UK ROADS LIAISON GROUP

Department for Transport

Design & Maintenance Guidance for Local Authority Roads

Provision of Road Restraint Systems on Local Authority Roads

October 2011

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Annexes

1. Executive Summary

The UK's roads are amongst the safest in Europe, nonetheless the number of accidents involving vehicles leaving the carriageway remains high when considered as a proportion of all accidents. Indeed in 2009 fatalities as a result of a single vehicle run-off represented nearly half of all UK road fatalities.

Despite the large numbers of accidents nationally the number of incidents of a vehicle leaving the carriageway at one particular site is likely to be low. Justifying the introduction of expensive Road Restraint Systems (RRSs) to reduce the risk is a challenge for local highway authorities, especially at a time when funding for maintenance and improvements scheme is already limited. Authorities must be confident that any measures taken represent good value for money.

The Design Manual for Roads and Bridges standard TD 19 – Requirements for Road Restraint Systems has been developed using accident data for routes with over 5000 AADT and a speed limit of 50mph or greater. Application of the risk based approach in that standard to low speed and low flow roads is likely to result in over use of RRSs and not represent best use of limited resources. TD 19 is therefore not suitable for use on the majority of the nation's local road network.

It is not possible to produce a prescriptive set of standards to govern the use of RRSs on local authority roads. This Guidance Document provides the outline of an appraisal process to help authorities decide when a RRS is justified. This appraisal takes account of the many diverse influencing factors including risk assessment, alternative solutions, system feasibility, cost benefit analysis and the availability of funding.

The Guidance contained here can be adapted by local highway authorities to create a pragmatic system for decision making to help them make best use of the finite resources available to them.

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2. Glossary of Terms and Definitions

The Guidance uses a number of acronyms and other terminology, the full description of which shall be found alongside the first reference to that acronym within the text. For ease of reference, a full list of the acronyms which this Guidance document makes use of is given below.

AADT	Annual Average Daily Traffic
ALARP	As low as reasonably practicable
CBA	Cost Benefit Analysis
DfT	Department for Transport
HA	Highways Agency
ISL	Impact Severity Level
KSI	Killed and Seriously Injured
MCHW	Manual of Contract Documents for Highway Works
PAS	Publicly available specification
PRS(s)	Pedestrian Restraint System(s)
RRRAP	Road Restraint Risk Assessment Process
RRS(s)	Road Restraint System(s) – General name for any Vehicle Restraint System(s) or Pedestrian Restraint System(s) used on the road.
SHW	Specification for Highway Works
TD19	Requirement for Road Restraint Systems (http://www.dft.gov.uk/ha/standards/dmrb/vol2/section2/td1906.pdf)
UKRLG	United Kingdom Roads Liaison Group
VRS(s)	Vehicle Restraint System(s) – A system(s) installed on the road to provide a level of containment for an errant vehicle.

Other terms used in this Guidance are defined below:

Contractor	The organisation undertaking the various phases of the scheme which might include design, construction and/or maintenance.
Designer	Any person who carries a trade, business or other undertaking in connection with which he prepares a design or arranges for any person under his control (including where he is an employer and employee of his) to prepare a design.
Highway authority	The highway or roads authority responsible for a road in England, Scotland, Wales and Northern Ireland.
Set-back	As defined in DMRB TD 27 and Section 9.1.4.
Working Width (W)	As defined in BS EN 1317-2 and Section 9.1.3.

3. Introduction

A Road Restraint System[1] (RRS) is intended to reduce the number and severity of injuries in the event that a vehicle leaves the road and would otherwise encounter a hazardous feature. Self-evidently in protecting a vehicle's occupants, a RRS also protects against damage to any highway asset located behind the system.

A RRS can also provide the indirect benefit of protection for road workers at places of frequent maintenance intervention where temporary working methods would otherwise require installation of physical barriers.

The introduction of a RRS does not always make a situation totally safe and the installation of a compliant system may come at significant expense. Every year, there are injuries caused when vehicles hit RRSs and, in some circumstances, it may be better to simply move or not protect a hazard. This Guidance recognises that any RRS has an inherent element of risk and that this risk has to be balanced by the benefit of mitigating the severity of any accident at an affordable cost.

RRSs are sub-divided into Vehicle Restraint Systems (VRSs) and Pedestrian Restraint Systems (PRSs). A VRS is generally not provided to protect pedestrians on footways, nonetheless the installation of such a system may affect pedestrian provision and this is considered within this Guidance. Advice on the use of risk assessment to support a decision to install or remove a PRS is given in "Local Transport Note 2/09 Pedestrian Guardrailing".

3.1 SCOPE AND APPLICATION

This United Kingdom Roads Liaison Group (UKRLG) Guidance Document has been prepared for use by highway authorities and their designers considering the introduction or replacement of RRSs on roads with low traffic flows and/or low traffic speeds. It describes a process to assist highway authority decision making with regards to investing in a RRS at a particular site. It includes the necessary supporting information to assist this process and takes account of risk, risk assessment methods, costs, benefits as well as further advice on performance specification and outline design.

TD 19 Requirement for Road Restraint Systems (DMRB 2.2.8) is the standard applicable for Trunk Roads and Motorways. The aim of this Guidance is to assist authorities in developing an appraisal method, including a risk assessment, as an alternative to the risk estimation element of TD 19, the Road Restraint Risk Assessment Process (RRRAP). Figure 3.1 illustrates when the RRRAP remains applicable.

This Guidance Document **does not replace** TD 19 but instead offers alternatives to the RRRAP used by TD 19. Once a decision to install a RRS has been made

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[1] Although Road Restraint Systems can be both vehicle and pedestrian restraint systems the use of the term in this document refers to systems intended to provide containment for an errant vehicle, unless stated otherwise.

the **design advice**[2] given in TD 19 remains relevant to low speed and low flow roads, but this Guidance note has been written to allow ease of cross reference to the most important aspects of TD 19.

