and roadside barriers to contain any road departures that may occur.

Scores ranging from zero to four are applied to each of seven typical crash types and each of the three risk influencers. A higher score indicates a higher risk for that particular crash type and risk influencer.

The product of the risk influencers for each crash type are calculated to give the total risk of harm for each crash type. The total risk score can be calculated as the sum of all the crash type risk scores. As can be seen here, Option 1 produces particularly high scores for run off road, head on and intersection type crashes, owing to high traffic volumes and the high severity of crashes when they occur.

Option 2 can be scored in the same way, providing a platform for directly comparing the risk generated by the competing options. It is important to remember that risk scoring is subjective, as each Safe System assessor may score each risk differently. This limitation can be mitigated by ensuring that comparative assessments are undertaken by the same assessor and that justification is given throughout the process as to the scores awarded for each category.

Slide 18

We can now see, side-by-side, the level of risk generated by each option. Option 2, which utilises road safety barriers over the more historical clear zones, offers a reduced risk of harm due to the reduction in crash severity that these barriers afford.

The Safe System assessment provides a way to compare each design and pinpoint where the respective risk originates. For this example, we can see that the reduction in overall risk is actually due to a reduced risk of run off road and head on crashes.

More than this, Safe System assessments allow us to see where a residual of risk resides. In this example, we can see that although the use of road safety barriers reduces the risk of lane departure type crashes, they do nothing to improve the risk of harm at intersections. In this way, we can see where a risk of harm still exists and therefore where further attention needs to be paid.

Slide 19

We will finish this snippet by looking at Kemm X, which represents one of several risk models that can be used to inform detailed design.

Slide 20

Kemm, which stands for the kinetic energy management model, is a conceptual model of the pathway to harm from crashes on our road network. In this way, it forms a model of the potential to be affected by the energy of a crash and the transfer of energy when a crash occurs.

At the centre of the model is the human vulnerability to harm. Radiating out from this are the barriers that exist along the pathway to harm, which can either protect a human from harm, or in the case of gaps within the barriers, lead to the occurrence of harm.

There are five layers to the Kemm model. From the centre of the model outwards are the human biomechanical tolerance to harm, which is the human bodies ability to withstand physical impacts; The transfer of kinetic energy of the crash to the human body; the kinetic energy of the crash event; the risk of a crash event per exposure; and the exposure to potential crash events

Slide 21

Kemm X is a version of the Kemm model that has been specifically developed for understanding the risk of harm at intersections. A key part of Kemm X is the risk of severe crash outcomes given the travel speeds of the vehicles involved in the crash.

In Kemm X, this risk is modelled on the impact speeds and impact angles of two colliding vehicles. Using this model, we can determine for two vehicles, U1 the bullet vehicle and U2 to target vehicle, what is the proportional likelihood of having severe injury outcomes as a result of a crash.

Kemm X is a powerful tool that can be employed by intersection designers to test the potential for harm to occur with different designs. By using this tool, system managers can select the most appropriate type of intersection and designers can detail the specific design of an intersection while being fully informed about the risks associated with each option. Tools like this provide system managers with the evidence required to make informed choices and to select the best possible outcomes for road users.

Slide 22

(No transcript)

Appendix D. Module 4 transcript

The following transcripts are from snippets 1 to 5 of Module 4.

Appendix D1. Module 4, Snippet 1 transcript

Slide 1

Welcome to Module 4 of Safe System for Universities. In this final module, we will explore some of the pragmatic barriers between us and zero death and serious injury throughout the road transportation system. Along this journey, we will look at some examples of how to put the safety theory we have previously covered into practice. First though, let's discuss the history of how road safety got to where it is, and where it now needs to go.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

To understand where road safety must head next, we firstly need to know where it has been. So let's start by taking a quick look at road safety through its generations and where its evolution has come to.

Slide 5

Early perceptions of road safety tended to treat crashes as a chance phenomenon and placed the cause of crashes on accident proneness – the idea that some people are more prone to having accidents and that crashes are therefore a result of certain personality traits. The perception that crashes happen by chance takes away a notion of responsibility and therefore the idea that anything can be done to stop them from occurring.

Later, the economic costs of crashes became a key driver for road safety. Ideas such as benefit-cost analysis were used to balance the economic burden of road safety initiatives against the economic gains made through fewer crashes. The shift to economic rationalisation of road safety comes from a desire to find a tangible way to deal with the issue. The benefit of this approach is the ability to consider road safety with respect to other important factors, rather than the earlier tendency to ignore road safety as we had no tangible way to comprehend it.

In essence, road safety became an economic issue instead of a human suffering issue. And this approach lingers on today. It can be seen in the way most road investments are prioritised. Benefit-cost analysis is still a primary tool used to rank investments. By perceiving road safety in such a way, it is inevitable that we aim to maximise the economic benefits of road safety.

Other methods for prioritising investment are entering the industry. A key alternative method that is becoming more widely used is multi-criteria analysis. Multi-criteria analysis provides a qualitative look at investment from the viewpoints of different important factors, such as environmental sustainability, health and safety, amenity and community needs. While a step in the right direction, multi-criteria analysis still allows these factors to be traded against one another, leading to compromised outcomes. Additionally, multi-criteria analysis is a qualitative tool and does not provide the quantitative approach that has been well-understood and favoured by system managers.

Slide 6

This is why we have previously discussed safety as being a function of mobility. Mobility is the driver of economic value from the road transportation system. Hence, when we treat all aspects of the road transportation system as an exercise in economic maximisation, they become a function of the economic value of the system, which is mobility. As highlighted by Claes Tingvall and Anders Lie in their 2017 review of the history of Vision Zero, safety investment has become defendable only when the economic value of its benefits are larger than the collective cost that it creates. In other words, only when it has an economic benefit to cost ratio of greater than one.

As a result, we have inadvertently come to accept some level of risk to road users as a trade-off for the economic gain that we can obtain from designing and operating the road transportation system in a certain way. A practical example is the case for roundabouts. Roundabouts are generally not seen along arterial roads in the urban environment. There are two key reasons for this. Firstly, roundabouts are perceived as having reduced capacity compared to conventional signalised intersections. They are perceived to result in reduced mobility. Secondly, they generally require a larger footprint that conventional signalised intersections, which creates an added economic cost. Despite the clear safety benefits of roundabouts, signalisation is often chosen because of the greater net economic benefits. We accept the greater level of risk afforded by signalisation because it provides greater economic benefits.

Hence, the Safe System is generally seen as in conflict with the notion of economic maximisation. Instead of safety being a function of mobility, the Safe System calls for mobility to become a function of safety. In other words, safety is expected to be delivered at no less than a threshold level of acceptance, such as the zero death and serious injury threshold that is currently considered in the Safe System. Mobility is then maximised within this boundary. However, to achieve such an outcome, we need to drive safety through more than just the mechanism of economic justification.

