2. Review of Remedial Measures

2.1 Introduction

In this section various remedial measures (countermeasures) will be reviewed. The principles used in the development of counter measured are first described. For brevity, the word 'driver' is used to describe both drivers and riders of motorcycles.

2.2 Principles of Engineering Remedial Measure Development

According to the Institution of Highways and Transportation, and National Association of Australia State Road Authorities guidelines, the process of countermeasure development should aim to:

- determine the range of measures likely to influence the dominant accident types and road features,
- select countermeasures which, on the basis of professional judgment and experience, can be expected to reduce the number or severity of accidents of the type dominant at the location,
- check that adopted countermeasures do not have undesirable consequences, either in safety terms (e.g. lead to an increase in the number or severity of another accident type) or in traffic efficiency or environmental terms,
- be cost-efficient, that is, maximize the benefits from the hazardous road location program
- be efficient, that is produce benefits, which outweigh the costs.

Given the limitations of human decision making, the design and management of a safe road and its environment must ensure that the many characteristics of the road environment (including road geometry, road surface, cross section, roadside features, median treatments, delineation, traffic signs, traffic control devices, route guidance, street lighting, access provisions, etc.) individually and in combination provide an environment through which the driver can travel safety. In other words, the road environment must not place demands upon the driver that are beyond the driver's ability to manage, or which are outside normal road user expectations (Rumar, 1982). A safe road has therefore been defined as one which is designed and managed with the following roles (Ogden 1996):

- warn the driver of any substandard or unusual features,
- inform the driver of conditions to be encountered,
- guide the driver through unusual sections,
- control the driver's passage through conflict points and road links, and
- forgive a driver's errant or inappropriate behavior.

Ogden listed a number of principles which should be considered in the development of countermeasures for specific locations.

Intersections

The main design principles for intersections are:

- minimize the number of conflict points and hence the opportunities for accidents; both t-intersections and roundabouts have fewer conflict points than a cross-intersection (see Figure 2.1), which is one of the main reasons for their superior safety performance,

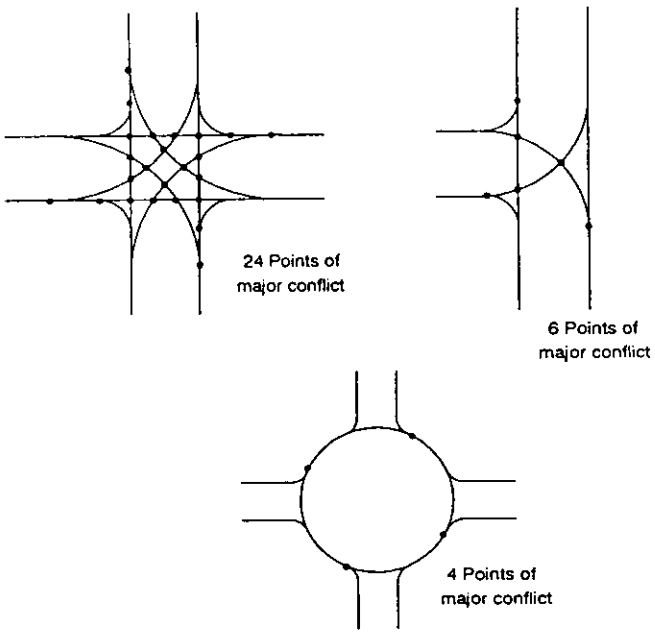

Figure 2.1: Conflict points at intersections

- give precedence to major movements through alignment, delineation, and traffic control,
- separate conflicts in space or time,
- control the angle of conflict; crossing streams of traffic should intersect at a right angle or close to it while merging streams should intersect at small angle to ensure low relative speed,
- define and minimize conflict areas,
- define vehicle paths,
- ensure adequate sight distances,
- control approach speeds using alignment, lane width, traffic control or speed limits,
- provide clear indications of right-of-way requirements,
- minimize roadside hazards,
- provide for all vehicular and non-vehicular traffic to use the intersection, including where necessary special provisions for heavy vehicles, public transport vehicles, and pedestrians and other vulnerable road users,
- simplify the driving task, and
- minimize road user delay.

Mid-block locations

For non-intersection location Ogden listed the following principle:

- ensure appropriate and consistent standards of horizontal and vertical alignment,
- develop roadway cross sections to suit road function and traffic volumes,
- delineate roadway and vehicle paths,
- ensure appropriate standards of access control from abutting land use, and
- ensure that the roadside environment is clear or forgiving.

Overlaying all of these principles is a vital need to consider the particular needs of all road user groups. Proper consideration of these needs is a major determinant in the quality of the final treatment. In particular, pedestrians have special needs that should be separately considered when investigating safety problems and developing countermeasures.