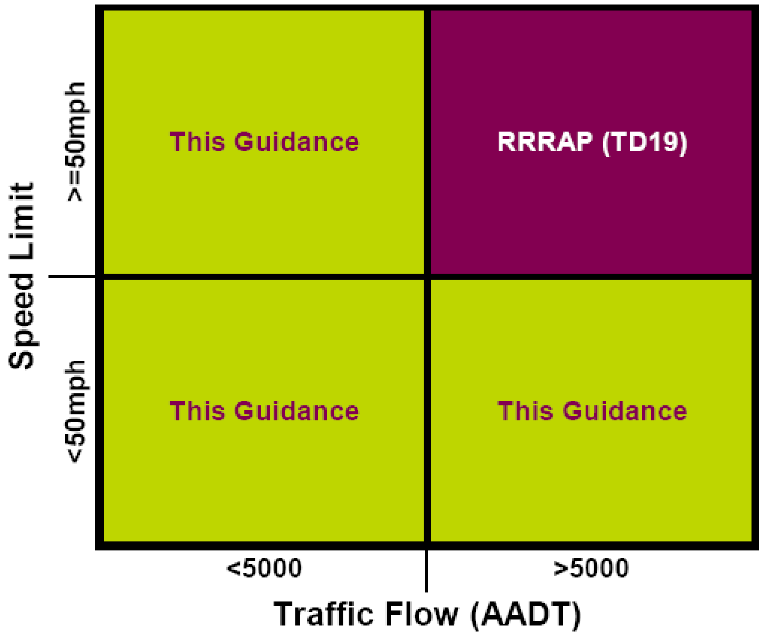

Figure 3.1 – Applicable methods for determining when a RRS is required.

This Guidance Document applies to:

- New roads (and the adoption of roads)
- Road improvements e.g. widening, junction improvements
- Where a new hazard is introduced or an existing roadside feature is altered e.g. the addition of roadside features
- Where the upgrade or replacement of a parapet is being considered.
- Maintenance schemes where a significant length of RRS is being replaced
- When the safety performance of a particular site has been questioned and risk reduction options are being assessed.

Although not written to specifically include advice for surface car parks or private roads much of the content would be equally applicable for these situations.

The large number of circumstances faced by highway authorities makes the provision of prescriptive guidance inappropriate. This Guidance Document has been prepared to assist with local decision making. Inherent in such decision making is framing such decisions within the context of an overall policy. It is therefore recommended that individual local authorities adopt a suitable policy for the provision of RRSs. This may take the form of a highway authority acknowledging the use of this Guidance in full or amending it to suit its own needs.

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[2] This statement assumes that an authority has recognised TD 19 in its suite of design standards. Similarly all references (in this Guidance) to "requirements" within TD 19 are only relevant where an authority has chosen to adopt TD19.

At several points in this document the reader will need to refer to TD 19 to find the necessary technical detail. Whether designing a RRS for a new motorway or an existing low speed road the fundamentals of design process remain the same. Where a site meets the criteria of the appraisal outlined in this document and a decision is taken to install a RRS the design advice within TD 19 can be used to ensure that the performance specification is sufficient and that the detailed design layout is fit for purpose.

Where the detailed layout does not comply with a mandatory requirement of TD 19 or the advice contained in this Guidance this can be assessed by the designer and agreed with the highway authority, taking into account the local circumstances.

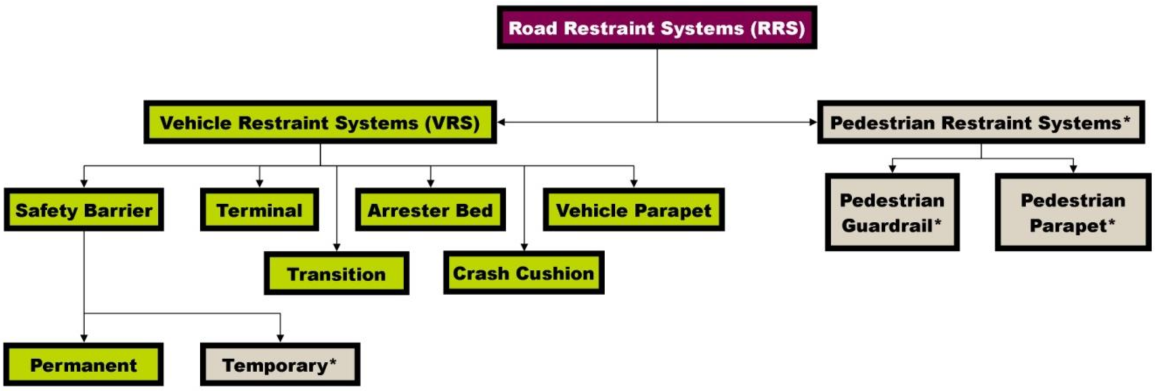

Figure 3.2 - Road Restraint System Family

(Note - Asterixed items in grey are not covered by this document)

3.2 ACCIDENT DATA

The UK's roads are amongst the safest in Europe, nonetheless the number of accidents involving vehicles leaving the carriageway remains high when considered as a proportion of all accidents. National accident statistics, reported annually by the Department for Transport (DfT) indicate the extent of the issue and are relevant in defining the risk. Table 3.2 provides data for accidents in 2009 for single vehicles leaving the carriageway.

Further analysis of traffic and casualty data collected by the DfT has also been used to determine the typical frequency at which these type of single vehicle Killed or Seriously Injured (KSI) accidents occur on different road classes. This data is reported in Table 3.1 which gives an indication as to how the different road classes perform across Great Britain. Clearly the data for each route type is based on a very broad range of routes with differing traffic flows and characteristics and illustrates that the case for the provision of a RRS will vary across different route types. The typical KSI accident return periods may also assist in helping define where a particular route is performing poorly.