Slide 7

Before we can understand how to move away from economic justification for safety, we must first understand why economic justification has led to a situation where safety is compromised. Next, let’s go through an example that shows how the economics of safety work.

Slide 8

Mobility is the primary function of the road transportation system. Its role is to transport people and goods. The world’s economy is dependent on our ability to stay mobile. Without mobility, our systems of trade, food and other vital services would cease to operate in the way to which we have become accustomed. It is therefore understandable that we have historically looked at our road transport system from an economical standpoint. We have historically balanced mobility on the economic benefit that we receive. Fundamentally, you can think of mobility as a combination of volume and speed. In other words, how much we can transport and how quickly we can transport it.

The primary benefit we receive from the road transportation system is economic productivity. This means the ability to trade goods, source commodities, transport people to work and provide vital services that prop up our communities. Logically thinking, an increase in mobility will come with an increase in economic benefit. Eventually, the demand placed on the system will reduce efficiency and the economic gain will become less pronounced. Similar to the volume-density relationship in traffic theory, there will be a point at which a peak economic benefit is reached.

But our road transportation system also comes with economic costs. One of these is the economic burden of crashes and injuries that occur on our roads. Even by assuming a linear relationship between mobility and crashes, we can see that economic costs result from an increase in mobility. The greater we increase mobility, the greater the number of crashes that will occur. From solely an exposure standpoint, this relationship is logical, as greater mobility equals greater exposure and greater exposure increases the risk that crashes will occur. But increased mobility has historically come with increased speed and energy on the road network. When not properly managed, these can translate to increased death and serious injuries as outcomes of the crashes that occur.

By taking into account the economic benefit of productivity with the economic cost of crashes, we can plot the net economic benefit of increasing mobility. At first, increasing mobility will come with an economic gain. However, there will come a point where the economic burden of crashes and injuries outweighs the benefits of productivity. At this point, the greatest net economic benefit of mobility is achieved. By balancing safety against mobility, we have maximised the economic benefit. However, as a result we have also created a system where some risk of harm is accepted.

Slide 9

As you can appreciate, this is a simplification of the real system. Other economic contributions, such as environmental costs, will affect the economic outcome. However, this model demonstrates the reasons why safety is often traded for economic gain.

At the point where economic maximisation occurs, there is some level of safety risk to road users. Often this level of risk is such that death and serious injury are a regular consequence of crashes. Think about our earlier example of signalised intersections. Signalisation often makes the most sense on economic grounds. Many projects employ signalisation as it is a well-understood and well-proven way to manage large volumes of intersecting vehicles. Unfortunately, signalisation does not deal well with the consequences of crashes when they do occur, which is why a large proportion of urban fatal and serious injury crashes can be seen at signalised intersections.

Under the Safe System, risk is managed in such a way that death and serious injury are no longer an acceptable outcome of system use. Crashes will still occur and while undesirable, low severity crashes are tolerated. In this situation, safety is not traded off against mobility. Instead, mobility and economic gain are maximised within the boundary of harm elimination.

Slide 10

Finally, let's take a look at the road safety paradigm through the lens of William Haddon Junior, a pioneer medical ecologist and road safety advocate who started the journey to scientifically-based road safety theory.

Slide 11

In 1970, Doctor William Haddon Junior, a medical ecologist and then president of the United States Insurance Institute for Highway Safety, published a paper in the Journal of Public Health. Entitled "on the escape of tigers: an ecologic note", this paper and its author have been attributed with founding a scientific basis for road safety. In this paper, Haddon outlined kinetic energy, and the need to manage it, as a fundamental social concern. While his examples vary over a wide range of systems, his work has become the basis for the modern scientific study of road safety.

Haddon, in his paper, describes ten strategies to control the losses that stem from kinetic energy. These strategies are presented in a hierarchical order, from most to least preferential. In this way, they are similar to more recently adopted tools that are being frequently used in industry, such as the hierarchy of hazard control, which we covered in module one, and the Safe System treatment hierarchy, which we covered in module three.

The first two strategies that Haddon outlines call for the control of energy production, either through outright prevention or through reduction in the amount of energy that is produced. Road transport examples of these strategies are the elimination or reduction of vehicular traffic, or the reduction of vehicle speed. The third strategy is to prevent the release of energy, which is akin to preventing crashes from happening and is something that we have become particularly used to practicing in the road design sphere. The fourth, fifth, sixth, seventh and eighth strategies are about something that we are not yet as used to doing in the road industry, which is shielding the human from the release of energy. In the Safe System, we talk about this in terms of reducing the consequences of crashes. Importantly, while Haddon placed likelihood affecting measures above those that affected consequence, in the Safe System this order is reversed. This has been done in acknowledgement that no matter what we do, we are unlikely to ever completely prevent all crashes from occurring, and so the only way to reach zero harm is by prioritising the reduction in crash consequence.

Slide 12

So, what has Haddon to do with the safety paradigm and how it can be changed? Haddon teaches us two fundamental lessons. The first is the importance of energy. A focus on the economics of safety brings focus to the economic importance of the road transportation system. While important, this focus when concerned with safety brings us away from the fundamental reason for having a road transportation system – to benefit people.

Haddon’s focus on energy makes us look at safety from the perspective of its direct effect on people. Safety, or a lack of it, causes harm to people. Road safety is primarily concerned with the release of energy. Therefore, energy, or a lack of its control, causes harm to people.

Haddon’s second lesson was coined in his 1962 paper “an analysis of highway safety strategies”. In a way quite different to how we define active and passive, Haddon distinguished these as to whether human intervention was or was not required. Active strategies, such as seatbelts and stop signs, require correct road user behaviour for them to work. The vehicle occupant must engage the seatbelt and the driver must stop the car and check for other traffic before proceeding. Passive strategies, on the other hand, are always working regardless of road user behaviour. Road safety barriers, for example, protect from collisions with more hazardous objects in a crash, no matter what the road user is doing.

Slide 13

Where these two lessons relate to a paradigm change is in their ability to guide the way we value safety and in the way we implement it. Haddon’s first lesson, on the importance of energy, guides us to look at the value of safety from a different perspective. To achieve the elimination of death and serious injury, we need to value safety in terms of the effect it has on people. In other words, we need to prioritise road investment through the lens of an ability to reduce the cause of harm. Currently, we maximise economic benefit as a primary goal. We settle for the safety benefits that can be achieved within this paradigm. We must change this paradigm to maximise safety. Safety becomes the primary objective which cannot be neglected or compromised. Mobility and economy can then be maximised within the paradigm of safety.

