Achieving Road Safety Targets Under the Safe System

Neil Hay, presented by Craig Gordon

Ministry of Transport, Wellington, New Zealand[1]

ABSTRACT

Since the mid-1990s several jurisdictions have implemented the safe system approach to road safety while setting ambitious targets for reduction in the road toll. More recently the principles of this system have been applied in Australia and are also being considered in New Zealand. This approach acknowledges that the limits to human performance mean that road user error is inevitable. Given that driver error will occur it is vital to reduce the seriousness of the consequences. There is considerable flexibility in the interpretation of the safe system approach suggesting that the details are of importance to the effectiveness of the approach. Setting priorities for interventions after taking into account the behavioural response to these changes will maximise the effectiveness. Implementation of this approach to achieve reduction in the road toll requires ongoing effort. It is also proposed that a broad conception of the system approach to crash causation, one which accounts for social and institutional values, should be encouraged and promoted across the many agencies involved with implementation.

1 INTRODUCTION

The following document outlines the safe system approach to road safety with a view to understanding some of the challenges associated with achieving the significant improvements in road safety. For several jurisdictions the safe system approach has been successful in realising reductions in road death and serious injury. In the next section, the principles of the safe system approach to road safety are discussed, noting the variations in focus and implementation. Interpretation of the principles has varied over time as well as between and within jurisdictions (Elvebakk and Steiro, 2007). Some interpretations support a focus on infrastructure and vehicle fleet change with less attention to human factors and a possible reduction in overall effectiveness. Interventions which change the road environment may have led to behavioural adaptation which can reduce the overall safety benefits. It is proposed that safety gains will be maximised by a clear understanding of behavioural responses to perceived and actual changes in the difficulty of the driving task.

The principles of the safe system approach to road safety represent a positive change relative to recent approaches. It is also proposed that applying a broad interpretation of the systems approach, one which encompasses social and institutional aspects of road use would be beneficial in achieving further reductions in road death and serious injury.

[1] The views expressed in this paper are those of the authors and do not necessarily represent the views of the Ministry of Transport.

2 THE SAFE SYSTEM

2.1 What is the safe system approach?

Borrowing from other safety critical industries, the safe system approach acknowledges that accidents often result from a number of causes. The responsibility for a road traffic crash is shared between the road users, and the system in which they act. Consequently, the designers of the road network and vehicles have a responsibility to design a system that removes the potential for humans to be exposed to such physical force that will cause death or serious injury.

The safe system approach starts with a set of principles:

- Human error is inevitable
- The human body has a limited tolerance to physical force
- The environment in which humans act should be designed such that error does not lead to such physical force as to cause death or serious injury.

In addition to road user behaviour, factors commonly implicated in traffic crash causation can be classified as relating to speed, roads and roadsides, and vehicles (e.g. MUARC, 2008). These causes of traffic crashes identified in the safe system approach then lead to a set of goals centring on making safer speeds, safer roads and safer vehicles. Roads and vehicles should be designed to protect those who are behaving responsibly and whose performance is reasonably unimpaired by alcohol, fatigue, etc. The value of safety in mobility is explicitly acknowledged. Recognition of this would be expected to change the practice of designing, constructing and managing the road network and the vehicles on it.

In acknowledging limits to human performance, the safe system model proposes human error is inevitable. However, the outcome of such error should not be death, a common outcome of errors in the road environment. The model enables a broad range of options including a clear understanding of the limits of human performance as it relates to the driving task, and the pursuit of harm minimisation through road network design. As will be discussed below, the interaction between the road users, vehicles and the road environment are crucial to achieving safety gains under the safe system approach. This need for an understanding of the environment in which the road user is embedded places the protection of the road user at the centre of the system.

The presentation of the safe system beyond the basic principle of sharing responsibility is open to interpretation such that jurisdictions have placed more or less focus on certain aspects both in theory and in implementation. Elvebakk and Steiro, (2007) reviewed Norway’s application of the Vision Zero program. They noted some differences as compared with the Swedish program, and also found that understanding varied between organisations responsible for road safety within Norway. Within the main road administration, some understood that the main focus of the approach was to improve the infrastructure, while others understood that the safe system might call for measures over and above this. Other organisations responsible for road safety had more diverse views on the implications.

