Safe System infrastructure: implementation issues in low and middle income countries

B. Turner and G. Smith

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Improvement to road infrastructure is a key mechanism for improving safety, including in low and middle income countries. A workshop was held to raise awareness regarding Safe System infrastructure treatments and to explore barriers to implementation of these in low and middle income countries. This report provides a summary of the workshop, including information on issues relating to the further uptake of Safe System infrastructure.

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Summary

More than 1.24 million people die and between 20 and 50 million people are injured on the world's roads every year, with the largest portion of this burden carried by those in low and middle income countries. Improvement to road infrastructure is a key mechanism for improving safety in all countries. A variety of proven road safety infrastructure treatments are available. While these treatments are all capable of delivering safety improvements, one group of treatments (termed Safe System, or Primary treatments) are able to move closer to the eventual elimination of death and serious injury on our roads.

A workshop was held in Bangkok, Thailand as part of the 2012 GRSP / iRAP Asia Pacific Workshop involving delegates from governments and road authorities around the Asia-Pacific region. The aims of the workshop were to raise awareness regarding Safe System infrastructure treatments and to explore barriers to their implementation in low and middle income countries. This report provides a summary of the workshop, including information on issues relating to the further uptake of Safe System infrastructure.

Key implementation issues raised included cost, compliance issues, design and implementation difficulties, public acceptance and familiarity with use, and maintenance.

The workshop provided an important basis for understanding the issues that need to be addressed in order to accelerate the uptake of highly effective infrastructure treatments, and in raising awareness of these issues.

1 Introduction

It is estimated that road crashes result in more than 1.24 million deaths every year, and between 20 and 50 million injuries (WHO 2013). The largest portion of this burden is carried by those in low and middle income countries, with up to 90% of deaths occurring in these countries. Improvement to road infrastructure is a key mechanism for improving safety in all countries. Under the Safe System approach, it is recognised that road managers need to take greater responsibility in the design and operation of the road system. Although most crashes are the result of some road user error, the vast majority of crashes can either be prevented, or should they occur, the severe outcomes reduced, through the effective use of infrastructure.

The Safe System approach to road safety recognises that humans as road users are fallible and will continue to make mistakes. In addition, humans are physically vulnerable, and are only able to withstand limited kinetic energy exchange (e.g. during the rapid deceleration associated with a crash) before serious injury or death occurs. Infrastructure is required that takes account of these errors and vulnerabilities so that road users are able to avoid serious injury or death in the event of a crash. Safe System principles aim to manage vehicles, road and roadside infrastructure, and speeds to eliminate death and serious injury as a consequence of a road crash. Based primarily on the Swedish Vision Zero and the Dutch Sustainable Safety approaches, the Safe System approach has been formally adopted by key international organisations as the key means to achieve significant safety outcomes. A more detailed explanation of the Safe System approach is provided in Appendix A, while key references can be found in Appendix B.

A workshop was held in Bangkok, Thailand in March 2012, with the intention of raising awareness about Safe System infrastructure, and exploring barriers to implementation in low and middle income countries (LMICs). Delegates from governments and road authorities around the Asia-Pacific region attended. The event was hosted by ARRB Group and the International Road Assessment Programme (iRAP) as part of the 2012 Global Road Safety Partnership (GRSP) / iRAP Asia Pacific Workshop (see www.grspasia.org).

The Safe System infrastructure workshop consisted of:

- an explanation of effective infrastructure treatments and engineering countermeasures which may be considered in order to work towards achieving a Safe System
- an explanation of the relevance of the Safe System approach and treatments in the context of LMICs
- a workshop session on individual treatment types, including an introduction to each, along with discussion of benefits, implementation issues, alternative design options, and discussion of specific concerns.

Discussion focused on the ‘Primary’ treatments, or those most likely to produce Safe System outcomes in LMICs. More specifically, these treatments are those most likely to reduce death and serious injury to near zero levels. The list of treatments discussed was based on previous investigation of such treatments (Turner et al. 2009), as well as through understanding of the crash types and treatments most common in LMICs.

This report provides a summary of the workshop, including information on effective engineering treatments, and issues relating to the further uptake of Safe System infrastructure in LMICs. It is intended that this report will provide a basis for better understanding of how the uptake of highly effective infrastructure treatments can be accelerated in LMICs.