Haddon’s second lesson highlights the importance of human error, and the need to use strategies that do not place a reliance on people giving one hundred percent performance, one hundred percent of the time. As we will explain in the next two snippets, we are entering a phase where we will need to transition from piecemeal safety actions and an overarching reliance on compliant road users, to a strategic transformation of the road transport system, where safe road use is guaranteed by passive strategies that will work regardless of whether or not people make mistakes.

Slide 14

(No transcript)

Appendix D2. Module 4, Snippet 2 transcript

Slide 1

Welcome to Module 4, Snippet 2 of Safe System for Universities. In this snippet, we will look at some of the key enablers that need to be realised before we can hope to achieve widespread implementation of the Safe System.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Firstly, we will discuss the philosophy of the Safe System in the context of moving from safer to safe – from coping with the road trauma problem to fixing it once and for all.

Slide 5

The people that manage the road transportation system are concerned with the safety of the people using it. It is unfair to say that safety has not been their concern. Much effort has been made to ensure roads become safer and harm becomes less likely. Since the dawn of the motor age, roads have come to the point where crashes are exceedingly unlikely on a personal level. For example, the number of annual deaths on our roads has fallen from a peak of thirty per one hundred thousand people in 1970, to about five per one hundred thousand people today. We have come to a point where most people will experience no more than a handful of crashes in their lives, and many will never be personally involved in a serious crash.

The level of safety that we currently enjoy is thanks to the advancements that have been made in road design, vehicle design and the education and enforcement of safe behaviours. However, we can also see that the fall in the annual death rate has been steadily reducing to a point near equilibrium. Serious injuries are even worse, having started to increase in both rate and overall number in the past few years. This begs the question; if we have become so good at reducing harm on our roads, why has our progress slowed down so much?

Over the previous few decades, we have become very good at guiding road users to do the safe thing. However, we have not explicitly realised that road users do not always follow this guidance. Crashes can occur when road users intentionally disobey guidance. But most of the time, crashes occur because road users have simply made mistakes – they have unintentionally used the road in a way that was not intended by the road designer. A great example is that of signalised intersections. Signalisation is a great way to guide road users through an intersection – it dramatically reduces the likelihood that crashes will occur between intersecting vehicles. However, drivers sometimes run red lights. Sometimes this is intentional, and sometimes it is not. Signalisation falls down in a Safe System because it does nothing to help the situation if a driver fails to obey the signal.

Slide 6

Like many other aspects of road design, signalisation is great at making roads safer. However, it does not make them safe. This is where we have fallen down. Much effort is put into advancements that make roads safer than they have been. And this has been our folly. When a new project is undertaken, or a section of roadway is upgraded, often at great expense, we are satisfied by the notion that the road has been made safer for those using it. But we often don’t ask the question; has the road been made safe?

The distinction between safer and safe is subtle but important. When we make a road safer, we reduce the likelihood that crashes and harmful outcomes will occur. But crashes and harmful outcomes can still occur, they are just less likely. When we make a road safe, we are ensuring the survivability of crashes. Crashes will continue to occur along a safe road, but harmful outcomes will not. By continuing to pursue safer outcomes, rather than safe outcomes, we are missing opportunities to realise the goal of zero harm.

Common examples can be found in large road projects that are undertaken every year, at substantial cost to tax payers who ultimately use and become harmed through use of these roads. Road design and operation for these projects often falls back to long used techniques that make the road safer, but not safe. We rarely make the distinction between safer and safe, and therefore rarely ask the question of whether a safe alternative can be utilised. A prime example are many kilometres of new freeways and motorways built each year that depend on design and operation poorly aligned with the Safe System. Where we could pursue safe by utilising solutions such as flexible barriers to control road departures and roundabouts where these roads intersect with the wider network, we all too often revert back to safer by using standard clear zone and signalisation based designs.

Slide 7

Moving from safer to safe will require a change in the way we manage the road transportation system. This is where the Safe System comes into play. Now, we will look at how the Safe System provides mechanisms for achieving safe outcomes.

Slide 8

Pursuing safe rather than safer outcomes will require a change in mindset in the way we pursue safety. This is where the Safe System comes in. The Safe System provides a new philosophical approach to road safety. In doing so, it provides an ethical argument for why we need to change our perspective on road safety, as well as a theoretical approach to achieve this. However, actually achieving a safe road transportation system will require operationalising the theory provided by the Safe System. To do this, we first need to prioritise methods and solutions that give the greatest promise of harm elimination.

The Safe System provides a method for categorising Safe System-aligned treatments from those that do no ensure survivability. It is impractical to expect road designers and operators to understand all the fundamental theory and research regarding the suitability of all options. As the front line of road safety, these practitioners require easy ways to make informed decisions. Within the Safe System, treatments are categorised as either primary, step-toward or supporting treatments. By categorising treatments according to their alignment with Safe System philosophy, practitioners can make informed decisions about which options to pursue first. Pursuing a safe transportation system means prioritising primary treatments, and only pursuing non-primary solutions when the application of primary treatments is unfeasible.

Slide 9

A significant barrier to prioritising the Safe System is how safety is treated within road investments. Generally speaking, road investments can be pursued because of road safety goals or because of other goals. Those falling outside of road safety goals may be pursued to increase mobility and efficiency, provide for certain interests such as freight, or to serve broader changes such as new residential developments. While these projects will include some consideration to safety, this is often one of many factors influencing the final outcome. On the other hand, road safety specific investments account for a small proportion of all road investments and are pursued to improve safety, such as through road safety barrier installation or intersection upgrades.

Our transition to a Safe System means a need to encompass all road investments in the bounds of safety. This means safety is no longer one of many factors that are traded-off against one another to fit the investment objectives. Instead, safety forms a bounding limit to the outcomes of investment. In other words, safety outcomes become a non-negotiable and all other factors are optimised within this limit.

The ultimate goal of the Safe System however is to make redundant the need for any road safety specific investments. Instead, safe road investments will be made that ensure every time a section of the network is upgraded, survivability is build into the design and operation of that part of the network. This is the idea of safe mobility that we explored in the previous module. Safe mobility means that use of the road transportation system allows for mobility within the confines of survivable operation.

Slide 10

Transitioning from our current system to one of safe mobility comes with some barriers that need to be broken. One of these is they way we implant safety into projects. Now, we will discuss the changes that need to be made in the project pathway in order to achieve harm elimination outcomes.

Slide 11

Most road projects, whether they are for new greenfield or existing brownfield roads, for design or operational changes, are developed through a standard project pathway. The changes that can be made to different aspects of the project depend on where it lies along this pathway. This concept is very important as it has repercussions as to how much the design and operation of a road can be informed by the Safe System.

A standard project pathway looks something like this. In the initial stages, the project is conceptualised, usually as a solution to some identified problem or desired improvement. At this stage of the project, detail is low and different solutions can be explored.