Criteria for countermeasure development

There are a number of criteria for countermeasure selection, including:

- technical feasibility: can the countermeasure provide an answer to the accident problems which have been diagnosed, and does it have a technical basis for success?
- Economic efficiency: is the countermeasure likely to be cost effective and will it produce benefits to exceed its costs?
- Affordability: can it be accommodated within the program budget; if not, should it be deferred, or should a cheaper interim solution be adopted?
- acceptability: does the countermeasure clearly target the identified problem, and will it be readily understandable by the community?
- practicable: is there likely to be a problem of non-compliance, and can the measure work without unreasonable enforcement effort?
- political and institutional acceptability: is the countermeasure likely to attract political support, and will it be supported by the organization responsible for its installation and on-going management?
- legal: is the countermeasure a legal device, and will users be breaking any law by using it in the way intended?
- compatibility: is the countermeasure compatible and consistent with other strategies, either in the same locality or which have been applied in similar situations elsewhere?

It can be seen that the decision to adopt a particular countermeasure may involve more than a simple matching of a solution to a problem. The development of countermeasure requires a clearly-understood technical and institutional framework to provide the guiding principles and motivation for action. (Ogden 1996).

2.3 Australia's Road Safety Strategy

Australian Transport Council (ATC, 2000) has prepared "The National Road Safety Strategy 2001 - 2010" covering a period of 10 years. Thirty five organisations contributed to the development of the Strategy which was coordinated by the Australian Transport Safety Bureau with the National Road Safety Strategy Panel and Taskforce. The Vision for the development of the Strategy was stated as 'Safe road use for the whole community' The Strategy aims to reduce the number of road fatalities per 100,000 population by 40% from 9.3 in 1999 to no more than 5.6 in 2010.

The Strategy aims to fulfill 10 strategic objectives. Details are given in Appendix B. The Strategy was implemented through the Action Plan which was prepared every two years, the latest Action Plan covering the period 2003 - 2004. Details are given in Appendix C.

2.4 Cost-Effectiveness of Some Road Safety Measures

From Tables 2.1 and 2.2 (FORS, 1995), it can be seen that fatigue tactile edge lining (a 100 mm wide, intermittent raised section thermoplastic located along edge of both side of roadway) ranks first in terms of lives saved. At a cost of some A$ 5,000,000 to the government, the intervention saved 73.6 lives or A$ 67,935 per life saved.

Table 2.1: Cost-effectiveness rations versus programming solution

Intervention Description	Cost to agency / govemmet	Lives saved	Agency cost per life saved
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section of thermoplastic located along edge of both sides of roadway	$5,000,000	73.6	$67,935
46 projects involving installation of safety bars along roads*	$149,579	2.11	$70,891
A fatigue edge lining project including : a publicity campaign; seminar/research on sleep apnea; fatigue monitors; and edge lining/tactile edge lining	$1,000,000	12.99	$76,982
Installing 16 new pedestrian traffic signals*	$536,010	6.36	$84,278
Promotion of wearing of protective headgear by passenger	$550,000	5.79	$94,991
Installing 57 new traffic signals*	$3,715,494	37.34	$99,504
Converting 20 cross intersections to T-junctions*	$497,459	3.97	$125,305
A package of speed counter-measures*	$1,150,000	8.38	$137,232
Installing 53 roundabouts*	$1,498,487	10.87	$137,855
Modifying 49 traffic signals*	$1,754,960	12.48	$140,622
A package of motor cycle counter-measures	$278,000	1.97	$141,117
A package of alcohol counter-measures*	$1,500,000	8	$187,500
Fitting of an ignition interlock as a condition of relicencing for all convicted drivers for 6 years	$4,680,000	24.77	$188,938
Training for responsible serving of alcohol in licenced premises	$9,247,000	40.7	$227,199
Regulation to forbid carriage of passengers of persons not seated in approved car seats in load areas	$550,000	2.16	$254,630
Increasing the legal drinking age from 18 to 21 years	$2,000,000	7.2	$277,778
A bicycle safety publicity campaign	$50,000	0.13	$384,615
44 new channelisations*	$2,759,082	7	$394,155
Night time curfew for drivers in the first year of driving	$1,400,000	3.33	$420,420
Traffic signal installations at 4-leg intersections in Victoria*	$12,965,067	29	$447,071
A $20 rebate to encourage the purchase of child seats	$232,000	0.36	$644,444
46 accident blackspot treatments*	$5,443,260	8	$680,408
Zero blood alcohol limit for all motorcyclists	$2,300,000	3.3	$696,970
A package of redlight camera counter-measures*	$2,200,000	2.82	$780,142
A speed management program involving publicity to support enforcement and inform on speed zoning review	$48,646,930	54	$900,869
A television and other media advertising campaign*	$18,000,000	15.59	$1,154,586