2 Implementing Safe System Infrastructure

This section presents the discussion from the workshop on each of the infrastructure treatment types. These treatments include roundabouts, barrier systems, pedestrian crossings, pedestrian footpaths, traffic calming, signalised intersections, shoulder sealing, and off-road cycle/motorcycle paths.

In each case, basic information is provided on the treatment, including information on use, benefits and effectiveness. Further information on each of these treatments is available from the iRAP Road Safety Toolkit (toolkit.irap.org). Information is then provided on issues and barriers surrounding the further uptake of these treatments, based on discussions with workshop attendees.

2.1 Roundabouts

A roundabout is a one-way roadway around a circular central island, with entry controlled by give-way markings and signs. Roundabouts can be installed for medium to high relative cost, and are effective at reducing a very large proportion of potential collisions (60% reduction in casualty crashes)[1]. High severity crashes are effectively eliminated at well-designed roundabouts due to reduced speeds on approach and through the roundabout, through reduction in angle of impact, and through the reduction of conflict points.

Figure 1: Two lane roundabout (Australia)

Benefits identified by workshop participants included minimal delays at lower traffic volumes, small maintenance requirements and lower crash severity compared to cross intersections.

[1] The information on expected crash reduction effectiveness and likely costs are drawn from the IRAP Road Safety Toolkit. Given the lack of information available on these issues in LMICs, these are often based on estimates.

Implementation issues raised by participants include:

- Poor design (including poor visibility on the approach, high entry speeds, or poor deflection through the roundabout), can lead to severe crashes. This has led to removal of some poorly designed roundabouts, and reduced use in some instances.
- They can be difficult for large vehicles to negotiate if not properly designed.
- There is increased risk for cyclists and other slow vehicles
- Cost is an issue.
- Compliance is required from all users (for example, experience in some countries is that vehicles often travel the wrong way and often do not give way to vehicles already in the roundabout).
- They require a larger and flatter area than other intersection types.
- They are unsuitable for unbalanced traffic volumes or in peak times.
- Multiple lane, higher volume roundabouts can be confusing, and may not have adequate influence on vehicle path deflection and therefore speed.
- Design and construction is difficult compared to other intersection types.
- There may be lack of familiarity with give-way requirements.
- The approach must be properly delineated including lane directions.
- There are potential concerns with public acceptance.
- There are concerns over safe pedestrian facilities.

2.2 Safety Barriers

Barriers are used to shield roadside hazards or to prevent head-on collisions from errant vehicles. Barriers can be flexible (e.g. wire rope), semi-rigid (e.g. steel beam) or rigid (e.g. concrete), and can be applied either on the roadside; centre of the road; or both. Barrier end treatments need to be appropriately designed to ensure vehicles do not become impaled or vault should they strike the end of the barrier. Barrier transitions (e.g. between flexible and rigid barriers) also need to be well designed. For a medium to high relative cost, a barrier system could be expected to provide significant safety benefits (40-60% reduction for a typical installation of roadside barrier; 60% or higher for central barriers; and up to 90% reductions when used together). The key types of crashes which can be reduced by barrier systems are head-on collisions and run-off-road incidents.

Figure 2: A concrete barrier used to create a motorcycle lane (China)

Benefits identified include reduced crash severity for out-of-control vehicles, and the prevention of cross-over accidents when used in the median.

Implementation issues raised by participants included:

- End points can be dangerous if not carefully designed and installed.
- Minor damage needs to be repaired to maintain integrity of the barrier.
- The barrier itself may be a hazard to road users.
- Barrier type may not be suitable for various vehicle types, such as buses or motorcycles.
- Steep embankments may make construction difficult.
- Design requirements and specifications for different applications and conditions are unclear.
- These may need to be delineated with chevron markers, reflectors or lighting.
- Access points must be considered and either accommodated or eliminated.
- Barriers may interfere with sight distance, especially when entering or leaving the road.
- They can interfere with pedestrian access, cyclists, parking.
- Maintenance requirements unclear and barriers will require manual inspection if incidents are not reported.
- Gabion systems may release debris onto the road.