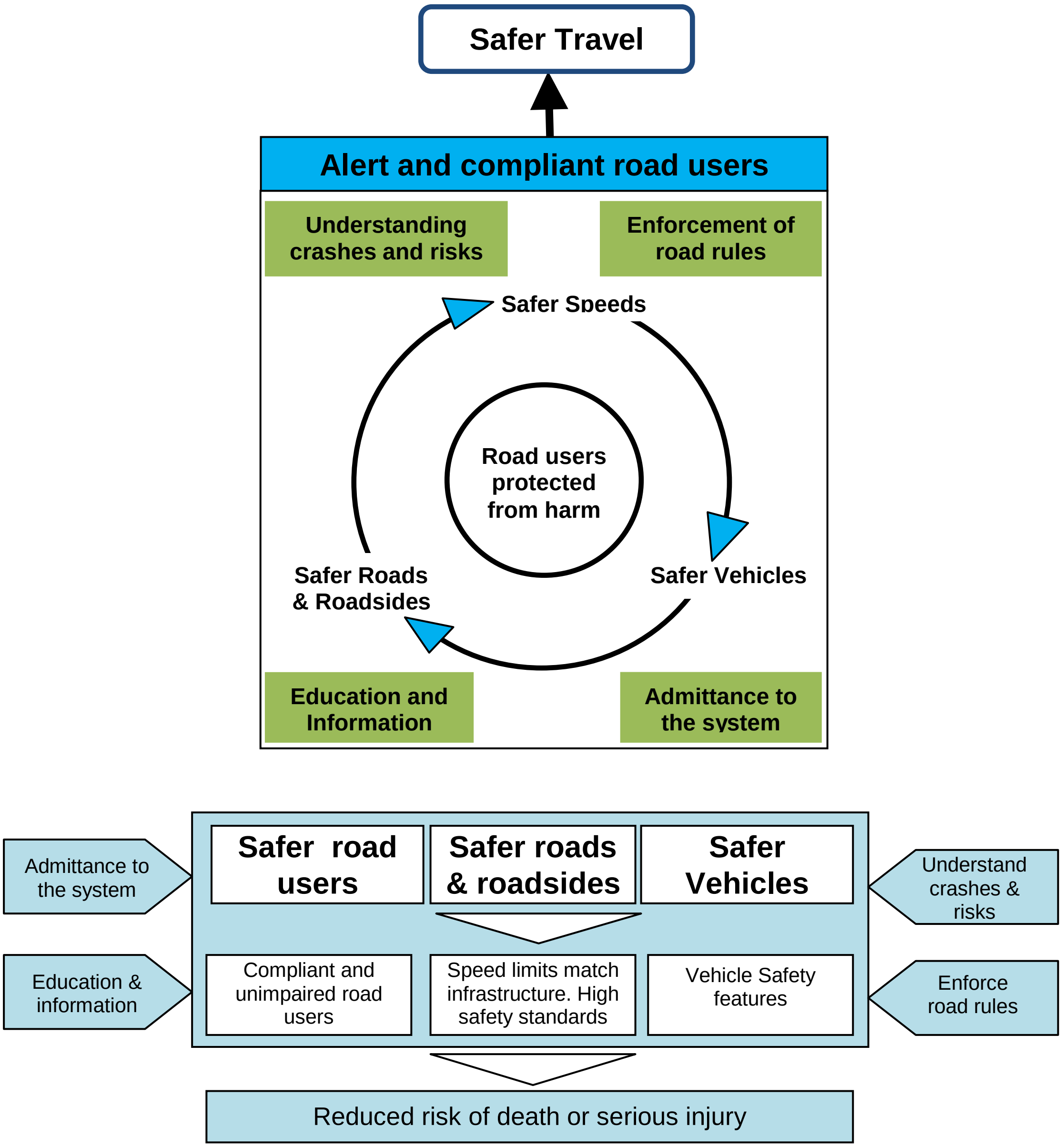

Figure 1: Two alternative diagrams of the safe system approach to road safety. (Adapted from ARRB, 2009; OECD, 2008; VicRoads, 2008)

2.2 How might the safe system approach be implemented?

In concept, the safe system approach identifies and classifies the range of causes of road traffic crashes. It acts as a safety management framework to make practical change to reduce the incidence and severity of road traffic crashes.