* Non-Australian studies
t Contains evidence of effectiveness in original study

Source : Modified from Table A4.5 p. 71 (FORS 1995)

Table 2.2: Ranking of intervention programs with net savings : ranked by lives saved

Intervention Description	Total cost	Net cost	Rank by lives saved
A fatigue tactile edge lining project (a 100mm wide, intermittent raised section thermoplastic located along edge of both sides of roadway	$5,000,000	($10,525,133)	1
Mandatory bicycle helmet use legislation in Israel	$23,358,503	($36,757,571)	2
A speed management program involving publicity to support enforcement and inform on speed zoning review	$48,646,930	($39,374,128)	3
Installing 57 new traffic signals	$3,715,494	($14,830,424)	4
Legalising footpath cycling	$1,250,000	($3,120,000)	5
A television and other media advertising campaign	$5,173,056	($4,336,584)	6
A fatigue edge lining project including : a publicity campaign; seminar/research on sleep apnea; fatigue monitors; and edge lining/tactile edge lining	$1,000,000	($229,556)	7
Modifying 49 traffic signals	$1,754,960	($4,445,381)	8
Installing 53 roundabouts	$1,498,487	($3,902,181)	9
A package of speed counter-measures*	$1,150,000	($148,465)	10
46 accident blackspot treatments in Victoria	$5,443,260	($2,249,103)	11
44 new channelisations	$2,759,082	($600,190)	12
Installing 16 new pedestrian traffic signals	$536,010	($2,624,142)	13
Converting 20 cross intersections of T-junctions	$497,459	($1,476,255)	14
46 projects involving installation of safety bars along roads	$149,579	($899,223)	15
A package of motor cycle counter-measures	$278,000	($68,827)	16
A bicycle safety publicity campaign	$50,000	($36,140)	17

* Non-Australian studies

Source : Modified from Table A4.4 p. 69 (FORS 1995)

2.5 Some Examples of European Good Practice

This section gives a list of tables prepared by the European Union Road Federation (ERF,2002) for dealing with safety problems on urban roads and inter-urban roads.

The problems include : speeding, conflicts between vehicles and pedestrians, dangerous turning movements, and vehicle run off the road.

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Exceeding speed limit	Reduce width of lanes at specific road sections (no longer than 50 meters)	Create a change in horizontal alignment	Cities	▪ A width of lane of 2.5 m can provide speed reduction up to 19 km/h. ▪ Reducing width so as to provide a unique lane is very effective. ▪ Flexible option: different widths are valid. ▪ Results achievable by road markings.	▪ If there is a unique lane and two directions are allowed, one of them with low traffic: small speed reduction is expected. ▪ If there is priority for one direction, often speed reduction just happens in the non-prioritised direction. ▪ Narrowing of just one lane at main roads is not recommended with traffic higher than 600 vehicles/hour during the rush hour.	LOW	LOW	MEDIUM	MEDIUM

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
		Chicanes	Create a change in horizontal alignment	Residential areas were low speeds are guaranteed (areas 30) and very good visibility	▪ Flexible option: different ways are valid. ▪ Highly effective.	▪ Social opposition due to change in street appearance. ▪ Similar effectiveness as reducing width of lanes, but more space is required. ▪ Not very effective if width needs to be defined according to heavy vehicles size. ▪ Could be identified as race-tracks; to avoid that, angular shapes are advisable. ▪ The larger the displacement of the road axis, the higher the difference of sidewalks width is. ▪ Bad experiences at some European countries. ▪ Requirements: Low speed and high visibility should be guaranteed.	MEDIUM	LOW	MEDIUM	LOW
		Transversal rumble strips	Create a change in vertical alignment	Cities	▪ Flexible option: continuous or discontinuous, rough pavement, variety of materials,... ▪ Speed reduction close to 10%. ▪ Improve road safety, as they make drivers perceive danger. ▪ Compatible with high cyclist traffic, by providing open spaces between 0.3-1 meter width.	▪ Very noisy. ▪ Speed reduction can decrease with time. Some types of rumbles are more comfortable to drivers if traversed at high speed. ▪ Can create problems to heavy vehicles.	LOW	LOW	MEDIUM	MEDIUM