Although the risk per mile on an "average" route is low, the number of run-off KSI accidents represents a high proportion of all road casualties. For example in 2009 there were a total of 2057 fatal accidents on all roads, meaning that the proportion related to single vehicles leaving the carriageway is approaching half the GB total of all fatal accidents. This proportion has increased over the last decade although the number of single vehicle accidents has also fallen over the same period.

ROAD CLASSIFICATION	KSI RETURN PERIOD (IN YEARS) PER MILE
Urban A Roads	1.9
Rural A Roads (exc A(M))	4.8
Urban B Roads	5.8
Rural B Roads	15.1
Urban C Roads	18.7
Rural U Roads	22.4
Rural C Roads	61.4
Urban U Roads	144.0
All routes	20.4

Table 3.1 - Return period of KSIs per mile on typical route classifications (GB)

Further analysis of accident severities shows that there is:

- Little change in severity outcome between built up and non-built up roads, indicative that the speed limit may not be a significant issue in assessing the outcome once a vehicle leaves the paved surface.
- Collisions with trees show high severity outcomes on all routes.
- Although there are small numbers of occurrences where a vehicle leaves the carriageway and becomes submerged these incidences have high severity outcomes.
- High severity outcomes also result from collisions at embankments/cuttings and at posts/poles.
- There is higher severity for accidents involving embankments and cuttings in rural areas.

It must be remembered that a proportion of run-off crashes involve the following undesirable road user behaviour that the road infrastructure is not designed to facilitate:

- Excessive speeding
- Involvement of drink/drugs
- Not wearing a seat belt

As part of the study further data has been received from DfT's statistics branch and this is shown in Annex C. This information has some use in understanding the nature of the problem but can only give limited information for the purposes of risk assessment. The data in Annex C does however indicate that for run-off accidents:

- Accidents on built up roads are more prevalent at junctions than on non-built up roads.
- On built-up roads accidents at junctions are a significant proportion.
- A high proportion of accidents happen at bends.
- Roads with low speed limits (20mph and 30mph) can still generate high numbers of fatal or KSI accidents.
- Even slow manoeuvres such as parking and reversing can also generate high numbers of accidents.
- Roundabouts are not as a significant an issue in built up areas as non-built up areas.

Object Hit	Fatal	Serious	Slight	All	KSI	KSI %
None	366	5,733	23,733	29,832	6,099	20.4
Road sign or traffic signal	14	102	508	624	116	18.6
Lamp post	31	218	920	1,169	249	21.3
Telegraph Pole/Electricity pole	7	51	232	290	58	20.0
Tree	32	216	562	810	248	30.6
Bus stop or shelter	3	17	75	95	20	21.1
Crash barrier	8	48	317	373	56	15.0
Submerged	1	1	3	5	2	40.0
Entered ditch	6	27	156	189	33	17.5
Other permanent objects	64	496	2,087	2,647	560	21.2
Not known	0	1	0	1	1	100.0
Total	**532**	**6,910**	**28,593**	**36,035**	**7,442**	**20.7**

Built up roads (excluding motorways)

Object Hit	Fatal	Serious	Slight	All	KSI	KSI %
None	95	977	3,089	4,161	1,072	25.8
Road sign or traffic signal	18	121	486	625	139	22.2
Lamp post	9	65	283	357	74	20.7
Telegraph Pole/Electricity pole	7	53	251	311	60	19.3
Tree	132	543	1,482	2,157	675	31.3
Bus stop or shelter	0	2	8	10	2	20.0
Crash barrier	22	118	715	855	140	16.4
Submerged	2	4	13	19	6	31.6
Entered ditch	20	247	1,191	1,458	267	18.3
Other permanent objects	66	470	2,161	2,697	536	19.9
Not known	95	977	3,089	4,161	1,072	25.8
Total	**371**	**2600**	**9679**	**12,650**	**2,971**	**23.5**

Non-built up roads

Object Hit	Fatal	Serious	Slight	All	KSI	KSI %
None	10	68	297	375	78	20.8
Road sign or traffic signal	3	11	32	46	14	30.4
Lamp post	1	10	28	39	11	28.2
Telegraph Pole/Electricity pole	0	0	2	2	0	0.0
Tree	11	32	93	136	43	31.6
Bus stop or shelter	0	0	0	0	0	-
Crash barrier	16	103	689	808	119	14.7
Submerged	0	0	0	0	0	-
Entered ditch	5	13	48	66	18	27.3
Other permanent objects	2	26	111	139	28	20.1
Not known	10	68	297	375	78	20.8
Total	**48**	**263**	**1,300**	**1,611**	**311**	**19.3**

Motorways

Object Hit	Fatal	Serious	Slight	All	KSI	KSI %
None	471	6,778	27,119	34,368	7,249	21.1
Road sign or traffic signal	35	234	1,026	1,295	269	20.8
Lamp post	41	293	1,231	1,565	334	21.3
Telegraph Pole/Electricity pole	14	104	485	603	118	19.6
Tree	175	791	2,137	3,103	966	31.1
Bus stop or shelter	3	19	83	105	22	21.0
Crash barrier	46	269	1,721	2,036	315	15.5
Submerged	3	5	16	24	8	33.3
Entered ditch	31	287	1,395	1,713	318	18.6
Other permanent objects	132	992	4,359	5,483	1,124	20.5
Not known	0	1	0	1	1	100.0
Total	**951**	**9,773**	**39,572**	**50,296**	**10,724**	**21.3**

All Roads

Table 3.2[3] - Reported single vehicle accidents: by objects hit off carriageway: built up and non-built up roads and severity 2009. (Note – 'None' in the above tables indicates the injury occurred despite not hitting a physical object, the injury may have occurred by the vehicle encountering an embankment or cutting)

[3] Developed from DfT Reported Road Casualties 2009 – Table 20.

3.3 LIMITATIONS OF TD 19

Advice on the provision of RRSs within TD 19 is based on the estimation of risk rather than the consideration of local accident history. This risk estimation tool, the Road Restraint Risk Assessment Process (RRRAP), has been developed based on accident records for roads with speeds of 50mph or greater, and with traffic flows of more than 5000 AADT.