In practice, the implementation of the safe system approach focuses on proximal causes; those related to the vehicle, the road and vehicle speed. The scale of the road network and vehicles makes change a long-term task and prioritisation of interventions a key factor of success. Implementation offers a range of choices in terms of prioritising interventions. This is demonstrated by other jurisdictions that have used the safe system approach as discussed below. Although there is no doubt the safe system approach represents a progression in responding to the road safety problem, there are gaps in the theory. The behavioural response of road users to change in the road environment presents a risk to safety gains. It is proposed that attention must be given to the interaction between human behaviour and the road environment in order to achieve change.

Within the systems approach it is possible to take into account a broad set of factors associated with causation such as regulation, institutions and social influence. Literature on the safe system approach to road safety has tended to focus on proximal causes. In doing so, some aspects of the road safety problem are de-emphasised, such as sensation-seeking behaviour. The wider set of causes is very relevant to effective management of the road safety problem.

2.3 How has the safe system approach been implemented in other countries?

One of the countries who have applied the safe system is the Netherlands (e.g. SWOV, 2006). Since the 1990s, the Sustainable Safety program has been applied to the country's road traffic system. Sustainable Safety is based on the principles of the Safe System, while explicitly placing a value on safety by stating that the loss of human life in the pursuit of mobility is unacceptable. Increasing mobility is a dominant force in road transport, implementation of this system aims to provide balance between objectives such that increased mobility is only acceptable if it can be achieved safely.

> "*Crash occurrence is* a priori *dramatically reduced by infrastructure design*."
> Koornstra et al. (1992 in SWOV, 2006)

Jurisdictions that have pioneered this approach, such as Sweden and the Netherlands, have engaged in significant programs of infrastructure change in order to align road design with function. This focus on infrastructure is at least in part related to the scale of the tasks involved in applying this model to an existent transport network. After fifteen years, a significant proportion of the network has had some treatment within the safe system but work is ongoing. Nonetheless, there are theoretical reasons behind attending to the infrastructure as a first step.

Road and vehicle design is a source of information for road users about how to behave. The most explicit source of information is from road signs which state road speed limits, approaching hazards, etc. However, there are a range of less explicit features of the road environment that influence road user behaviour. For example, it has been noted that speed choice is related to factors such as road width, alignment and the presence of buildings (Martens et al. 1997).

On this basis, the authorities in the Netherlands have sought to design the road environment with a set of perceptual characteristics which indicate an appropriate speed for that road (self explaining roads). In pursuit of this, they identified the function of each road in the network within a hierarchy. Each road is either an access road, a distribution road or a through road. An access road, for example is designed to enable safe access to homes for a range of road users: pedestrians and cyclists as well as motor vehicles. This means a range of road user interaction is likely. Given the commission of road user error on an access road it is possible that a car may hit a pedestrian. Environmental design and speed limits are oriented toward minimising the risk of serious injury or death. The appropriate speed limit is then set at 30km/h, relating to the impact speed where an unprotected road user such as a pedestrian or cyclist might avoid serious injury.

The aim of infrastructure change within the safe system is to design a road environment which supports appropriate behaviour. For example, residential access roads are designed to appear constricted, with few signs or road markings, providing the experience of a shared space where low speeds are appropriate. Each road type in the hierarchy has a consistent, characteristic set of features which are intended to maximise the ease of identifying road function and consequent behaviour.

Evaluations of the safe system approach have generally been positive, although reductions are not always as large as might have been hoped. There is suggestion that on-road vehicle speed has not been reduced as much as the speed limit in the Netherlands (i.e. the relationship is elastic, a 20km/h reduction in speed limit has resulted in a much smaller reduction in average speeds) (VTI, 2000). Although factors other than road design are involved in drivers' choice of speed, it appears that drivers' assessment of the difficulty of the driving task is out of line with the system designers' assessment. This raises the question of what factors should be changed to assist drivers to increase the salience of the danger inherent in driving, changes which would support appropriate driving behaviour. To this end, effort is ongoing to identify and implement a set of characteristics for each road type which are recognisable and enable differentiation (Goldenbeld and van Schagen, 2007).