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Exceeding speed limit	Speed humps	Create a change in vertical alignment	Accesses to cities or areas of 30 km/h.	• Most common and very effective way of reducing speed; also good results achieved at reducing number of accidents. • Well-known and highly used devices. • In spite of discomfort, humps are good for cyclists' safety. • Variety of materials and profiles (shapes).	• Limited power as traffic calming element; its main objective is reduce speed and divert passing traffic. • If spacing between humps is not right (should be 50 m at long routes), traffic flow is highly irregular, with continuous braking and speeding. • If height is not right, humps are not effective at reducing speed (should be higher than 7.5 cm). • Bad for cyclists; to avoid that, humps should be lower at the edge of the lane or provide canals for cyclists. • If design is not proper, humps disturb public transport. The use of prefabricated humps is advisable to avoid this inconvenience • Can cause troubles at night; good lighting and singing is required. • Advanced warning signs are strictly necessary. • Potential slight increase in road noise.	MEDIUM	LOW	LOW	LOW
		Speed tables	Create a change in vertical alignment	Accesses to cities or areas of 30 km/h.	• Effective in reducing vehicle speed. • Not as jarring to vehicles as speed humps. • Can be employed on higher volume speed roads. • Can also be used as pedestrian crosses. • Combined humps can reduce speed of buses and cars in a different way. • Variety of materials and profiles (shapes).	• Same disadvantages as speed humps. • More expensive than speed humps. • Deterrent elements are sometimes required, in order to avoid illegal parking.	MEDIUM	LOW	LOW	LOW

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Exceeding speed limit	Speed cushions	Create a change in vertical alignment	Accesses to cities or "areas of 30 km/h" with high volume of buses.	▪ Allow cyclists and buses to cross them comfortably. ▪ Variety of materials to build them. ▪ Variety of profiles (shapes). ▪ Pedestrians do not perceive them as crossing facilities. Avoid wrong perceptions for pedestrians and drivers.	▪ Poor comfort. Width of device should be designed considering space between wheels of vehicles that use the softened alternative.	MEDIUM	LOW	MEDIUM	MEDIUM
		Textured pavements	Create a change in the driving environment	Accesses to cities.	▪ Speed reduction between 4-10 km/h, depending on the type of road and conditions. ▪ Can draw attention to pedestrian areas.	▪ Periodic maintenance is required, especially if heavy vehicles are common. ▪ Potential slight increase in road noise.	MEDIUM	MEDIUM	HIGH	MEDIUM
		Mini roundabouts	Create a change in the perception of the road	Cities	▪ Can be partially or fully mountable by larger vehicles. ▪ By using mini roundabouts it is possible to reduce speed of vehicles approaching intersections.	▪ Implementation restricted to urban roads where speed of approaching vehicles is between 30-50 km/h and average daily traffic volumes less than 3.500 vehicles.	MEDIUM	MEDIUM	MEDIUM	MEDIUM
	Conflicts between vehicles and pedestrians	Separation between traffic flows (Access limited)	Avoid interaction between different traffic flows	Residential areas	▪ Well known, highly used and very effective measure. ▪ Improves residents' quality of life and aesthetics of a neighbourhood.	▪ Very restrictive measure; only could be implemented with strong community support. ▪ It should be carefully studied, as it can cause conflicts at other areas. ▪ Access is restricted for residents. ▪ Emergency services can be obstructed unless closure is traversable.	HIGH	LOW	MEDIUM - HIGH	MEDIUM - HIGH

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Conflicts between vehicles and pedestrians	Provide pedestrians guard-rails	Protect and guide pedestrians	Cities	▪ Very useful to guide pedestrians towards specific crossing points. ▪ Help the drivers to perceive the urban environment.	▪ Some types of guardrail can mask pedestrians, reducing their visibility. ▪ Non-respected if very long guardrails are installed without providing adequate crossing points.	LOW	LOW	MEDIUM	MEDIUM
		Shelters and medians	Protect pedestrians	Urban roads with no very high speed levels	▪ Very suitable for intersections with low pedestrian traffic. ▪ Low cost, if compared with other measures. ▪ Can reduce number of accidents. ▪ Allow control of parking at the area. ▪ Users perceive a reduction in the risk. ▪ In addition, speed reduction is achieved.	▪ Reduction in the number of accidents is not as large as expected. ▪ Design should consider cyclists, wheelchairs, baby carriages...	LOW	LOW	HIGH	HIGH
		Footbridges or pedestrian underpasses	Provide safe infrastructures for pedestrians	Urban roads with high speed levels	▪ Very effective, as all measures with separation between traffic flows. ▪ Good alternative to traffic signals (in case they cause a dangerous situation, such as in main roads with high speed).	▪ High construction cost; only suitable for situations with high pedestrian traffic crossing roads with high traffic. ▪ It is sometimes expensive to adapt these infrastructures to cyclists, as more space is required and slopes needed may change. ▪ Periodic maintenance is required: structural maintenance for footbridges and good drainage system and continuous cleaning for underpasses. ▪ Unguarded underpasses unsafe at night time ▪ Can attract commercial stalls.	HIGH	MEDIUM	LOW	MEDIUM - LOW