The RRRAP is an integral part of the decision to provide safety barrier in TD 19 methodology and is also used to test when it is necessary to provide a parapet which exceeds the minimum requirements set out in the standard. The provision of other forms of RRSs described in TD 19 (e.g. terminals) is dependent on the decision to provide safety barrier or a vehicle parapet and as such not directly dependant on the RRRAP.

There are a number of reasons why use of the RRRAP risk model may not produce useful results when applied on low speed and/or low flow roads:

- The data is from a large number of routes that share a large number of common features. Local highway authority routes are much more diverse and a huge variety of circumstances exist.
- The data is for routes that have a substantially better road alignment.
- The data is from routes that have other safety features that would not typically be present on local highway authority routes. E.g. Motorway Incident Detection and Automatic Signalling.

4. Legal Aspects

It is only trunk roads that are required to be designed according to the Design Manual for Roads and Bridges, for all other roads the decision over the design and the methodology remain in the hands of the local highway authority.

In general terms, omissions in design or non-compliance on the existing road network that may be a potential contributory factor in a personal injury accident are very unlikely to result in successful legal outcomes for plaintiffs.

The UKRLG publication “Highway risk and liability claims: A Practical Guide to Appendix C of The Roads Board report ‘Well Maintained Highways - Code of Practice for Highway Maintenance Management’ ” - notes that:

“Road users bear responsibility for their own safety. Courts will apportion responsibility. Claimant will have to establish that they were entrapped into danger. It is only in exceptional circumstances that individuals may be able to establish a breach of duty of care.”

In general drivers have to “take the road as they find it”. The low risk of a highway authority being held liable in law is lessened further still if any departures from its own or national standards could be shown, via records, to have been adequately considered. This advice also extends to the recording decisions “not to act” when dealing with an existing known highway risk.

It is important to note that decisions are not normally made on the grounds of safety alone. Decisions are usually balanced and take account of all relevant factors and constraints. Highway authorities may exercise considerable discretion in developing and applying their own local policies and standards.

Key requirements of this Guidance, that would be relevant during any form of legal challenge, are no different to those in TD 19:

I. The decision to provide or omit a RRS must be taken and recorded. It must not be allowed to happen by default;
II. The decision must be taken at the correct level in the organisation; if necessary devolving responsibility to those who are best able to obtain and assess the evidence on which to base a decision;
III. The decision taker must not be afraid of doing nothing, if to do nothing is the proper conclusion of the assessment process outlined in this Guidance.

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5. Appraisal Process

The decision to provide a RRS in a low flow or low speed scenario is a difficult one due to the high costs and the potentially low risk of accidents at a particular location. The occurrence of one accident involving a vehicle leaving the carriageway may be a result of numerous highway factors but can result in considerable public pressure to provide a RRS.

There are many disparate factors that the highway authority must consider in choosing to provide or omit a RRS. The generally lower frequency at which vehicles leave the carriageway will make provision of a RRS less likely than in the high speed/high flow scenarios on the trunk road network. This lower frequency of occurrence means that risk is less of a direct factor in determining provision and a more balanced appraisal is appropriate.

This Guidance provides an outline structure for this appraisal, with a series of criteria requiring analysis, each of which must be met in order for a RRS to be provided. The relevant tests are:

- The hazardous feature cannot be relocated or redesigned.
- Other means of reducing risk to vehicle occupants are inappropriate or unaffordable.
- The expenditure on provision of a RRS has been justified using cost benefit analysis.
- Installation of an acceptably compliant RRS is possible.
- Installation of a RRS would not establish an unsustainable precedent resulting in extensive work along a route or at other similar locations.
- The issue is of sufficient high priority when measured against other competing funding pressures to justify expenditure.

Figure 5.1 shows the outline of the proposed process with each step explained in the following sections. This process is intended for RRS schemes based on safety fence provision, the appraisal process for provision of parapets is described in Section 1.