Road design is one of a set of factors which might give information about appropriate speed. Many other factors affect the road conditions and thus the appropriate speed. This creates a challenge for those setting the speed limit to accommodate a broad range of conditions.

This intervention has been a long-term effort for the authorities in the Netherlands which has included reviewing the whole network, changing construction and design guidelines as well as the huge task of implementing change. If applied over the longer term, the application of a safety intervention such as self explaining roads will be likely to create a better environment for road users, despite the difference between objective and subjective assessment of appropriate driving behaviour. Evaluation of elements of road design in terms of impact on safety is available (e.g. Elvik and Vaa, 2004), however the implementation of these requires a long-term commitment.

The Sustainably Safe program in the Netherlands has instituted a set of 'essentially recognisable' road design guidelines. In spite of this it appears that public awareness of such details is low. It might be suggested that this represents a failure of the intervention, that drivers should be able to recognise features of the road environment to which they respond. Achieving public buy-in to safe behaviour might indeed be desirable but it is not likely to be desirable at the level of road design. Perception and interpretation of the environment is largely a subconscious process. As a result, drivers' behaviour has been shown to be responsive to changes in road features without their explicit acknowledgment of which features help them make their decision (Lewis-Evans and Charlton, 2006).

Figure 2 is a representation of the logic of behavioural adaptation (based on Elvik and Vaa, 2004). An intervention has an expected effect on road safety based by affecting one or more risk factors that contribute to accidents. However, road users can also respond to the intervention, in a beneficial or negative manner. If the behavioural response is negative this can lessen the impact of the road safety intervention. However, behavioural adaptation is likely to be partial, that is it reduces the road safety benefit to some degree rather than cancels it out. Some of the factors that influence behavioural adaption include (Bjornskau, 1994 in Elvik and Vaa, 2004):

- visibility of the measure,
- whether the measure reduces accidents or injuries,
- whether road-users previously have compensated for the risk factors which the measure is meant to influence or not,
- the size of the engineering effect, and
- the benefits of changing behaviour.

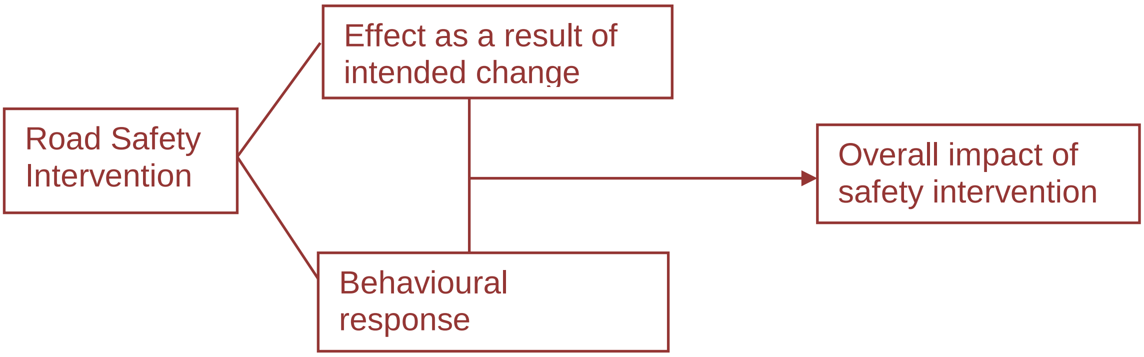

Figure 2: Behavioural adaptation (based on Elvik & Vaa, 2004)

In addition to road environment design, application of the safe system approach supports greater uptake of safety-oriented vehicle technology. As discussed below, these improvements are also likely to be mediated to some extent by the impacts upon driver behaviour.

One theory of driver behaviour proposes that feedback about the difficulty of the driving task has a substantial influence on behaviour such as a driver's speed choice. The driver chooses a level of difficulty and possesses a certain capability, the relationship between the road user's capability and driving task difficulty dictates whether the driver is in control and hence the occurrence of a crash. This model is known as the Task-Capability Interface (TCI, e.g. Fuller, 2005). Thus, a driver selects a level of difficulty which they wish to maintain and behaves in order to do so.