2.3 Pedestrian Crossings

A variety of pedestrian crossing treatments are available to help improve pedestrian safety. These include marked crossings, raised crossings, signalised crossings and pedestrian overpasses or underpasses. The cost of crossings varies from low (for marked crossings) to high (e.g. for grade separated crossings), depending on the type. Pedestrian crossings can have a significant effect in decreasing the incidence of vehicle-pedestrian crashes as compared to a road with no designated crossing point (25-45% reduction for at-grade crossings, and 60% or greater for grade separation).

Figure 3: Raised, at-grade pedestrian crossing (United Arab Emirates)

Implementation issues raised include:

- High traffic volumes require expensive signalised crossings.
- Clear sight distances are needed.
- Education and enforcement are needed.
- They are only effective if drivers give way to pedestrians (the experience in many countries has been that drivers rarely give way).
- They have to be placed where pedestrians will use them (i.e. along pedestrian desire lines).
- They need to be properly delineated to alert drivers (especially for night time).
- Approach speeds need to be low enough to allow safe stopping before the crossing (raised crossings may assist this).
- Non-standardised designs may cause confusion and non-compliance.
- High pedestrian volumes will cause traffic disruption if they are always given priority.
- Implementation is difficult on high speed roads.
- Raised, at-grade crossings may unnecessarily impede traffic when no pedestrians are present.
- Use of grade-separated crossings by the disabled, or cyclists may be difficult.
- Increased time or distance is required to traverse a crossing which may result in disuse.

2.4 Pedestrian Footpaths

Pedestrian footpaths can reduce crashes by providing additional separation between pedestrians and vehicles. They can be used in urban areas, as well as rural areas where there are a higher number of pedestrians. In rural environments the safety benefits will be greatest if the footpath is separated from the road (for example, by a drain, a grass verge or a barrier). For a low to medium relative cost, footpaths can significantly decrease the incidence of vehicle-pedestrian crashes (40-60% reduction).

Figure 4: Pedestrian footpath (Cambodia)

Benefits include a reduced injury and fatality risk for pedestrians, as well as an increase in the appeal and use of walking as a transportation mode, which in turn reduces road congestion and provides health benefits.

Implementation issues include:

- Maintenance is required to ensure paths remain useable.
- If the road shoulder is used as a pedestrian footpath, additional signage and delineation/rumble strips are required to warn drivers.
- Additional space is required for a separate footpath of sufficient capacity which may not be available.
- Footpaths must be kept clear of obstructions, such as vegetation, rubbish, parked vehicles, and commercial activity.
- Inconsistent implementation or availability may reduce reliance and usage.
- Pedestrian-only usage must be enforced on footpaths.
- Motorcycles and cyclists pose a risk to pedestrian traffic if used on paths.
- Lack of funding and planning priority compared to main roads can result in poor quality and lack of consistency, leading to disuse.
- Road access and property entries interrupt paths and create hazards for pedestrians.

2.5 Traffic Calming

Traffic calming treatments are used to help lower traffic speeds and volumes, and sometimes, prevent particular types of vehicle travelling through an area. Traffic calming treatments cause drivers to change their driving pattern. Usually they have to reduce their speed but sometimes drivers are exposed to something undesirable (e.g. rumbling, or delays) which encourages them to choose a different route.

There is a wide range of traffic calming devices available. These include: roundabouts, kerb build-outs, speed humps, raised tables, entry treatments, speed cushions, modified intersections and many others. Some of these treatments are described under the 'speed management' treatment page on the iRAP Road Safety Toolkit .

Importantly, drivers should not have to be taught about traffic calming devices in order for them to be effective. They should be self explaining and self-enforcing. For medium to high relative cost, these treatments are effective in reducing crashes (typically a 25-40% reduction).

Figure 5: Road narrowing and speed hump combined

Benefits include a reduction in crash occurrence, reduced traffic volume in the area, and an improved environment for pedestrians and cyclists.

Implementation issues raised include:

- There is a potential for negative public feedback.