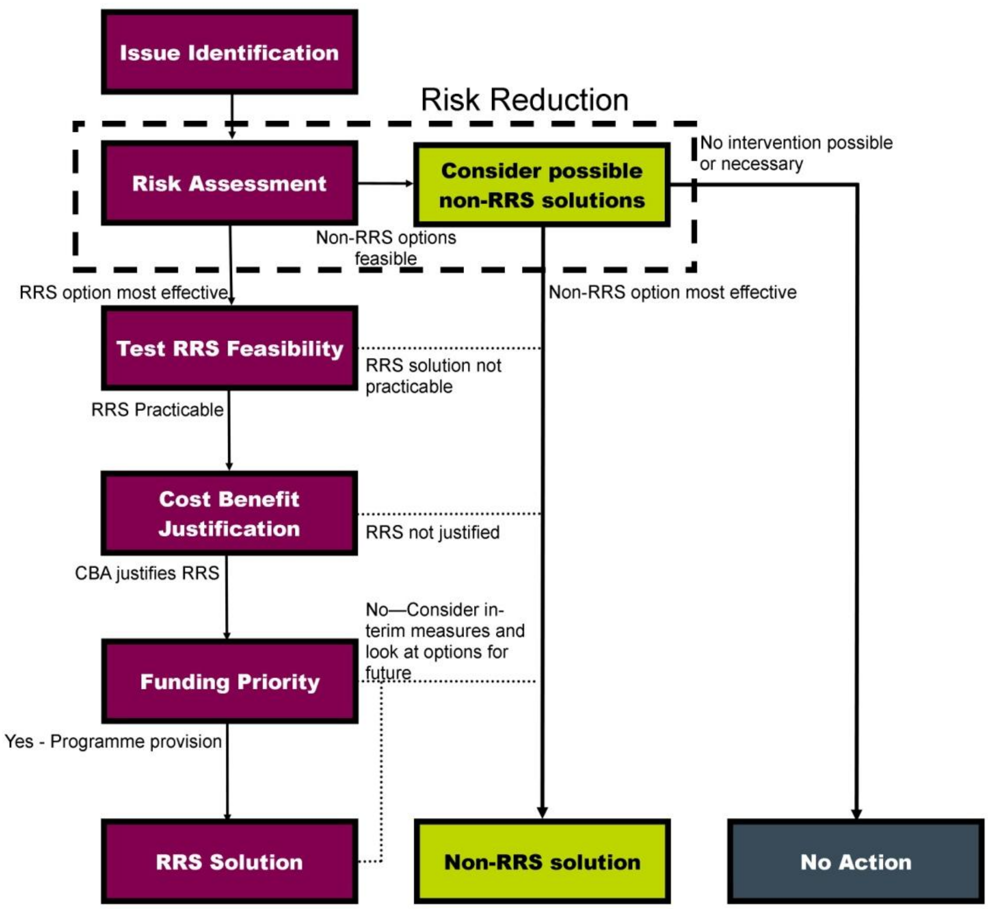

Figure 5.1 - Appraisal Process

5.1 RISK IDENTIFICATION

This process can be applied in all the circumstances described in Section 3.1. The way in which highway authorities manage the risk of vehicles leaving the carriageway and colliding with a roadside object will vary across the country and will not only depend on the nature of the routes the authority maintains but the funds available to them at the time an issue comes to light. These differences will influence what risk level an authority considers ‘tolerable’.

Table 5.1 provides a list of potentially hazardous roadside features. It is recommended that the introduction of any of these features on a new or existing route, within close proximity of the edge of the running lane[4] of the carriageway, justifies the application of the appraisal process.

There have been numerous studies that have investigated the selection of appropriate clear zones. This is a multi-faceted issue and depends upon the angle and initial speed at which a vehicle leaves a road, the intervening ground friction and whether a hazard is an object or a non-object such as an embankment or water. In the case of these non-object hazards a vehicle fall would occur at any residual off-road speed. In the case of objects, the percentage of serious or fatal injuries starts to become significant at residual

[4] In some cases the feature may be outside the highway boundary. This may limit the options for reducing the risk but should not be used as a reason to abandon the assessment.

speeds as low as 15m/s. Research[5] has also shown that on higher speed roads the initial speeds that vehicles leave the road are mostly within the speed limit, but on lower speed roads excessive speeds above the speed limit are more typical. For example a typical case would be a vehicle leaving a 40mph road at 50mph, with a typical deceleration rate of 0.5g, the residual speed at 10m from the road is around 15m/s. If unhindered by any other object the same vehicle would only come to rest 20m from the road so any unprotected drop within 20m may be reached. For a 60mph initial speed the values of 10m and 20m rise to approximately 20m and 30m respectively.

Achieving true clear zones in the order of these magnitudes is extremely unlikely in the context of existing or any new UK roads. Therefore the focus will normally be on minimising risk using the techniques referred to in Section 5.2 or providing a RRS near to the road edge where the residual risk is considered high. It should be noted that the list in Table 5.1 is not exhaustive and the authority may identify other hazards or circumstances which could justify appraisal.

Where a barrier already exists and is life-expired the authority may wish to undertake a review before automatically replacing the system. The initial justification for the barrier should be understood and a determination made as to whether this justification is still valid. Maintenance records and an inspection of any damage to the system may indicate that the barrier has served its purpose. The lack of maintenance and/or an accident problem may not always justify complete removal. Following the advice in Section 5.2.2 it may be possible to reduce the risk by other means which could allow for the removal of the barrier. Where it is expected that the system will be renewed TD 19 can be used for the design of the new system. Where routine maintenance is planned or short sections of an existing system are damaged and require replacing it is not expected that a review would take place. TD 19 Clause 1.18 (iii) includes a list of scenarios where a review may be considered for a maintenance project.

When designing new schemes it is imperative that early co-ordination with other design disciplines (i.e. drainage, signing, lighting, communications, structures, highways etc.) is undertaken to ensure that opportunities to reduce the risk to vehicles leaving the carriageway are maximised. This may include a simple analysis to see how the different design elements overlap and thus ensure the early identification of potential clashes. Simple measures such as placing lighting columns on the inside of bends may reduce or remove the risk.

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[5] The travel of errant vehicles after leaving the carriageway, TRL report PPR298

TYPE	EXAMPLES	COMMENTS
Roadside obstructions	Retaining walls including crib walls and gabions which do not have a smooth face adjacent to the traffic extending for at least 1.5m above the adjacent carriageway level.	A ‘smooth’ face may include a surface that may have an irregular surface finish subject to the maximum amplitude of the steps and undulations in the surface not exceeding 50mm when measured with respect to a plane through the peaks. The plane must be broadly parallel to the road alignment. A structure that has a 25 mm wide chamfered construction joint in its surface would be regarded as smooth. Particular attention must be paid to wall ends and the end of gabion baskets.
	Rock slopes	At exposed rock faces (1 in 1 or steeper).
	Strengthened cuttings	At locations having strengthened or geo-textile reinforced cutting slopes. Such slopes may not be a particular hazard to the motorist but the consequences of the cut slope failing may be unacceptable. Exposed soil nails and anchors are likely to be a hazard.
	Structures	Including exposed ends of bridge parapets abutments or wing walls.
	Trees	Young trees can be assumed to be a hazard as growth will occur.
	Lighting columns	Unless the lighting column meets passive safety requirements.
	Sign Posts	Posts of 89mm in diameter or more unless a passively safe post/column is used. (If, however, an 89mm diameter post has a gauge thickness not greater than 3.2mm then it does not generally need protection from cars.)
	Control cabinets, pillars and masts	No comment
Hazards that road users may fall off or into	Embankments over 3m	Particularly on the outside of curves less than 850m radius.
	Water	A permanent or expected water hazard with depth of water 0.6m or more, such as a river, tidal water, reservoir, stilling pond, lake/loch or other hazard which, if entered, could cause harm to the vehicle occupants.
	Retaining walls	Where the height is greater than 1.5m.
	Culvert headwalls	No comment
Hazards where others could be affected	Roads, railways, subway entrance	On embankments where there is a road, railway or other feature, such as a subway entrance, at or near the foot of the slope.
	Playgrounds, recreational areas	Public meeting places where a number of people would be present for some time such as schools, hospitals, recreational, retail facilities or factories.
	Flammable material storage and other such works.	Chemical works, petroleum storage tanks or depots, facilities manufacturing or storing hazardous materials in bulk.