It is important here to note the distinction between a road user's perceptions of the capability/task difficulty relationship and the actual capability/task difficulty relationship. Road users' subjective assessment of their ability and the likelihood of a crashing as a result of their behaviour has been shown to be very different from the objective assessment (Forward, 2008). As a result, a driver's actions may be much closer to their capability than they intend. This subjective perception is likely to underlie certain critical behaviours such as close following, speeding. This is likely exacerbated by the fact that the road environment is a relatively indifferent one; error and risky behaviour do not usually lead to a crash. Conversely, feedback from good behaviour tends to be neutral. The reinforcement of behaviour via feedback then is irregular. Another issue is that the difficulty of the driving task can change unexpectedly such that the difficulty of the task exceeds the capability of the driver to control the vehicle.

For the road environment to be a safe system, it would be one which would not only protect road users from objective danger but would also be one that would give feedback about task difficulty in a manner which is interpreted correctly by an attentive road user. If this feedback is absent, then the road user may become complacent. Of particular concern is the consequence of driver behaviour for more vulnerable road users such as pedestrians. Relative to the current situation then, a successful intervention would in fact need to raise the perceived difficulty of the driving task while, at least, leaving the actual difficulty unchanged. Self explaining road design is a road safety intervention that is in line with such requirements. It assists road users to make a correct assessment of the difficulty of the task and consequently behave appropriately.

Road safety interventions under the safe system approach are likely to change the road and vehicle environment. In doing so, the perceived difficulty of the driving task can change as well as the objective difficulty. The Task-Capability model suggests these interventions are likely to result in changed behaviour by drivers who seek to maintain their selected level of task difficulty. Whether the behavioural adaptation is positive or negative is likely to depend on the nature of the intervention and characteristics of the driver.

Change to driver behaviour, known as behavioural adaptation, is often discussed in relation to new technology. An aim of the safe system approach is the employment of technology to make vehicles safer. This being the case, behavioural adaptation could lessen to some degree the road safety impact if the behavioural response is negative.

ABS is one of the few examples of in-vehicle technology advances which have been well documented with regards to the effect on road safety (Sorensen and Mosslemi, 2009). Used correctly, an Anti-lock Braking System (ABS) enables steering while under full braking and can shorten the stopping distance for a given vehicle speed, especially on wet or icy roads. Claims of the effectiveness of this system are common, and are often based around reductions in the type of crashes which the system was designed to reduce. Thus, rear-end collisions have been found to reduce substantially.

However, it appears that other types of crashes increase when a vehicle has ABS (MUARC, 2004). It is likely that some form of behavioural adaptation is involved. For example, it may be that a driver learns or assumes knowledge of the limits of an ABS system. In response to the decrease in perceived task difficulty, the driver may then adjust their speed to take account of this. A related possibility is that drivers misinterpret the function of the system, believing that traction is improved overall rather than under extreme braking where the wheels lose traction. MUARC (2004) note the increase in single vehicle run-off type crashes, a crash likely to be related to excess speed but unlikely to relate to traction under braking. A further possibility relates to the fact that, when the ABS system operates, the brake pedal vibrates quite abruptly and there is often a metallic grinding noise. It has been suggested that this alarms the road user and they subsequently reduce the pressure on the brake pedal.

Extensive research effort has gone into assessing the real-world benefits of ABS. It is clear from this research that the actual safety benefits of ABS are much lower than were expected. Given the increase in some types of crashes and the decrease in others, it appears that drivers do tend to adjust their behaviour in response to a changed perception of the demands of the driving task, (e.g. NHTSA, 2003, MUARC, 2004). Reviewing several studies, these reports suggest little, if any, overall safety benefit from cars fitted with ABS. In addition, much of the change in crash type is consistent with ABS cars travelling at a higher speed, suggesting that behavioural adaptation is a part of the picture.

In terms of the task-capability model, this implies that ABS lowers the perceived level of task difficulty. In response, drivers are choosing to drive at a higher speed to maintain their chosen level of task difficulty. What is striking about this response is that the new technology compensates for a specific behaviour but appears to have resulted in a generalised behavioural response, one that has a negative impact on safety.