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Conflicts between vehicles and pedestrians	Ears	Make pedestrian movements easier and speeding more difficult	Cities	▪ Provide pedestrians with crossing opportunities. ▪ Provides a safer pedestrian environment. ▪ Prevent illegal parking at the corners of streets. ▪ Speed reducing effect, due to narrowing of the road and reduction of turning radius. ▪ Road furniture could be placed on them, so that sidewalks are free of objects. ▪ Placed at "T" junctions, ears and parked vehicles make drivers perceive the proximity of the junction, behaving as a traffic calming measure.	▪ Suitable design is required: if radius is too big, illegal parking will not be avoided; if it is too small, manoeuvres for large sized vehicles are complicated.	MEDIUM	LOW	HIGH	HIGH
	Dangerous turning movements	Traffic signs and signals	Provide advance warning	Junctions at cities	▪ Suitable for urban areas, where high capacity is required and speeds are low.	▪ Traffic signals with fixed phases at intersections with low traffic are usually non-respected. ▪ Not suitable for high capacity rural roads. ▪ Require regular maintenance. ▪ Expensive installation.	HIGH	HIGH	LOW	HIGH
		Channelled intersections with appropriate layout design and high quality markings, road reflectors and appropriate signing	Improve perception of junction	Junction at cities	▪ Can be used in a wide range of situations. ▪ Speed reduction. ▪ It is an easy-to-implement and low cost measure if canalisation is provided just by road markings. ▪ Separation of traffic flows allows drivers to clearly perceive the intersection. ▪ Traffic islands can also be used as pedestrian refuges.	▪ Effectiveness decreases if drivers do not respect "stop" or "give way" signs. ▪ Some traffic islands used for canalisation are not wide enough to protect vehicles turning. ▪ Canalisation with road markings requires maintenance in a regular basis. ▪ Canalisation usually requires widening of the road at the intersection, which sometimes is used for illegal over takings.	LOW - MEDIUM	LOW	MEDIUM	HIGH

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Dangerous turning movements	Prohibition of turnings	Eliminate conflicts	Areas of cities without high traffic volumes	▪ Advisable when accidents involving turning vehicles are very frequent or when turning movements are especially dangerous (e.g. due to poor visibility). ▪ Reduction of conflicts between vehicles and pedestrians. ▪ Lower cost than complete or partial closing of the route.	▪ It should be carefully studied, as it can cause conflicts at other areas. ▪ Access is restricted for residents and emergency vehicles. ▪ Turning should be prohibited using physical objects or with the help of the police. ▪ Using physical objects is not always possible, due to space limitations.	LOW	LOW	HIGH	LOW
	Safety problems due to illegal parking	Relocation of parking	Avoid parking which create unsafe conditions	Accesses to cities	▪ Providing parking areas clearly signed will create safer conditions for drivers and pedestrians. ▪ Legal parking does not affect pedestrians' visibility and even provides them with safer opportunities to cross the street. ▪ If provision of parking facilities involves a reduction in the width of lanes, speed reduction will be achieved.	▪ If not planned properly, can lead to dangerous situations in case drivers have to walk along the road. ▪ Vehicles stopping to enter or exit from parking facilities can create unsafe situations.	MEDIUM	LOW	MEDIUM	LOW
	Poor visibility	Provision of lighting	Safer environment	Cities and their accesses	▪ Helps to reduce the number of accidents at night. ▪ Improves personal safety.	▪ Regular maintenance is required; if not, poor lighting levels are dangerous. ▪ Placing of lighting poles at roadsides should be carefully studied, as they are dangerous obstacles in case of road exit. ▪ If installed as an isolated measure, it can induce an increase in vehicles' speed.	HIGH	HIGH	MEDIUM - HIGH	HIGH

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN ROAD	Poor visibility	Improve road signing High performing retro-reflective materials using micro-cube technology sheeting should be suggested	Provide advance warning	Accesses to cities	• Advance warning is provided to the driver. • Reflectance warning signs helps to reduce the number of accidents at night when there are not lighting facilities.	• Requires maintenance at a regular basis. • Installing too many traffic sings is not advisable: drivers get used to them and are less respected.	LOW	LOW	MEDIUM	LOW
		Improve road markings using high quality markings and/or road reflectors	Delineate the road limits	Accesses to cities.	• Traffic regulation effect. • Provides warning and guiding to drivers. • Strengthen information provided by traffic sings. • Not redundant.	• Requires maintenance at a regular basis.	LOW	LOW	HIGH	LOW
		Traffic guidance equipment	Delineate the road limits	Accesses to cities.	• Very useful for delineating the road limits and special road locations (narrowing of the road, junctions...) • Especially important at roads without lighting devices.	• Requires maintenance at a regular basis.	MEDIUM	MEDIUM	MEDIUM	LOW