Table 5.1 – Hazards (within close proximity of running lane) which justify appraisal.

5.2 RISK REDUCTION

5.2.1 Risk Assessment

One of the fundamental criteria to justify provision of a RRS is to establish if the risk level without a RRS is unacceptable. The RRRAP estimates the risk using national data for the type of route in question and classifies the risk into three categories using the principles of ALARP[6], 'Broadly Acceptable', 'Tolerable' and 'Unacceptable'. On identifying a site for assessment the approach applied in this Guidance is to prioritise the site into one of the following groupings:

CATEGORY	RISK LEVEL	OUTCOMES
Higher Priority Site	Risk cannot be accepted save in extraordinary circumstances.	Where the risk assessment has defined a site as Higher Priority the installation of a RRS is justified in terms of the level of risk. Further consideration is then required to determine if the site meets the other appraisal criteria. Even at high risk sites non-RRS interventions may reduce the risk to a level where a RRS can be omitted.
Medium Priority Site	Intervention may be required to introduce control measures to drive residual risk towards the Lower Priority Site category. The residual risk can be tolerated only if further risk reduction is impracticable or requires action that is grossly disproportionate to the reduction in risk achieved.	Where the risk evaluation has identified a site as Medium Priority a RRS may be justified however a non-RRS approach to reducing the risk may prove sufficient to negate the need for a RRS. If suitable effective measures cannot be introduced then the appraisal process would normally continue in order to consider the other criteria.
Lower Priority Site	Level of risk regarded as generally acceptable. Further effort to reduce risk is not likely to be required as resources to reduce risk would be grossly disproportionate to the risk reduction achieved.	Where the risk evaluation identifies a site that is lower priority further appraisal is not required and the level of risk does not normally support installation of a RRS. Simple low cost measures that could reduce the risk can still be considered.

Table 5.2 - Site Risk Categories

[6] ALARP – As low as is reasonably practicable - http://www.hse.gov.uk/risk/theory/alarp.htm

This Guidance principally aims to advise highway authorities on how to undertake the risk assessment in order to classify a particular site into one of these categories. Several assessment methods are available:

- Accident Assessment (A) – This approach is only suitable for existing roads where accident data is available. This method is not suitable for Road/Rail interfaces and new construction.
- Network Rail Methodology (B) – This approach is only suitable where there is a road/rail interface.
- Risk Scoring (C) – This method is available for use on new routes where no accident data is available, this is not suitable for road/rail interfaces.

Method A: Accident Assessment

As detailed risk data is not available for the type of routes covered by this Guidance the RRRAP approach is not directly compatible. Instead it is possible to use the national data discussed in Section 3.2 to guide the risk assessment process. The national average KSI accident rates for vehicles leaving the carriageway is given in Table 3.1 and the appropriate average value for each type of road may represent a suitable intervention level that could highlight where further investigation is required. Any site below this intervention level could be considered to be a ‘Lower Priority Risk and any with a rate above this could be in the ‘Medium’ or ‘Higher’ risk priorities. Reducing run-off road accidents is just one of the safety challenges for a local highway authority. Individual highway authorities may wish to adjust the intervention value to fit with other area safety scheme intervention levels.

Determining the upper bound of a Medium Priority Site category is difficult, considering the variety of possible existing circumstances. The point at which the level of risk cannot be accepted and can be classed as high priority is to be determined by the individual highway authority. Authorities may find it useful to look at the accident records of sites where a RRS has been provided previously to ensure consistency.

In some situations where the existing accident history does not indicate a significant likelihood of a future safety problem there may remain doubts surrounding the non-provision of a RRS particularly where the potential accident cost could be substantially higher than indicated by past accident histories alone e.g. in populous areas. In these situations method C (risk scoring) may further inform the risk categorisation.

Method B: Network Rail Methodology

Following the Selby (Great Heck) Rail disaster a significant amount of work was undertaken at the request of central government to look at the risk of vehicle incursion onto railways. This resulted in the development of a risk ranking tool that was used at the time to prioritise, in terms of risk of incursion, all approaches to road/rail interfaces. The risk estimation tool described in the DfT document ‘Managing the accidental obstruction of the railway by road vehicles’ remains the preferred method for assessing the risk in all situations where there is any interface between a road and a rail line.

The resultant scores from this assessment can be used to classify the risk at a particular location into the three risk categories used in this document:

- Score of 100 or more – Higher Priority Site
- Score of 70 or more – Medium Priority Site
- Score of less than 70 – Lower Priority Site

Method C: Risk Scoring

Method A (Accident Assessment) may not be suitable in a number of instances:

- On new roads.
- On improved roads: where the nature of the layout has changed sufficiently to make reference to historic accident data a poor indicator of future performance.
- Where accident data is not available.

In these circumstances it is only possible to estimate the risk; and, in Section 6, this Guidance provides an alternative method to the RRRAP. There are a number of possible methods for undertaking such an assessment of the risk. Highways authorities may wish to establish a procedure for estimating the risk and can adopt and/or amend the procedure described in Section 6.

5.2.2 Alternatives to RRSs

In many cases the provision of a RRS can be considered as a 'last resort', on the grounds of cost, engineering difficultly or the visual impact of provision. As such the highways authority may find it beneficial to consider whether other measures can be introduced that would assist in reducing the risk of vehicles leaving the carriageway or encountering a hazard when they leave the carriageway. Examples include:

- Complete removal of the roadside hazard.
- Relocation of the roadside hazard.
- Replacement with passively safe street furniture.
- Resurfacing or treatment of the carriageway to reduce the skid risk.
- Speed control measures.
- Re-alignment of the carriageway.
- Installation of chevron and warning signs, including vehicle activated signs.
- Installation of bollards.
- Installation of passive roadside features as a visual cue to a hazard e.g. deformable reflective posts.