ABS is a well-documented example of a specific vehicle based intervention that did not deliver on its promise for road safety and this may have been related to behavioural adaptation. However, this does not mean that advances in vehicle technology have not played an important role in improving road safety. There are many examples of vehicle design measures, even if some behavioural adaptation may be present, that have significantly contributed to achieving road safety benefits (Elvik and Vaa, 2004; Newstead et al, 2007; Regan et al, 2005). Overall there has been an improvement in road safety over time, however achieving ambitious targets with limited resources requires that the right combination of measures be given priority.

The construction of roads using porous asphalt is less well documented than the example of ABS. Porous asphalt enables water to drain from the road surface more quickly. Less standing water leads to improved friction and lower spray results in improved visibility. Empirical studies of the safety benefits of using porous asphalt tend to find that drivers increase their speed on roads with porous asphalt relative to traditional non-porous asphalt (Elvik and Greibe, 2005).

Electronic Stability Control (ESC) is a relatively new technology appearing in the majority of the car fleet over the past five years. The claims of crash reduction for cars with ESC are currently very high, initial evaluations are showing positive outcomes in terms of crash and injury reduction (DfT, 2007; MUARC, 2007). It remains to be seen how driver behaviour will adapt in response to this new safety feature and what impact it will have on safety, if any (VTI, 2009).

The above suggests that technological change can result in adaptation of driver behaviour in response to changed task demand. In order to achieve improvements in road safety it is important that the behavioural response be accounted for. Relating this back to the safe system, it is important that an intervention toward a safe system account for the change in perceived task difficulty. Moreover, the success of the safe system depends on the extent to which the interventions given priority are designed with human behaviour as the first consideration. In the next section, it is suggested that attention to other factors which affect road user behaviour is likely to present opportunity to achieve the desired reduction in road safety.

3 OTHER FACTORS IN CRASH CAUSATION

The previous discussion was around interventions which are focussed on the immediate causes of road traffic crashes, (the road environment, the vehicle and the vehicle speed). The safe system approach enables interventions which change these aspects. However, there are other factors which impact upon road safety outcomes. For example, some interpretations of the safe system seem to have a lesser focus on road users who deliberately break the rules and those who might be called sensation seekers. It also does not explicitly acknowledge institutional and cultural values which might support improved safety as a result of change to the road environment.

The scope for reduction of death and serious injury within the safe system approach is substantial, as evidenced by the pioneers of the approach who have realised substantial safety gains. The next significant step forward in a model of crash causation could be one which offers practical steps to a shift in the values or culture associated with use of the road environment.

Taking a wider view than the proximal causes of a crash, Reason (1990) conceptualised the distal factors causing a crash in what is sometimes referred to as the Swiss cheese model. This model has proven useful in safety-critical industries as a tool to identify the range of issues which lead to an accident. In particular it accommodates the concept of the myriad organisational and cultural forces which shape behaviour.

Practice in other safety critical industries has changed in recognition of the many layers of factors which lead to critical incidents. The aviation industry is a leader in safety management, rail and maritime also undertake significant effort to identify the broad range of factors in incident causation. Within road safety, some interventions might also be seen to be compatible with this broad view of the factors which cause crashes. This can be seen in commercial vehicle monitoring (such as the Operator Rating System in New Zealand) which acknowledges the role of the employer in the road safety record of their fleet and in supporting car buyers’ ability to compare the safety rating of different cars (Used Car Safety Rating).

Implementation of the safe system represents a shift in thinking about responsibility for the road safety problem. Under the safe system responsibility is shared between users and system providers. While it is clear that action can be taken to improve the driver environment, the institutional settings, rules and guidance as well as the value of mobility relative to safety can also be reviewed. Change to these broader social and institutional settings must be encouraged in pursuit of improved road safety.