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
INTER-URBAN ROAD	Exceeding speed limits	Improve road signing	Regulation of speed levels	Rural roads	▪ Drivers are very familiar with traffic singing. ▪ Easy, cheap and well-known way to warn drivers.	▪ Requires maintenance at a regular basis. ▪ Not very effective if not applied with additional measures that make the driver perceive the danger of the road section. ▪ Installing too many traffic sings is not advisable: drivers get used to them and are less respected.	LOW	LOW	MEDIUM	LOW
		Transversal rumble strips	Warn drivers	Rural roads	▪ Very effective to attract drivers' attention.	▪ Requires maintenance at a regular basis. ▪ Very noisy. ▪ Efficiency decreases with time, as drivers get used to these devices. ▪ Dangerous for motorcyclists driving at high speed.	LOW	MEDIUM	MEDIUM	LOW
		Transversal flat strips	Warn drivers	Rural roads	▪ In some countries, as this measures is less used than rumble strips, it surprise drivers, achieving a high efficiency. ▪ Do not create any disturbance to drivers or to neighbourhood.	▪ Not effective for usual drivers along the same route. ▪ Not effective under adverse weather conditions or with poor visibility.	LOW	LOW	HIGH	LOW
		Traffic guidance panels at curves	Warn drivers about dangerous curves	Rural roads, specially at mountainous areas	▪ Criteria easily understood by all drivers. ▪ Good visibility at night and under adverse weather conditions.	▪ Homogeneous criteria should be followed for all curves, so that drivers could undoubtedly identify the degree of danger of the road section.	LOW	LOW	HIGH	MEDIUM

		Speed enforcement by radar[15]	Prevent over speeding	Rural roads	▪ Highly effective Produces a change on driver behaviour	▪ Mobile or fixed radars together with police control are expensive, as they require human resources. ▪ Radars without police control (just to inform the driver) are usually only effective along a short road section. ▪ Fixed radars are only effective at the long term, as drivers get used to that situation. Social rejection.	HIGH	HIGH	LOW	MEDIUM
	Frequent rear-end collisions (Specially at junctions	Provide high skid resistance pavement	Avoid skidding accident problems	Rural roads	▪ Great comfort for the driver. ▪ Especially helpful when installed at areas with frequent adverse weather conditions. ▪ Drivers perceive a change in the route, which makes them be on the alert.	▪ Partial re-surfacing creates road sections with different skid resistance, leading to loss of control accidents.	MEDIUM	MEDIUM	HIGH	LOW

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
INTER-URBAN ROAD	Frequent rear-end collisions (Specially at junctions)	Improve road signing. High performing retro-reflective materials using micro-cube technology sheeting should be suggested	Warn drivers	Rural roads	▪ Advanced warning is provided to the driver. ▪ Advanced informative signs allow the driver to decide safely which way to follow.	▪ Requires maintenance at a regular basis. ▪ Installing too many traffic sings is not advisable: drivers get used to them and are less respected.	LOW	LOW	MEDIUM	LOW
	Frequent accidents due to adverse weather conditions	Improve road marking with high quality markings and/or road reflectors	Delineate the road limits	Rural roads	▪ Traffic regulation effect. ▪ Provides warning and guiding to drivers. ▪ Strengthen information provided by traffic sings. ▪ Not redundant.	▪ Requires maintenance at a regular basis, as reflectance levels decrease with time. ▪ Some materials used for road markings diminish skid resistance, which is especially dangerous for cyclists. ▪ Anti-skidding materials produce dark road markings and lower reflectance level.	LOW	LOW	HIGH	LOW
		Jiggle bars at edges	Avoid road exit	Rural roads	▪ Guide drivers, making driving more comfortable and safe. ▪ Drivers perceive the proximity to the edge of the road even under adverse weather conditions.	▪ Dangerous for cyclists. ▪ Maintenance of road markings is more difficult and expensive.	MEDIUM	MEDIUM	HIGH	LOW

		Retro reflecting road studs High performing retro-reflective materials using micro-cube technology sheeting should be suggested	Delineate the road limits	Rural roads	▪ Guide drivers and provide comfortable driving, especially during nighttime. ▪ Not dangerous for motorcyclists and cyclists.	▪ Requires maintenance at a regular basis. ▪ If not clean, they loose all properties.	MEDIUM	MEDIUM	HIGH	LOW
		Marker posts	Delineate the road limits	Rural roads, except where it snows frequently	▪ Guide drivers and provide comfortable driving, especially during nigh time and under adverse weather conditions. ▪ May be used to warn of special road locations: bridges, narrowing...	▪ Requires maintenance at a regular basis. ▪ High vulnerability. ▪ If used very often, warning effect decreases.	MEDIUM	MEDIUM	HIGH	LOW