Once a concept is settled upon, funding is sought. Because funding is closely tied to the concept that is proposed, it is difficult to change the fundamental concept once funding is secured. Details fixed at this stage may be the basic geometry and geometric design, the location and the amount of land that will be used or that needs to be acquired.

Once funding is secured, a detailed design can be developed. This stage will include design such as the detailed earthworks, line marking and signage, roadside furniture and services, and detailed geometry. Changing any fundamental aspects of the design, such as opting for roundabout control over intersection signalisation, is all but impossible at this stage of a project.

Once a detailed design is settled upon, physical works can commence. Through this stage, small corrections to the design can be made as unforeseen issues arise. Once built, operation commences. During the operational life of a project, minor physical amendments and operational changes can be made to suit changing operational conditions and new values, such as an increased awareness of road safety issues.

Slide 12

Safety is a core element of any project. Thinking about the safety of road users needs to come in at every step along the pathway. But when is safety currently considered, and when does it need to be considered to have maximum impact?

Currently, safety is mostly thought about in the latter stages of a project, after a concept has been devised and funding has been secured. While consideration of safety is of course important at the detailed design, build and operation stages, there is only so much that can be influenced and changed. A common forum for highlighting safety issues at these stages is the road safety audit, which is useful for identifying issues in the details of a project, not in its fundamental concept.

Where safety is really required is at the conceptualisation and funding stages of a project. At the conceptualisation stage, the fundamental design of a road can be altered to suit safety objectives. At this stage, fundamental questions can be explored, like why not implement a safe solution, such as a roundabout, instead of a less safe solution, such as a signalised intersection? At the funding stage, procedures can be written into the funding that ensure safety is maintained at an acceptable level, instead of writing safety out as a side consideration.

With safety being considered at all stages of a project, we can ensure safe solutions are pursued first, while ensuring that the integrity of safety is continued from conceptualisation all the way to construction and operation. While this concept may seem simple, realising it is not. Realisation will require a fundamental change in the way we perceive safety, which is what the Safe System is all about. Next, we will take a look at one possible way to solidify the philosophical concepts of the Safe System into reality, so that fundamental issues such as ‘when safety is considered’ can be brought into practice.

Slide 13

All that we have discussed so far are logical ways to operationalise the Safe System, but they do not provide the practical approach required to achieve transformation. Next, we will introduce the concept of a transformative approach through the example of the zero twenty-fifty framework.

Slide 14

A transformative approach is about operationalising the Safe System. While Safe System philosophy and rhetoric has been discussed in strategic plans and other high level circles, we have failed to practically implement the solutions that will lead to zero harm on a widespread basis. Operationalising the Safe System will create the mechanisms required to achieve practical implementation.

In order to operationalise the Safe System, we will need to change the status quo. Historical thinking and historical practice has been well aligned to balancing safety with other objectives, which in practice often means that safety is compromised in order to achieve other desires. Changing the status quo means changing this mindset to one where safety is the primary consideration, where we set non-negotiable objectives around safety, then set about achieving other desires within these bounds. In other words, it means making roads safe, rather than just making them safer.

Transformation is also about visualising the future that we want, and how we are going to get there. Everyone needs a map to find a previously unexplored place. A zero harm future is no different. We need a map to show us what a zero harm road could look like and that work our way back until we can see a pathway between where we are now, and where we want to be. A key part of a transformative approach is providing this map and providing the directions on how we need to change in order to achieve the future that we want.

Slide 15

Zero twenty-fifty is a form of transformation, as perceived by the state of Victoria. Zero twenty-fifty is the way in which Victoria is defining the vision of their future and mapping the pathway to get there. It is important to remember that zero twenty-fifty is a framework; it does not tell us what the solution is, but it allows us to define possible solutions and see whether they can get us to where we want to go.

Zero twenty-fifty transforms the way we look at safety, from the traditional road safety strategy approach of defining intermediate targets with no clear end objective in sight, to a Safe System-aligned approach that defines the future time when we expect to achieve zero harm. Zero twenty-fifty changes the mentality from one where we are content to reduce harm but have no vision of how to eliminate it, to one where we have a clear goal and clearly defined timelines for when it will be achieved.

But zero twenty-fifty is more than just a vision. It provides the tools necessary to transform the way in which we approach safety. These tools come in the form of predictive analyses to define what a zero harm road system looks like; models to map the path from our current system to one in-line with Safe System principles; and indicators to let us know how we are performing and whether we are remaining on-schedule to meet our milestones.

Importantly, zero twenty-fifty helps to quantify the magnitude of effort and investment that needs to be made in order to achieve a zero harm future. By doing so, we can put forward arguments to re-align the magnitude of funding that goes into our road transportation system, and the ways in which it is utilised. Importantly, doing so will help to solidify the argument that current levels of investment will not allow us to achieve a goal of zero harm.

Slide 16

(No transcript)

Appendix D3. Module 4, Snippet 3 transcript

Slide 1

Welcome to Module 4, Snippet 3 of Safe System for Universities. In Snippet 2, we concluded with the discussion of Victoria’s zero twenty-fifty transformation framework. In this snippet, we will detail what the zero twenty-fifty framework is and how it is being used to operationalise the Safe System objective of harm elimination.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Transformative approaches are going to be required if we are to achieve a safe road system. Zero twenty-fifty is the state of Victoria's transformative approach to achieve harm elimination by the year 2050. Now, we will take a look into what zero twenty-fifty comprises and why it is being prioritised over more traditional road safety strategies.

Slide 5

Zero twenty-fifty starts with a goal. Like traditional strategic frameworks, zero twenty-fifty is defined around a goal-setting agenda. However, this is where the similarities tend to end. Traditional frameworks rely on agendas that call for short-term reductions in harm over short-term timeframes, which call for road safety improvements but ultimately fall short at setting a path to harm elimination. Zero twenty-fifty is set to the agenda of harm elimination. Like its name suggests, zero twenty-fifty sets a date of 2050 for complete elimination of harm on the Victorian state road network. This is a long-term goal set over a long-term timeframe.

Achieving a safe road transportation system is a huge undertaking. Such an undertaking can be divided into more manageable sized steps. Like traditional strategic frameworks, this could be in the form of piecemeal improvements. Unlike traditional strategies, these improvements are tied to the overall goal of achieving harm elimination. Doing so allows milestones to be placed into perspective with the overarching objectives, which has commonly been absent from previous strategy. In the remainder of this snippet, we will discuss the steps by which the objective of harm elimination can be visualised and operationalised.

Slide 6

The first step to transformation is to define the future road transportation system that we wish to achieve.