- They can be costly and time consuming to implement.
- Isolated treatments may be a hazard.
- Treatments may present a hazard during the initial period following installation, or if traversed incorrectly.
- Behavioural changes associated with implementing various treatments in a given location may be unpredictable or undesirable.
- It may be difficult to determine the most suitable type of treatment for a given location.
- Reduction in traffic volume in one area will be compensated by an increase in another area.
- Impeding key routes may cause traffic flow problems and lack public acceptance.
- Lack of standardisation of treatment types can create confusion.
- They must be properly delineated to minimise hazard to road users.
- The treatment may increase noise, pollution, fuel usage and vehicle wear.
- Attempting to avoid devices may create a dangerous situation such as cross-over.
- Treatments are likely to impede access for heavy vehicles or emergency services.
- It is important to keep traffic calming facilities well maintained.

2.6 Signalised Intersections

Traffic signals are used at intersections to control traffic flow and prevent conflicts. For medium relative cost, this treatment reduces the incidence of crashes (25-40% reduction). Signalised intersections can help to reduce both vehicle-vehicle impact and vehicle-pedestrian crash types.

Figure 6: Traffic signals at an intersection (Thailand). Photo Courtesy of D. Best

Benefits of installing signals can include increased intersection capacity, reduction in crashes such as side impacts, improved pedestrian and cyclist safety, control of priority, and signals are generally well understood, improving compliance.

Implementation issues raised include:

- Compliance by road users including pedestrians is required for effectiveness.
- Rear-end crashes can increase.
- Signals must be visible to drivers.
- Signals need continuous power.
- A good maintenance regime is required.
- Signals are not suitable for high speed situations.
- Disruption to traffic flow and decreased efficiency may result.
- Signals must be programmed carefully and dynamically to allow optimal flow and maximum efficiency.
- Signals should be coordinated to avoid frequent stopping, adding complexity.
- There is a potential for user frustration from having to wait with no other traffic present.

2.7 Shoulder Sealing

A sealed shoulder is a strip of additional roadway next to the main roadway. This shoulder allows errant vehicles to return to the roadway if they stray from their lane. Without such shoulders, vehicles can easily lose control. By providing a greater error margin for drivers, the incidence of head-on and run-off-road crashes can be reduced. For medium costs, adding a sealed shoulder can decrease crashes by 25-40%.

Figure 7: A road with a sealed shoulder and tactile edgeline (China)

Other benefits include additional provision for vehicles in an emergency (e.g. during a breakdown), additional structural support to the main roadway, a safe cycling space, and prevention of water seepage, and intrusion of vegetation and debris onto the main roadway.

Implementation issues raised include:

- If over-wide they might be used by vehicles as an extra lane.
- They can be used for commercial activity if not carefully regulated.
- The high cost may limit use to key routes only.
- They should be clearly indicated as not a lane for driving by tactile strips, markings, signs.
- There is a lack of standardisation and clear design requirements.
- They must be maintained along with the main roadway, increasing ongoing costs.
- They may increase perceived safe speed and overtaking attempts.
- Vehicles parking on the shoulder can create a hazard, especially for bicyclists and at night.
- They may still have significant edge-drop, making It more difficult to re-enter the roadway.

2.8 Off-road Cycle / Motorcycle Paths

Off-road cycle or motorcycle paths are a separate lane, exclusively for the use of bicycles or motorcycles, and away from the main roadway. For a low to medium relative cost, a path can be expected to reduce the incidence of crashes by 25-40%.

Figure 8: Off-road motorcycle path (Malaysia)

Benefits include improved safety for cyclists or motorcyclists, and increased use of bicycles, which in turn reduces congestion and provides health benefits.

Implementation issues raised include:

- They are more expensive than on-road paths.
- High surface quality is needed.
- The path must be clear of obstructions and have adequate sight distance.
- Land may not be readily available on which to construct a path.
- Paths with poor capacity, routing or continuity are less appealing to users.
- Priority must be controlled at potential hazard sites such as crossings.
- There is a lack of standardisation and clear design requirements.
- Usage must be properly indicated and restricted to the intended user group.
- Policing and enforcement is more difficult than on main roadways.
- There is a lack of research for cycle and motorcycle specific Safe Systems practices.

3 Discussion and Recommendations

The measures discussed above represent some of the more effective treatments that can be used to help eliminate death and serious injury, including on roads in low and middle income countries (LMICs). Other treatments are also available (see toolkit.irap.org), but typically deliver smaller, incremental safety benefits. Greater use of all treatment types is encouraged, but this is especially so for these Primary treatments.