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
INER-URBAN ROAD	Serious accidents due to road exits	Jiggle bars at edges	Avoid road exit	Rural roads, specially at long straight alignments	▪ Guide drivers in situations of poor visibility. ▪ Make drivers react in case they fall asleep.	▪ Possible risky manoeuvres after contacting jiggle bars. ▪ Dangerous for cyclists and motorcyclists. ▪ Maintenance of road markings is more difficult and expensive.	MEDIUM	MEDIUM	HIGH	LOW
		Provide a clear roadside	Reduction of the consequences of an accident	Rural roads	▪ Regardless of the reason for a vehicle leaving the roadway, a clear roadside enhances the opportunity for reducing accident severity.	▪ Can be expensive, although it is cost-effective. ▪ Environmental impact. ▪ May produce an increase in the driving speed, as the drivers perceive a safer situation.	HIGH	LOW	HIGH	HIGH
		Soften roadside slopes	Provide recoverable roadsides	Rural roads	▪ A clear roadside with stable, flattened slopes reduces accident severity, avoiding overturning. ▪ Softening sharp cuts avoids potential ground slips.	▪ Can be expensive, although it is cost-effective. ▪ Environmental impact.	HIGH	MEDIUM	HIGH	HIGH
		Protect roadside obstacles	Reduction of the consequences of an accident	Rural roads	▪ Unique choice when it is not possible to remove the obstacle.	▪ Restraint level should be carefully studied for the characteristics of the traffic.	HIGH	LOW - MEDIUM	MEDIUM	MEDIUM
		Install road safety barriers where required	Avoid road exit	Rural roads and specially mountainous areas	▪ To be applied when the consequences of an accident without safety barrier are worse than with it. ▪ Avoid overturning, vehicles crashing with fixed objects on the roadsides and invasion of vehicles on the opposite way. ▪ Variety of types; at environmentally sensible areas, wooden safety barriers are highly recommended.	▪ Safety barriers require immediate replacing after a crash. ▪ Restraint level should be carefully studied for the characteristics of the traffic. ▪ Some types of safety barriers could be extremely dangerous for motorcyclists, causing cuts with edges and severe impacts with posts.	HIGH	MEDIUM - HIGH	MEDIUM	MEDIUM

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
INTER - URBAN ROAD	Wrong perception of junctions	Improve road signing and markings. High performing retro-reflective materials using micro-cube technology sheeting and high quality markings and/or road reflectors should be suggested	Warn drivers	Rural junctions	▪ Advanced warning is provided to the driver. ▪ Advanced informative signs allow the driver to decide safely which way to follow.	▪ Requires maintenance at a regular basis. ▪ Installing too many traffic sings is not advisable: drivers get used to them and are less respected.	LOW	LOW	MEDIUM	LOW
		Marker posts using high quality marking materials	Delineate the road limits	Rural junctions, except where it snows frequently	▪ When used to delineate the road in the proximity of the junction they help to increase drivers' attention. ▪ Guide drivers and provide comfortable driving, especially during nigh time (in case artificial lighting does not exist) and under adverse weather conditions.	▪ Requires maintenance at a regular basis. ▪ High vulnerability, especially by winter maintenance equipments. ▪ It is not advisable to use marker posts at all junction; installation is only recommended at dangerous junctions, as if they are used very often, warning effect decrease.	MEDIUM	MEDIUM	HIGH	LOW
		Increase sight distance	Avoid wrong decisions	Rural junctions	▪ Increase sight distance for the main and secondary road makes decision taking easier. ▪ Also good to react under a surprising situation (for example, sudden appearance of an animal in the road). ▪ Cutting vegetation is a very effective and cheap measure.	▪ May requires demolition and expropriation. ▪ Will not eliminate all problems, as dangerous manoeuvres will still happen if waiting times are excessive, although visibility is right.	LOW - MEDIUM	MEDIUM	MEDIUM	MEDIUM

		Channelled intersections with appropriate layout design and high quality markings, road reflectors and appropriate signing	Improve perception of junction	Rural junctions	• Can be used in a wide range of situations. • Speed reduction. • It is an easy-to-implement and low cost measure if canalisation is provided just by road markings. • Separation of traffic flows allows drivers to clearly perceive the junction. • Easier identification of the stop line.	• Effectiveness decreases if drivers do not respect "stop" or "give way" signs. • Some traffic islands used for canalisation are not width enough to protect vehicles turning. • Channelling with road markings requires maintenance in a regular basis. • Channelling usually requires widening of the road at the intersection, which sometimes is used for illegal over takings.	LOW - MEDIUM	LOW	MEDIUM	HIGH