Slide 7

The first step to transformation is to visualise what a future of zero harm may look like. This could be achieved in many ways, and the ways in which we visualise this now may change as we move into the future. Because of this, it is important that the steps we develop, as well as the transformation framework itself, be agile enough to contend with future developments that may change the trajectory along which we chose to move.

Slide 8

If we plot out a safe transportation system to the founding structure of the Safe System, we can define the future road transportation system as a function of three separate elements. These signify a future road transportation system based upon safe vehicles, safe roads and safe road users. Speed is not in itself a separate element, as it becomes a function of the three other elements within the framework. In other words, a safe speed is defined as a function of the level of safety guaranteed by the road, the vehicles travelling along the road and road users using the road.

It is important to remember that each element does not in itself guarantee a safe road transportation system. Instead, each element sets the boundaries under which a safe road transportation system can operate. Such a setup allows for adaptability. For example, safe road users are defined as those who do not undertake extreme violations. However, if such behaviour is unable to be guaranteed, then the other elements can be managed to maintain a safe system, such as by introducing vehicle equipment to more stringently manage access control to those unable to maintain appropriate behaviour. Alcohol interlock systems are an example of such an already available access control technology.

For those managing the road network, the question becomes one of “what do roads need to look like to achieve zero”? This is the question that will be tackled by the next steps through the transformative approach.

Slide 9

However, before we get to the roads themselves, let’s take a look at what a safe vehicle may look like in the year 2025. Most technological improvements will focus on automating the driving task. Full autonomy is unlikely to be widespread by the year 2050. Instead, autonomy will focus on taking control of the vehicle in dangerous situations, such as when an imminent collision is detected. Other advancements will provide greater assistance to drivers in normal operation and may help to regulate access to those unfit to drive, such as those who are excessively fatigued or intoxicated.

Slide 10

You may have noticed that we define a safe vehicle in the year 2050 as a vehicle from 2025. But why not just use a vehicle from 2050? As this graph demonstrates, it takes time for improvements to infiltrate the wider car automobile market. A technology available today may not be standard fitment in all new vehicles for a number of years. This is also dependent on whether a technology is regulated. Electronic stability control is a good example, as its fast infiltration into the new car market has been due to its regulated inclusion into all new passenger vehicles.

The other reason for choosing a 2025 vehicle as the minimum standard in the year 2050 is the time it takes for new vehicles to infiltrate the fleet. In Australia, the average vehicle age is about ten years. The time taken for the vast majority of vehicles in the fleet to renew is much longer. Choosing as a minimum standard a 2025 vehicle provides gives twenty five years for the majority of the vehicle fleet to turn over.

In other words, by the year 2050, the vast majority of vehicles on the road will have been built on or after the year 2025.

Slide 11

The main challenge for those managing the road transportation network is to consider what a safe road may look like in the year 2050, within the bounding definitions of a safe vehicle and safe road user. For zero twenty-fifty, rural roads have been defined into three categories based on their cross-sections. Roads of adequate quality will be allowed to operate at higher speeds. For those where the level of quality cannot be maintained, speed limits and speed management will be corrected to ensure survivability.

This is not the only way in which a safe road can be defined. However, any way in which a safe road is defined should be predicated on Safe System theories of survivability. In other words, energy needs to be managed so that any crashes that do occur are survivable.

Slide 12

Once the future has been defined, we need to know where we are in order to determine what needs to be done. Next, we will look at how we can map the current state of the road network.

Slide 13

Mapping the current state of the road transportation network is an essential part of the transportation process, as it gives insight into the quantum of effort that is required to achieve a safe road transportation system. It also allows us to direct discussion towards Safe System speak. By mapping the current network our in Safe System language, we can more easily understand the changes that are required, and more easily disseminate this information to decision makers and the wider community.

Slide 14

The first step along this journey is to map the road network. While this may seem a trivial task, it is often not that easy. Not all roads are controlled by the same entity. Some roads are federally controlled, some controlled by the state government and some are controlled by local entities, such as with local government roads. In most states around Australia, state and local government roads constitute the majority of road kilometres. In Victoria, forestry roads also constitute a substantial proportion of the network. This can make sourcing basic data, such as traffic volumes and basic asset data, a challenge.

Once the road network has been mapped, the level of safety that each road affords can also be mapped. One way to achieve this is to contextualise each road against Safe System theories of survivability. For example, this could mean mapping out the extent of primary Safe System treatments such as road safety barriers and roundabouts. Such direct measures can be hard to ascertain in detail, but are good for giving a direct comparison as to the level of investment that is needed in order to achieve harm elimination.

Another way to map the current state of the network is through the use of network risk assessment tools, such as the Australian Road Assessment Program. Such information is likely to already exist for state and federal roads and so can make a good way to start contextualising the current network. However, such data is less likely to be obtainable for local government roads, where the cost of data collection is prohibitively expensive. Another consideration, it is also important to remember that network risk assessments may not be as well aligned to Safe System principles as is desired.

Slide 15

Mapping the current state of the road network gives good insight into the general state of affairs. As this map shows for state controlled roads throughout the state of Victoria, most roads are poorly aligned to Safe System principles. This does not mean that these roads are sub-standard in the context of road design standards and guidelines, but instead highlights the inconsistencies between current design standards and what level of design actually ensures crash survivability.

Slide 16

A key step in the process is to understand the ways in which the network is utilised, and how this utilisation is likely to change into the future. Such information is vitally important when it comes time to decide how investments will be distributed. Some roads may be little utilised and so will attract little future funding, relying more heavily on speed limit corrections. At the other end, some roads will form key strategic parts of the road network. These may be for reasons of mobility, such as with freeways, or they may be important for economic reasons, such as the roads that support substantial freight movements. Knowing what roads serve which functions will help to inform the quantum of investment that needs to be made.

Another task is to assess what has been done so far to improve the road network. While this may seem like a trivial matter, even understanding the locations of major infrastructure assets can be a challenging task. As previously discussed, different parts of the road network are controlled by different levels of government and even different organisations within government, making the task of data collection a challenging process.

Controlling entities also have varying and often relatively poor knowledge of what is contained on their network. For example, the locations of recently installed road safety barriers may be well documented, but knowledge of older barriers is often missing or lost in outdated databases. Compounding this issue is that of maintenance records, as even the safest infrastructure is no good if it is not maintained to operable levels. Again, new infrastructure may be well documented but older parts of the network are likely to be under-documented.

Slide 17

(No transcript)

Appendix D4. Module 4, Snippet 4 transcript

Slide 1

Welcome to Module 4, Snippet 4 of Safe System for Universities. In Snippet 3, we introduced the idea of transformation and the approach taken by the state of Victoria through its zero twenty-fifty strategy. In this snippet, we will continue through the steps of transformation.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Boundary conditions are needed to understand within what domain we can operate the road transportation system. Next, we will discuss what these boundary conditions are and how they fit into a transformative framework.