A number of implementation issues were raised during discussion about the use of these treatments. Although some of these issues were expected (e.g. cost), others were less well known but potentially just as important. The implementation issues identified could be classified into the following groups:

- Cost
- Compliance issues
- Design and implementation difficulties
- Public acceptance and familiarity with use
- Maintenance.

The following table shows the treatment types associated with each of these issues.

Table 1: Implementation Issues Identified

	Roundabouts	Barriers	Pedestrian crossings	Pedestrian footpaths	Traffic calming	Signals	Shoulders	Off-road paths
Cost	✓		✓	✓	✓		✓	
Compliance	✓		✓	✓		✓	✓	✓
Design/ Implementation	✓	✓			✓	✓	✓	✓
Public acceptance	✓		✓		✓			
Maintenance		✓		✓	✓	✓	✓	✓

As expected, cost was raised as an issue for many of the treatments, although not all. Of greater interest is that issues relating to compliance and design/implementation were raised as issues for more of the treatments. Compliance by road users for treatments is a significant issue for LMICs, and it is very likely that the treatment effectiveness will be less because of this. Issues to suffer from this compliance issue were:

- Roundabouts (resulting from failure to give way, and even vehicles circulating in the wrong direction)
- Pedestrian crossings (failure of traffic to give way)

- Pedestrian footpaths (obstruction and misuse by vehicles including motorcycles)
- Signalised intersections (failing to stop)
- Shoulder sealing (misuse as an extra lane, parked vehicles, roadside trading)
- Off road cycle / motorcycle paths (obstructions on paths, misuse by inappropriate vehicles).

Design and implementation issues will also have an impact on the effectiveness of treatments. If the treatment is not well designed, and the installation is not of a high standard, the crash reduction potential will not be achieved. This was considered an issue for all of the treatments discussed.

Lastly, maintenance is also an issue that will impact on the crash reduction effectiveness of treatments. It is common for treatments to deteriorate to levels where they become less safe (or possibly to a point where they are higher risk than if the treatment was not present).

Although all of these issues are likely to be concerns for high income countries (HICs), they are possibly more pronounced in LMICs, and will certainly have an impact on treatment effectiveness. The extent of this effect is not known, but it can be expected that because of these issues, treatment effectiveness is likely to be different (typically less) than when the same treatments are used in HICs.

Although not a comprehensive exploration of the barriers to implementing Primary treatments in LMICs, the workshop provided an important basis for understanding what issues need to be addressed in order to accelerate the uptake of highly effective infrastructure treatments. The workshop also assisted in raising awareness of these issues among workshop participants.

The knowledge contained in this report will be disseminated to road authorities and researchers throughout the region, and will also be used to update the Road Safety Toolkit (toolkit.irap.org). The findings will also guide planning for future training and workshops.

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WHO, 2013, Global Status Report on Road Safety 2013, World Health Organization, Geneva, Switzerland.