It may be the case that the highway authority chooses to implement several of these measures at once as part of a local safety scheme or incrementally introduce measures over a period of time. The highway authority may wish to keep the situation under review to determine if the measures have been a success.

Highway authorities and their designers may find it useful to test the potential non-RRS options by re-running the initial risk evaluation. However it should be noted that more subtle interventions may not be recognised by the different evaluation tools. Previous experience of the effectiveness of non-RRS solutions is essential in understanding the change in risk.

The highway authority may wish to satisfy itself that the chosen measures result in a residual risk that is acceptably low and that the installation of a RRS is not required. As such the introduction of measures would more often than not result in a lower priority score.

5.3 RRS FEASIBILITY

A check can then be undertaken to ensure it is possible to provide a compliant barrier system. Guidance on the specification of RRSs is given in Section 9 and this should assist in determining if a RRS solution is suitable.

5.4 COST BENEFIT ANALYSIS

Where the above appraisal stages have indicated that it is advantageous to lower the risk level further using a RRS a simple Cost Benefit Analysis (CBA) will assist the highway authority in deciding if a RRS is economically justified. There are several ways this assessment could be undertaken and the highway authority can improve its accuracy by making use of the best available cost data.

Section 7 of this document provides advice on CBA for provision of RRSs. As part of the appraisal it may also be worth assessing competing non-RRS solutions, as these may have more wide ranging benefits and be cheaper to implement. In assessing non-RSS options it is worth remembering that some may only have an effective life of 5 years (e.g. carriageway marking) where a RRS may not require replacement for 20 years[7].

As with the previous stages of the appraisal, a positive result from the CBA on its own will not fully justify provision but will be helpful for designers in balancing the cost of provision against the accident cost savings.

5.4.1 Funding Priority

Where the appraisal criteria have been satisfied there is outline justification for a RRS to be provided. Highway authorities nationally have differing road safety strategies and will have different funding priorities. Although work may be justified at a particular site there may be limited funding available. There may be competition for funds within the road safety budget or across the entire authority and other schemes may offer a better return or present an immediate need.

There will be cases where a site or sites have come to light due to an accident or a series of reported near misses and the highway authority does not have funds available in-year. In these types of circumstances it is recommended that the scheme is built into a programme of works for future years. Consideration

[7] Designers should consider what type of system is likely to be provided to meet the specification. Some RRS types will require frequent maintenance and their design life may be shorter (e.g. approved timber system)

would normally be given to any necessary interim measures in these circumstances.

In cases where an improvement or development is being planned the decision to incorporate a full assessment of the risk into the design phase and ensure the cost of any RRS is built into the scheme estimate can help avoid problems once a scheme is operational.

Highway authorities may wish to adopt a consistent approach across their own network. Clearly each location assessed is likely to have its own unique risk factors. Nonetheless provision at one particular location may set a precedent at other very similar sites. Highway authorities may wish to further prioritise such sites to ensure there is a clear audit trail to support the selective installation of a RRS.

5.5 RECORD KEEPING

Regardless of the result of the appraisal the information collected to justify the decision would normally be recorded and retained in line with the authorities own document retention policy. This is especially important where a RRS is not being provided at a location that meets some but not all of the above criteria.

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6. Risk Scoring

For new or significantly amended layouts, highway authorities may wish to develop a system for evaluating the risk. An example of such a risk scoring methodology is outlined in this section and authorities can adopt this in its existing form or modify it to suit their needs. The scenarios where use of this risk scoring tool is envisaged are outlined in more detail in Section 5.2 (Method C). This would not normally be the primary assessment method where accident data can be used to estimate the risk or there is a road rail interface.

It is stressed that this process is provided as guidance only and discretion must rest with the highway authority and the designer in determining the need for risk reduction measures including RRSs. If personal injury accidents were easy to predict then a prescriptive set of standards could be produced. The purpose of this process is to assist in categorising the total risk at a site. Common with all forms of risk evaluation and assessment, professional judgement has been required in its development and will be required in subsequent application or adjustment. It is recommended the site is inspected prior to the carrying out the risk scoring. The most difficult assessments may come from sites with a large number of secondary factors where there is no high scoring location or alignment factor.

The scoring methodology used here assumes a primary roadside hazard has been identified. Where there are a number of hazards present within a length of 50m it is suggested that the one considered to have the highest severity outcome should be assessed. The risk scoring needs to be repeated at each location where a discrete hazard is considered to be present and it is recommended the results of the scoring process are recorded including any supporting information justifying the selection of each score.

6.1 HAZARD CATEGORY

This step is particularly useful where the decision to provide a RRS is not clear-cut and the risk to errant vehicles is hard to determine. There are a number of scenarios where the risk can be assumed to be sufficiently high to justify automatic progression to the next stage of the appraisal. These scenarios are where there is a realistic possibility of a vehicle leaving the carriageway and reaching one of the following features:

- Public Building
- Place of regular congregation (e.g. outside a school)
- Office block/Work Place
- Large block of flats
- Playground/Open Sports Area

6.2 LOCATION FACTOR

The level of risk present will vary based on the type of the route, the speed limit as well as the amount and make-up of traffic on the route. The location factor collectively considers all of these issues, acts as a proxy for the probability of a vehicle leaving the carriageway and results in a risk score that represents the nature of the road adjacent to the hazard in question. Where a road is atypical of road of that category in the area, the category that represents the worst case can be picked e.g. for an urban B Class road carrying volumes of traffic more normally associated with an urban A class road, the A class risk factor can be selected. The suggested ranking and risk scores, based on the contents of Table 3.1 is shown in Table 6.1

PRIORITY RANK	RISK FACTOR SCORE
0 - All other roads	0
1 - Rural U & B roads and urban C roads	1
2 - Rural A roads[8] and urban B roads	3
3 - Urban A Roads	6

Table 6.1 - Location Factor

6.2.1 Layout Factor

There are a number of layouts that could increase the risk of the vehicle hitting a road side object, the first considered as part of this risk scoring tool is bend radius.

