Safe System Decision Support Tool

The Safe System approach for road safety originated in the Netherlands in the 1970s. Later, Sweden, Australia, and New Zealand adopted the Safe System. The concept behind the 'Safe System's approach is to build a road transport system that allows for human error and minimizes casualties following road crashes. The five pillars of the 'Safe System' approach are 'Safe Road Users,' 'Safe Road,' 'Safe Speeds,' 'Safe Vehicles,' and 'Post-Crash Care.' In contrast to traditional road safety approaches that primarily focus on road users and risky behaviors, the 'Safe System' approach provides a systematic method to reduce crash occurrences and subsequent injuries in the event of a crash. The U.S. DOT has adopted the Safe System approach as the guiding paradigm to address roadway safety in 2022.[8] A Safe System approach incorporates the following principles:

- Death and Serious Injuries are Unacceptable
- Humans Make Mistakes
- Humans Are Vulnerable
- Responsibility is Shared
- Safety is Proactive
- Redundancy is Crucial

The research team identified several key contributing factors by exploring association rules mining. Table 8 shows a Safe System-based ADV-related decision support matrix tool. This tool can be useful for both ADV operators and transportation agencies, and was developed in a way to link the research findings to an applicable tool. As the U.S. DOT is moving toward a Safe System approach, the current tool can work as a high-level decision support matrix to understand the impact of ADV-related safety issues. In addition to the score, responses can be added to each of the cells to help identify the specific issues of concern. This is intuitive in determining the key risk factors for infrastructure.

Seven critical factors were primarily determined as the risk factors for ADV mobility. These factors are rear-ended collisions, front-to-front collisions, AV in autonomous mode, AV in conventional mode, stopping of AVs, intersections, and others. It is important to note that the columns (e.g., rear-end) indicate risk measures in terms of crash, near-crash, or conflict. Once there is a score in each cell for the exposure, likelihood, and severity rows, the product of each column is calculated and entered in the final row, labeled 'total.' The purpose of this multiplicative process is that if a score of zero has been given for any component of a crash type (i.e., exposure, likelihood, or severity), that collision or conflict type scores zero (meaning that it has reached a Safe System). The sum of the total scores for each collision or conflict type is then added to the final cell on the right-hand side. This score is out of a possible 448 and represents two specific infrastructure-based Safe System pillars (safe road and safe speed). The closer that

[8] https://www.transportation.gov/NRSS

the score is to zero, the more the project in question is in alignment with the Safe System principles (see Table 9 for score details). Additional Safe System pillars (i.e., road users, vehicles, and post-crash care) are considered in the following rows, where prompts are given to direct the users to consider how the project interacts with road users, vehicles, and post-crash care. The research team also considered infrastructure pillars (safe road and safe speed) following the other three pillars in a way to provide a complete picture of the interactions and reasoning behind the scores.

Table 8. Proposed Safe System based ADV related Decision Support Tool

Risk Factors	Rear-end	Front-to-front	Autonomous Mode	Conventional Mode	AV Stopped	Intersection	Other	
Exposure	__/4	__/4	__/4	__/4	__/4	__/4	__/4	
Likelihood	__/4	__/4	__/4	__/4	__/4	__/4	__/4	
Severity	__/4	__/4	__/4	__/4	__/4	__/4	__/4	
Product	__/64	__/64	__/64	__/64	__/64	__/64	__/64	Total = __/448

Pillar	Contexts	Response
Safe Road User	• Are road users likely to be alert and compliant? • What is the density of non-motorists?	--*
Safe Vehicle	• Has vehicle breakdown been catered for? • What is the distribution of multiple modes? • What is the vehicle ownership per household?	--
Post-crash care	• What is the distance to the nearest hospital? • Do emergency and medical services operate as efficiently and rapidly as possible?	--
Safe Roads	• What are the counts of fixed objects? • Number of driveways? • Is there on-street parking? • Is there any roundabout? • Is there a park nearby?	--
Safe Speeds	• What is the posted speed limit? • Is the operational speed much higher than posted speed limit?	--

*Note: *responses are kept blank.*

Table 9. Proposed Scoring Method

Road User Exposure	Crash likelihood	Crash severity
0 = there is no exposure to a certain crash type.	0 = there is only minimal chance that a given crash type can occur.	0 = should a crash occur, there is only minimal chance that it will result in a fatality or serious injury to the relevant road user involved.

Road User Exposure	Crash likelihood	Crash severity
1 = volumes of vehicles that may be involved in a particular crash type are particularly low, and therefore exposure is low. *AADT is < 400 vehicles per day (vpd).*	1 = it is highly unlikely that a given crash type will occur.	1 = should a crash occur; it is highly unlikely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies must be fairly low during a crash.*
2 = volumes of vehicles that may be involved in a particular crash type are moderate, and therefore exposure is moderate. *AADT is between 400 and 1,000 vpd.*	2 = it is unlikely that a given crash type will occur.	2 = should a crash occur; it is unlikely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies are moderate.*
3 = volumes of vehicles that may be involved in a particular crash type are high, and therefore exposure is high. *AADT is between 1,000 and 2,000 vpd.*	3 = it is likely that a given crash type will occur.	3 = should a crash occur; it is likely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies are moderate but are not effectively dissipated.*
4 = volumes of vehicles that may be involved in a particular crash type are very high, or the road is very long, and therefore exposure is very high. *AADT is > 2,000 vpd.*	4 = the likelihood of individual road user errors leading to a crash is high given the infrastructure in place.	4 = should a crash occur; it is highly likely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies are high enough to cause a fatal and serious injury crash.*