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
INER-URBAN ROAD	Safety problems due to wrong design of junctions	Provision of traffic lights at rural road junctions	Enforce the respect of preferences at junctions.	Rural roads	• Great reduction of accidents, specially of those involving left turning vehicles. (right turning vehicles in UK). • Eliminates drivers wrong perceptions of intersections and the way they should behave. • Improves safety conditions of vulnerable users (pedestrians, cyclists, etc.)	• Requires the provision of warning signs. • Relatively frequent non-fulfilments, specially with low traffic volumes. • Large space is required, specially when an extra turning lane should be provided. • Traffic lights activated by traffic are more effective but they are more expensive • Design of signalised junctions should carefully consider traffic volumes turning left (right in the UK), so that long queues could be avoided (and rear-end collisions with non-turning vehicles).	MEDIUM-HIGH	MEDIUM	MEDIUM	HIGH
		Provide an additional turning lane with separate left turning Signal phases	Avoid dangerous turning manoeuvres	Rural junctions with high traffic volumes	• Vehicles turning can safely wait for their turn. • Unnecessary waits for vehicles not turning are avoided.	• Requires maintenance at a regular basis. • Space requirements.	HIGH	LOW	HIGH	HIGH

		Removal of objects on the central islands of roundabouts	Reduction of the consequences of an accident	Rural roads with accident records related	▪ Reduces the consequences of possible accidents.	▪ Worsen drivers' perception of the roundabout.	MEDIUM	LOW	MEDIUM	MEDIUM
		Provide lighting	Reduce conflicts during night time	Rural junctions	▪ Safer and more comfortable driving. ▪ Avoid drivers falling asleep. ▪ Safer conditions for pedestrians and cyclists.	▪ In rural areas, it could be expensive to provide electricity supply. ▪ If there are not restraint systems and "breakaway supports" are not used, lighting supports are fixed objects which can lead to severe consequences in case of accident. ▪ If installed as an isolated measure, it can induce an increase in vehicles' speed. ▪ Environmental impact.	HIGH	LOW	HIGH	HIGH
		Provide or lengthen acceleration/ deceleration lanes	Avoid conflict between different traffic flows	Rural junctions with high traffic volumes	▪ Avoid sudden manoeuvres of vehicles turning, as junction is identified in advance. ▪ Avoid queues of vehicles entering the deceleration lane. ▪ Queues of vehicles using the acceleration lane are out of main road, so dangerous situations are avoided. ▪ Increase visibility of drivers on the main and secondary road. ▪ Increase junction capacity.	▪ Could be expensive. ▪ May requires demolition and expropriation.	HIGH	MEDIUM	HIGH	HIGH

AREA	PROBLEM	POSSIBLE SOLUTIONS	TARGET	AREA OF APPLICATION	ADVANTAGES	CONSTRAINTS	COST OF INSTALLATION	COST OF MAINTENANCE	USERS' ACCEPTANCE	VISUAL IMPACT
URBAN OR INTER - URBAN ROAD	Conflicts between motorized vehicles and bicycles	Separated cycling lanes	Provide safe routes for cyclists	Urban and rural areas	• If well planned, this measure will induce higher cyclist traffic and reductions in the number of accidents. • Environmentally friendly. Reduce air pollution, energy consumption and noise levels. • More comfortable, safe and higher quality service. • Not interfering with motorized traffic. • Old routes, not used for traffic, can be adapted to cycling.	• If not well planned, cyclist traffic will not increase and number of accidents will not decrease. • Sometimes used by pedestrians or skaters. • Higher cost of construction and maintenance than through the integration of cycling lanes.	HIGH	MEDIUM	MEDIUM	HIGH
		Integrated cycling lanes	Provide safe routes for cyclists	Urban and rural areas	• If well planned, this measure will induce higher cyclist traffic and reductions in the number of accidents. • Environmentally friendly. Reduce air pollution, energy consumption and noise levels. • Expropriation is not necessary, in most of cases, so construction is cheaper. • Maintenance is cheaper than for separated cycling lanes.	• If not well planned, cyclist traffic will not increase and number of accidents will not decrease. • Could be illegally used by motorcyclists; to avoid this, barriers should be placed. • Cyclists are more vulnerable, especially when turning. • Conflicts at bus stops. • Could be illegally used as parking areas.	MEDIUM	LOW	MEDIUM	HIGH