Slide 5

As we discussed in the last snippet, the main goal of transformation is to operationalise Safe System principles and theory into the road transportation system in order to make road transportation safe. This means operationalising all four pillars of the Safe System. In principle, this means creating safe roads with safe speeds, having safe vehicles to travel within and having safe road users operating within the system. It should be noted that while safe speeds is dealt with as a separate pillar within the Safe System, in the zero twenty-fifty strategy, speed is defined as a function of all the other elements. This is because the level of road design, vehicle technology and road user behaviour that can be achieved will dictate what speeds are safe.

In practice, this means controlling road design and operations within the domain of survivability, maintaining speeds that are compatible with road and vehicle design, implanting greater safety technologies within the vehicle fleet, and managing road user behaviour through education, enforcement and access control. We've so far looked in some detail as to what this practically looks like for roads and vehicles, but how does it all fit together?

In essence, road design and operation, speed control and vehicle safety all act within a larger domain. Road design and vehicle technology set the stage for what can be physically controlled. Speed then becomes a function of road design and vehicle technology. In other words, we correct the speed limits and manage speeds for what is safe, given the level of road design and vehicle technology that is available.

Around this domain, education, enforcement and access control form the boundary conditions under which the other elements must act. Only so much can be expected from road users; the elements of road design, vehicle technology and speed must make up the shortfall in human performance, from both a biomechanical and cognitive standpoint. In other words, we design roads, set speeds and provide vehicle technology that can together enable survivable mobility given the limitations of road user performance.

Slide 6

Once we understand the system as it currently stands and the boundaries in which we must operate, we can start to identify the gaps and develop scenarios for filling these gaps.

Slide 7

Gap analysis means understanding the gap between where we currently stand and where we want to be. This process then directly informs the development of future scenarios. There is not one defining scenario that will reach the goal of harm elimination. Instead, there are many scenarios that can reach the same goal. The challenge lies in identifying the scenario that best fits the goals of harm elimination and the wider goals for our road transportation system and our society.

Slide 8

At its most basic level, gap analysis means defining the difference between the level of safety on the current network and the level of safety that we wish to attain. To make use of such knowledge, we then need to ask ourselves key questions. For example, what does a safe road network actually look like in comparison to what we current have? For the zero twenty-fifty strategy, this means comparing the current road network to the safe cross sections that have been developed.

Other questions that need to be asked are what are our options for changing the network, and how much will this cost? These two constraints are likely to be the major factors that define how we achieve a safe road transportation system. It is important to remember that the options we have today may not necessarily be the options that we have in ten or twenty years, as technological advancements of the future are not always clear today.

Slide 9

An example of a future scenario is the transformation of freeways within the state of Victoria. Prior to transformation, the freeway network is built to a high current standard and some patches have been designed to Safe System-aligned levels or identified and treated as high risk locations, but much of the network still falls short of alignment with Safe System principles. To achieve transformation, most of the freeway network will need to be retrofitted with treatments that ensure survivability in a crash.

Part way through the transformation process, we can see that continuous lengths of each corridor have been treated, rather than just the high risk locations that would have historically been targeted. Notice that the routes closest to and between major centres have now been treated. The high volumes and high level of strategic importance of these roads means that they are good candidates to treat first.

At the conclusion of transformation, the freeway network will be survivable in almost any crash. The idea of transformation means that the entire freeway network is rendered safe, rather than just high risk locations identified as sub-standard or with a prior crash history. This does not mean crashes will cease to occur, but instead means that no one should be killed or seriously injured when using this section of roadway. Exceptions are likely to occur and when they do, it is the system managers' duty to investigate why and mitigate the mechanisms that still allow harm to occur.

Slide 10

Key performance indicators are the way we measure performance. Next, we will discuss their role and how they enable transformation to occur.

Slide 11

Key performance indicators are the way we measure and communicate performance of the network. The reporting of crash statistics is a very visible key performance indicator that has been widely used as the sole measure of network safety performance. The problem with using crash statistics is the indirect relationship between these statistics and the performance of the network. Crashes are a function of risk. A higher crash risk does not necessarily mean a crash will occur, but means it is more likely to occur than if the crash risk was lower. Relying on crash locations to pinpoint areas of the network that need to be treated means that only those locations where crashes have occurred are going to be identified.

Slide 12

More direct measures, based on the road and roadside environment, directly tie safety performance measures to the investments that are used to improve safety performance. The theory behind these investments provides the link between investment and survivability.

Slide 13

The main reason for key performance indicators is to track the progression of transformation over time. The first step to creating a key performance indicator is to set milestones for when certain levels of progression will be achieved. We can start from the end goal, by setting a date for when we want complete transformation to occur, and work our way backwards to work out when certain levels of progression will need to be achieved.

By following the path between these milestones, we have a map that guides us from the current state of the network to where want to be. Placing dates and progress indicators along this map allows us to track progression over time. For example, we could track the progression of continuous flexible barrier installation along major rural roads. By using this map, we know the objective timeframe for installing continuous flexible barrier along the network and can track current progression against where it is meant to be.

Slide 14

There are many key performance indicators that could be used to track progression. The trick is to pick those that directly relate to the ways in which transformation will be achieved. All elements of transformation need to be tracked, which means that many key performance indicators may be required. While this may seem more complicated than using an aggregate indicator such as crash numbers, the directness of these many indicators means that progress can be easily tracked. And remember, indicators are not just required for elements of the road network itself. We also need to track the other elements that form bounding conditions, such as the rate of vehicle safety improvements and the level of enforcement and access control.

Slide 15

(No transcript)

Appendix D5. Module 4, Snippet 5 transcript

Slide 1

Welcome to Module 4, Snippet 5 of Safe System for Universities. In this final snippet, we will discuss three key factors critical to the implementation of the Safe System. Sometimes viewed as barriers, these factors in fact hold the key to unlocking Safe System practice in the real world.

Slide 2

(No transcript)

Slide 3

This snippet is made up of a number of sections. Click on the below links to go through each section. To advance a slide, press enter on your keyboard or click the slide. If you miss anything that has been said, you can replay the narration to each slide. A printed version of the narrative is also provided in the curriculum guideline.

Slide 4

Our response to harm drives the way we manage safety within the road transportation system. Generally, our response to harm involves two key factors: the ethical responsibility and legal liability of system managers. Now, we will discuss these two factors and how they can contribute to a good or poor response when harm occurs.