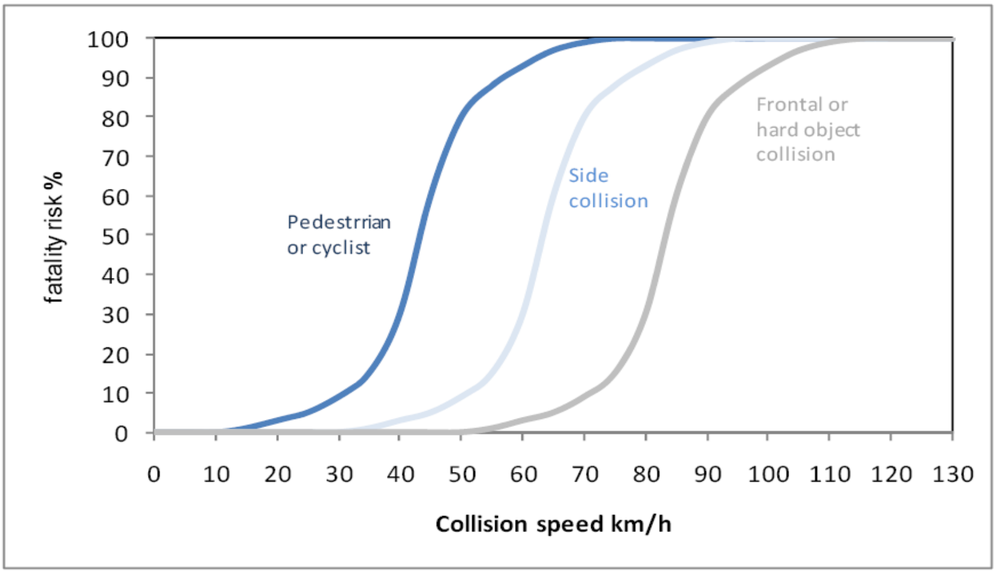
Appendix A: Safe System Summary

The Safe System approach represents a significant change in the way that road safety is managed and delivered. The approach recognises that humans, as road users, are fallible and will continue to make mistakes. In addition, humans are physically vulnerable, and are only able to withstand limited kinetic energy exchange (e.g. during the rapid deceleration associated with a crash) before serious injury or death occurs. Infrastructure is required that takes account of these errors and vulnerabilities so that road users are able to avoid serious injury or death in the event of a crash. Safe System principles aim to manage vehicles, road and roadside infrastructure, and speeds to eliminate death and serious injury as a consequence of a road crash.

The Safe System approach reflects a holistic view of the combined factors involved in road safety. A Safe System protects responsible road users from death and serious injury by taking human error and frailty into account, and has four essential elements:

- alert and compliant road users
- safe roads and roadsides
- safe speeds
- safe vehicles.

Management of speed is a core feature of the Safe System approach. Human tolerances need to be considered in the setting of speed limits so that, in the event of a crash, the chances of road users being killed or seriously injured are minimised. For example, in collisions between cars and pedestrians, the chance of survival decreases dramatically above speeds of around 30 km/h. Unless adequate infrastructure is provided (such as separation of cars and pedestrians), speeds need to be below this level to ensure survival in the event of a crash. Similar critical speeds exist for side collisions (e.g. at intersections) between cars (50 km/h) and head-on crashes (70 km/h). These are illustrated in Figure A1 below.



Source: Wramborg (2005)

Figure A1: Fatality risk (cited in OECD 2008)

To prevent death or serious injury involving these crash types, infrastructure must be provided to minimise the chance of a crash, or the severity if a crash does occur, or the speed must be below these levels for car-pedestrian and car-car impacts. For collisions involving heavy vehicles and large stationary objects survival rates will be considerably lower, making the task of managing speeds and impact forces even more critical.

The Safe System approach is based primarily on the Swedish ‘Vision Zero’, and the Dutch ‘Sustainable Safety’ approaches. Vision Zero suggests that it is not acceptable for fatal or serious injuries to occur on the road system, and that account must be taken of human tolerances when designing road infrastructure. The Sustainable Safety approach is based on the following concepts, the first four of which relate most directly to road infrastructure improvements and road use management:

Functionality: roads should be differentiated by their function, with through roads which are designed for travel over long distances (typically at high speed, ideally on a motorway); distributor roads which serve districts, regions and suburbs; and local roads, which allow access to properties.

Homogeneity: differences in vehicle speeds, direction of travel and mass on specific roads should be minimised.

Predictability: the function and rules of a road should be clear to all road users. This approach has led to the development of the ‘self-explaining road’ (e.g. Theeuwes & Godthelp 1992).

Forgivingness: roads and roadsides should be forgiving to road users in the event of an error.

State awareness: road users should be able to assess their capability of handling the driving task.

Appendix B: List of Resources

Safe System documents

Organisation for Economic Co-operation and Development (2008), Towards zero: ambitious road safety targets and the safe system approach. Organisation for Economic Co-operation and Development (OECD), Paris, France. http://www.internationaltransportforum.org/Pub/pdf/08TowardsZeroE.pdf

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Global Road Safety Partnership (2008) Speed management: a road safety manual for decision-makers and practitioners. Global Road Safety Partnership, Geneva, Switzerland. http://www.who.int/roadsafety/projects/manuals/speed_manual/en/

iRAP and Global Transport Knowledge Partnership (2013) Road Safety Toolkit (http://toolkit.irap.org).

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