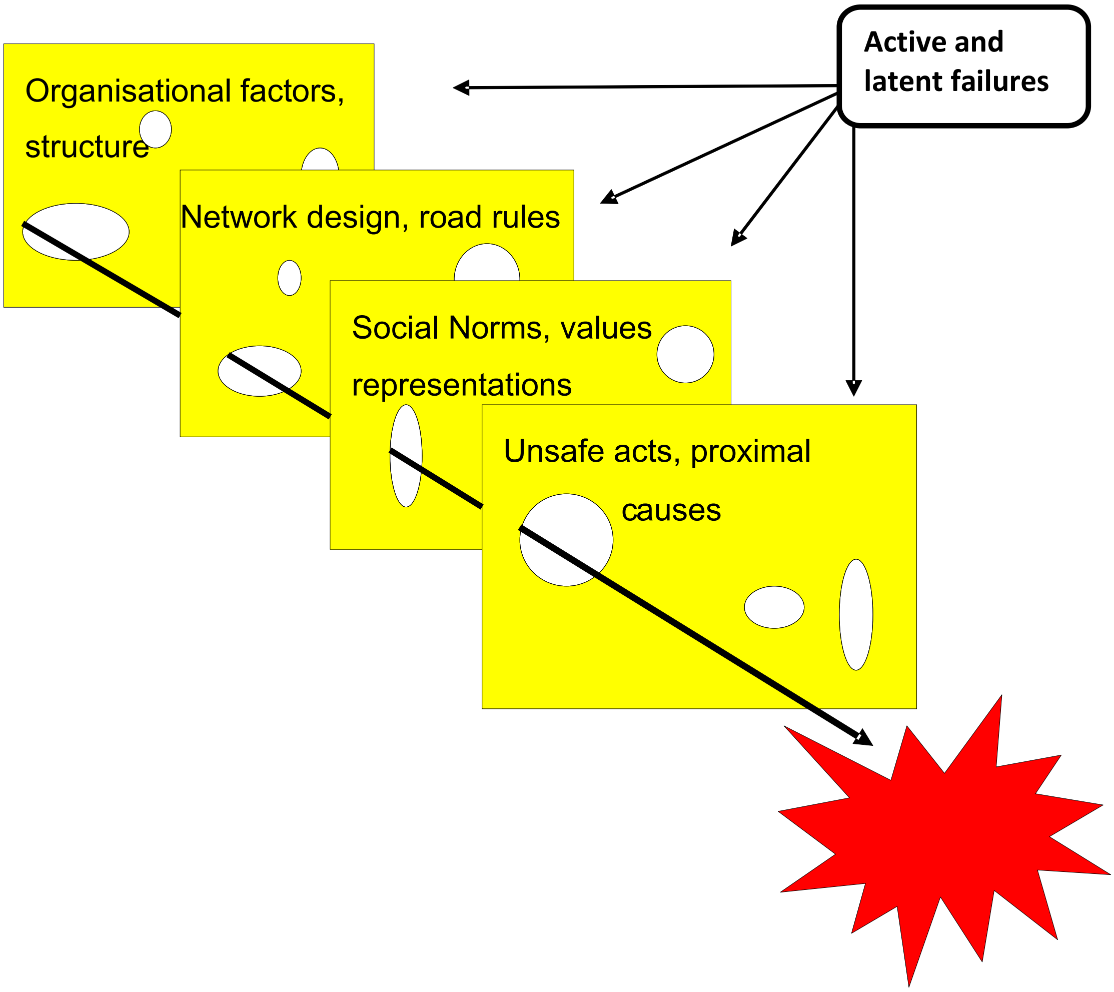

Figure 3: Crash causation. Adapted from Reason (1990)

4 CONCLUSION

Since the mid-1990s a number of jurisdictions have applied the safe system approach to road safety. Some representations of this system seem to be focussed on the proximal factors which cause a crash. The implementation of the safe system includes road safety interventions which focus on changing the road environment, especially changing road infrastructure. This approach has been successful in reducing the road safety problem although it is possible that safety benefits have been less than expected due to a mismatch between the difficulty of the driving task as perceived by the road user and the actual difficulty as reflected in the number of road traffic crashes. It has been argued here that consideration of the effect on the perceived difficulty of the driving task is important when changing the road environment.

The systems approach to safety is one which can take into account factors such as social and organisational influences on behaviour in addition to proximal factors such as the vehicle and the road environment. It is possible to interpret the Safe System approach to road safety in a simple way, with a resulting focus upon changing the immediate causes of road crashes such as vehicles and roads. Alternatively, it is possible to foster a broad view, accounting for behavioural, social and institutional factors. This broader view is evident in the literature and to some extent can be seen in the practice of road safety, suggesting that this broader view could lead to interventions which change the information on which road users' decisions are made.

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