Slide 5

Ethical responsibility and legal liability are two concerning factors that should weigh into any decisions made by system managers. These two factors play a critical role into both day-to-day functions and the responses made when something goes wrong. The ethical responsibility of a system manager is generally concerned with ensuring the safety of the people who use and work within the road transportation system. On the other hand, legal liability is concerned with ensuring that system managers are taking all reasonable precautions to minimise the risk of loss or harm that could burden a system stakeholder. When loss or harm does occur, legal liability is about a reasonable level of defence for the decisions made by system managers.

When harm occurs on the road network, our response is critical to preventing more harm from reoccurring in the future. A well-reasoned response will consider both the ethical responsibility and legal liability of system management. A good response will help to protect the system managers who made sound decisions, as well as prevent harm from further occurring in the future.

A good response will involve a review of the safety conditions that led to the harm occurring in the first place. This should be more than just a review of the standards and guidelines, and will ideally involve a thorough investigation of all the factors that led to the crash and subsequent harm, such as through the processes outlined in the Austroads Guide to Road Safety. The aim here is to minimise the risk that harm will reoccur, especially when the mechanisms of that harm can be reasonably identified and countermeasures exist to mitigate the risk.

The second part of a good response is to review the legal liability of the road authority and the decision makers who manage the road network where the harm occurred. The best response is a proactive response. This means ensuring that system managers have a reasonable level of defence for their decisions, should something go wrong and someone is harmed. One way of achieving this is by considering the standards and guidelines that spell out how the road system should be designed and managed, and the design domain under which those decisions are made. We'll talk more about standards, guidelines and the design domain later on. For now, you can think about a good legal liability response as one that considers the reasonable level of defence for the decisions made by a system manager, given the financial, capacity and capability constraints under which they operate.

Slide 6

Now let's look at the response to harm through the lens of risk management. We want to design the road to minimise the net risk of harm. While we would ideally like to eliminate the risk of any harm, it is well known that system managers work within constraints that mean this is not always possible. These constraints could be the limited availability of funds, meaning we have limited capacity to ensure safety. They could also be constraints of knowledge, meaning we do not always have the data and understanding required for perfect judgement. Simply put, we prioritise and make decisions to minimise the overall risk to road users, while working within the constraints that are laid upon us.

We design and build roads while trying to minimise harm. But in doing so, we also know that we are creating a system in which some people will be harmed. However, we do not always understand exactly where or how this harm will manifest itself. Therefore, when harm does occur, we must use the knowledge gained through these events to address the deficiencies that led to harm occurring in the first place.

A reasonable response will consider both the system managers' ethical responsibility to minimise harm, as well as their legal liability with regard to the decisions that they make. In the context of risk management, this means we must respond in a way that reduces the risk to road users, through both identifying and mitigating existing risks, and ensuring that we have and will continue to work within the limits of our capability and knowledge.

A poor response, on the other hand, will view risk only from the perspective of liability towards the road authority and the system managers who act within it. Such a response can lead to practice that aims to ensure only the minimum required standards are met. As outlined within the Austroads Guide to Road Design, a road designed to meet the minimum standards is not necessarily safe.

A response to harm should ultimately lead to a point where prior decisions and practices are critiqued and revisions are made to correct prior errors and oversights. A good response will view this in light of the trade-offs between design parameters that are inputted and the level of safety that results. When harm does occur, the question should be asked as to whether the design parameters were sufficient to reasonably minimise the risk of harm. In the context of risk management, this is analogous to the factor of safety that is used in other areas of engineering. In this sense, we need to ask ourselves whether the factor of safety was sufficiently great enough to ensure a harmful event does not occur.

On the other hand, a poor response will likely not question design beyond the scope of the minimum required standards. Such a response may cover a road authority and its system managers in the sense of their legal liability, but will ultimately fail to question whether the safety requirements of road users where reasonably addressed. In taking such an approach, we fail to consider our ethical responsibility towards road users by failing to use our sound engineering judgement to minimise risk within the constraints with which we work.

The result of a good response to harm should lead to recommendations for improving design practices, should insufficient practices be identified. A good response can also help identify factors outside of the design realm that may need to be rectified, with recommendations to improve practices both inside and outside of a road authority's direct control. These recommendations can then be weighed up against the trade-offs that may result, such as the cost of rectifying insufficient design. Moreover, when system managers are informed of the risks posed by current practices, the defence for continuing these practices is reduced and change which further minimises the risk of harm is more likely to occur. In this sense, the added value of such a process is the ability to inform future design practices, so that similar risks can be identified and improved design practices can be implemented.

The results of a poor response are, on the other hand, less likely to inform better design practices in the future. Instead, business as usual will continue to occur and the same mistakes that led to harm in the first place are more likely to be repeated.

Slide 7

In the previous section, we mentioned standards and guidelines, and their role in a reasonable response to harm. Standards and guidelines form a basis for the minimum level of design that should be attained. However, they can sometimes be viewed as an instruction manual that outlines the level of performance to which a road should be designed. The difference between these two ideas is subtle but important. Next, we will discuss the role of standards and guidelines in the context of minimising harm.

Slide 8

Standards and guidelines have been created as safety nets that set a minimum acceptable level of performance. In this sense, standards and guidelines ensure that design and operational practices below minimum accepted limits do not enter the road transportation system. In practice, this removes much of the possible risk to road users and is a substantial reason why we today do not see considerably more death and serious injury on our roads.

However, the purpose for which standards and guidelines have been created is not the same as the way they are sometimes put into practice. A response to standards and guidelines may be to treat them as a benchmark for good design, instead of a safety net to mitigate the risk of sub-standard design. Such a response is counter to the idea that designing to minimum standards does not guarantee safe outcomes. The risk here is that the minimum standards of design become the only values that we adopt. The context of design and the relationship to risk are both forgotten. In other words, we set out to achieve the minimum level of performance, without considering what the minimum level of performance entails.

Slide 9

A leading idea within the current design fraternity is that of context sensitive design. Context sensitive design is about recognising the environment in which a road will operate. This allows a designer to create solutions while recognising the trade-offs and limitations with which the design must contend. A key consideration of context sensitive design is the need to adopt design that is in keeping with the Safe System approach. In this sense, context sensitive design needs to incorporate consideration of how to make a road safe, rather than just how to make a road safer within the confines of the current standards and guidelines.

As stated by the United States Federal Highway Administration and outlined within the Austroads Guide to Road Design, context sensitive design asks questions about the needs of transportation. In the context of the Safe System, this means asking questions about providing safe transportation. In this sense, we can use context sensitive design as a way to pursue Safe System outcomes by better understanding how design can be sensitive to the needs of providing safe mobility. In the following section, we will pursue this idea in the context of the design domain, an concept of road design that is closely aligned to the idea of context sensitive design.

Slide 10

We finished the last section by introducing the design domain. Next, we will discuss the concept of the design domain, its relationship to context sensitive design, and how this may be used to pursue safe road design within the context of a Safe System.

Slide 11

The design domain may be viewed as the tangible boundary in which context sensitive design can be practiced. It is the bounding area under which accepted levels of practice are situated. In the real world, the design domain forms the set of design and operational practices that lead to a certain level of performance. The concept of a road design domain in Australia was developed several decades ago. This concept was based around the idea of context-sensitive, cost-effective design that considers the performance limitations of drivers and their vehicles. As such, much of the design domain is focussed on the geometric design of rural and high speed roads, such as through setting standard lane widths and curve geometry based on assumptions of vehicle performance. The normal design domain as shown here is the performance standard to which we design when building new roads or upgrade existing roads. The lower bound of the normal design domain constitutes the current minimum acceptable level of performance for these situations.

Next to the normal design domain sits the extended design domain. This is essentially an area of diminished performance. It is our acknowledgement that previously built and currently operated parts of the road network will not always perform to the same level to which new roads are designed. As you may have noticed, traffic volume plays a part in deciding where the boundary of the domain lies, as higher traffic volumes mean it is harder to justify a low level of performance due to the greater number of people that are exposed to the design. As such, the minimum level of acceptable performance increases with the traffic volume.

Legal liability and a scope for defence are two concepts that we have previously discussed. In short, they represent the ability for system managers to defend their decisions on the grounds of sound engineering judgement. In the context of the design domain, the selection of design values below the bounds of the design domain increases the scope for legal liability, should something go wrong and a road user is harmed. In other words, the scope for defending one's decisions are decreased. In this context, it is possible to view any design above the bounds of the design domain as appropriate, given that design within the design domain can form a defence for one's decisions.

As outlined within the Guide to Road Design, there is a potential for collisions to occur on any road, and so designing a road to a set of standards does not necessarily guarantee safety. Improving survivability on our roads beyond the capability of current practice can mean the need to look to new and innovative ideas. However, such practices can lie outside of the current design domain, because they are often too new or innovative to yet reside within the standards and guidelines that have been agreed upon as the scope for normal design practice. This means that we can potentially discourage design that brings us closer to the elimination of harm, purely because it sits outside of our current idea of normal practice.

Slide 12

In this light, we can ask the question as to whether the current concept of a design domain is adequate? Should there be a Safe System design domain in which design and operational practices move closer and closer to achieving a safe road transportation system where all crashes are survivable? It is important to note that such a domain does not currently ensure survivability and will not achieve survivability within the confines of infrastructure improvements alone. Instead, a Safe System design domain, applied within a transformation context, sets us towards the goal of zero deaths and serious injuries within a foreseeable timeframe by utilising capabilities from all pillars of the Safe System.

A Safe System domain lies within the context of more than just infrastructure. A systems-based approach is needed that integrates infrastructure decision making within the context of vehicle technology, speed, and other elements. The backbone of such a systems-based approach is the design and operational practices that manage energy within the road transportation system to survivable levels.

By looking at safety performance from this perspective of survivability, we can question whether our current design practices can produce survivable outcomes and therefore whether these practices are acceptable in the context of a Safe System. Where practices under the current design domain are unable to guarantee survivability, we will need to look beyond the current accepted norms and to the proposed Safe System design domain, with practices that are increasingly able to produce survivable outcomes. Additionally, while the design domain as it currently stands can incorporate Safe System aspects of design, the effect of vehicle technology and speed on energy management need to be included together with geometric design considerations to provide a system response, rather than one built specifically on one aspect of road transportation.

Slide 13

Ultimately, transformation would see a future where the proposed Safe System design domain becomes the normal design domain, and anything below this qualifies as sub-standard to accepted minimum levels of safety performance. In other words, design and operational practices that are based on energy management and ensure survivability become the minimum accepted level of performance. Achieving this will require a complete rethink of the standards and guidelines to which we currently design and operate the system.

Slide 14

As an example, let's look at the way intersection control is dealt with in the current Austroads guidelines, and how this could differ in a Safe System design domain. Currently, the Austroads Guide to Road Design promotes the use of both signalisation and roundabouts as way to control traffic at intersections. Guidance for both types of control falls within the normal design domain, based on standardised design informed by a range of factors including safety and mobility.

Where the current guidelines fall short is in discerning the priority of use based on safety criteria. The use of both signalisation and roundabouts are justified on safety grounds, but there is little guidance to discern safety performance in the context of energy management and alignment with Safe System objectives. While this type of information is available in other Austroads publications, such as their research report on improving Safe System performance at intersections, guidance within the standards and guidelines utilised by designers may take years to manifest and has the potential to be diluted by competing agendas, such as the need to maintain intersection throughput.

Slide 15

In a Safe System design domain, performance of design options would need to be clearly illustrated in the context of energy management and alignment to Safe System objectives. This would then feed into design hierarchies that promote the use of well-aligned design first, and give clear reasoning for when lesser design can and cannot be considered as alternatives. In a Safe System design domain, the safety superiority of certain design, such as roundabouts, and the potential for risk of harm associated with each form of design would be clearly outlined and used to govern guidance.

Slide 16

Now that we have a better understanding of some of the barriers to achieving safe roads, let's finish by summarising how the management of risk can help to inform a Safe System.

Slide 17

In this snippet, we have discussed some of the key barriers to transformation. There are likely to be others, and these will become clear as we work closer towards dissolving the barriers of which we are already aware. For now, we need to progress beyond a tendency to design to minimum requirements. The design domain and context-sensitive design have helped move the industry away from this tendency. Going forward, we need to align these design practices with the design principles implied by the Safe System.

At the start of this snippet, we looked at the concept of ethics and liability, and how aiming to achieve risk minimisation, rather than conformation to minimum standards, can help to achieve a good response to harm on our road network. Ethical responsibility and liability go hand-in-hand. Going forward, we need to better define the ethical responsibility of road managers towards road users.

As we have discussed, there is a risk of treating standards and guidelines as design benchmarks, instead of the design safety nets for which purpose they were created. A response to harm that is predicated on liability alone is more likely to prioritise the achievement of minimum standards, rather than a level of design that minimises the risk of harm. We need to be mindful of this issue and instead base our response to harm on an ethical foundation, as well as a liability one. Doing so will lessen the risk that we base our design decisions on meeting minimum standards and instead design towards an agenda of minimising harm within the context of our current levels of understanding.

Finally, the design domain was created to shift the design goalposts beyond attaining only minimum acceptable levels of design. This is currently achieved through the notion of a context-sensitive approach to design. Going forward to a Safe System future, we will need to adopt leading-practice in safety as our benchmark for design. To do this, we need to establish design guidance that is not only context-sensitive, but also harm-sensitive. In other words, we need to adopt a design domain that is based on mitigating the mechanisms of harm.

Slide 18

(No transcript)