Fully assessing risk at bends is not a simple matter. According to published accident information, the majority of run-off accidents are not reported at bends, although the vast majority of accidents are not subject to a detailed scientific assessment of the features that make up road alignment. In fully assessing the risk at bends, it is necessary to consider the approach speeds, the bend radius, the superelevation, the influence of transition curves as well as the surface characteristics. An additional consideration is whether a series of more generous bends precedes a tighter bend resulting in over-confidence of the road user.

Table 3 of TD9/93 is relevant for road horizontal radii. Herrstedt and Greibe (2001) plotted the relative risk of highway curves in relation to approach speed and safe speed required to negotiate the bend. This work recognised that the risk increases as the curve design speed drops below the approach speed (85% percentile). Where the design speed of the curve in question is known it is possible to determine whether this complies with TD9 using Table 3 of the standard. The suggested approach of this Guidance (see Table 6.2) is to take each step below desirable minimum for all radii and/or super elevation combinations in this table as a 1 point increase in risk. Where the design speed of the curve is not known it is possible to determine the value; a methodology for calculating the design speed is given in Annex B.

The provision of warning signs or chevrons (passively safe) may be appropriate where the layout factor (part one) is greater than zero. Provision of such signs would normally be considered before a decision is taken to install a RRS in front of a hazardous feature, using the advice in the Traffic Signs Manual.

[8] Excluding A(M)roads

PRIORITY RANK	RISK FACTOR SCORE
0 - Straight alignment and/or complies with TD9	0
1 - One step below desirable minimum R with superelevation of 5%	1
2 - Two steps below desirable minimum R with superelevation of 5%	2
3 - Three steps below desirable minimum R with superelevation of 5%	3
4 - Four steps below desirable minimum R with superelevation of 5%	4
5 - Five steps below desirable minimum R with superelevation of 5%	5

Table 6.2 - Layout Factor (Part One)

The second factor (see Table 6.3) to consider is the complexity of the carriageway layout at the location of the hazard. There may be an increased risk of a vehicle leaving the carriageway:

- In the vicinity of merge and diverge points.
- On overtaking sections of rural roads.
- At priority T-Junctions, particularly where the sideways visibility is poor or where a junction's form is hidden by the carriageway alignment or a see-through problem exists.
- At locations where space is constrained and reversing/positioning manoeuvres take place.
- At traffic signals where the approaching driver may not be aware of a queue of stationary traffic.
- Near roundabout exits and on central islands.

Scoring the degree of risk at a junction requires judgement. Whilst it is not always the case that layouts not in accordance with standards are more prone to accidents it may be useful to consider the degree of compliance with standards when judging the magnitude of this component score.

PRIORITY RANK	RISK FACTOR SCORE
0 - No reason for lane changing/manoeuvres.	0
1 - Some potential for lane changing, overtaking, positioning manoeuvres or avoiding action.	2
2 - High likelihood of lane changing, overtaking, positioning manoeuvres or avoiding action.	3

Table 6.3 - Layout Factor (Part Two)

It is recommended that the maximum of the two Layout Factor scores selected for this factor is taken forward as the total layout factor risk score.

6.3 COLLISION FACTORS

6.3.1 Longitudinal Features

A spot hazard such as a traffic sign post or lighting column provides less of an obstruction than a longitudinal hazard such as a retaining wall or parallel canal. Where there are a number of hazards grouped together, such as a copse of trees or a number of signs in a nosing a decision would need to be made as to whether this should be treated as a group of spot hazards or one continuous hazard. This factor (see Table 6.4) also recognises the increased risk posed by a hazard that is placed so that a longitudinal feature, such as a wall, could divert vehicles leaving the carriageway towards the hazard.

PRIORITY RANK	RISK FACTOR SCORE
0 – Individual spot hazard	0
1 – Series of individual hazards less than 50m apart or a longitudinal hazard that might be reached.	1
2 – Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2

Table 6.4 - Collision Factor (Part One)

6.3.2 Severity of outcomes

Any vehicle impact with a roadside hazard is likely to result in some form of injury. However the severity of the possible impact can be considered and the national percentage of KSI data summarised in Table 3.2 can be used to determine the correct value. Exposed parapet ends should be considered to have the same severity percentage as ‘other permanent object’.

Where there are multiple hazards present it is suggested that the severity value associated with the most aggressive hazard is used. Values are given in Table 6.5.

PRIORITY RANK	RISK FACTOR SCORE
0 - Percentage of KSI for primary hazard < 20%	0
1 - Percentage of KSI for primary hazard 20 -30%	1
2 - Percentage of KSI for primary hazard >30%	2

Table 6.5 - Collision Factor (Part Two)

6.4 CONSEQUENTIAL FACTORS

6.4.1 Secondary Incidents

In some cases an initial collision may result in a secondary event that creates a hazard for other road users and increases the risk of a secondary incident. This may be because of a collapse of the primary hazard when struck and may be particularly relevant for example for a pylon carrying power lines, telegraph poles or street lighting columns that may collapse onto the main carriageway or an adjacent route. The consequences of the item collapsing onto a footpath or footway can be ignored in most cases unless it is likely a pedestrian would be present for the majority of the time.

Where the collapse may result in a major secondary incident off carriageway this would normally be considered as constituting a higher priority site automatically. Values are given in Table 6.6.

PRIORITY RANK	RISK FACTOR SCORE
0 - No secondary events likely.	0
1 - When damaged or collapsed the feature could give rise to the risk of secondary vehicular accidents.	1

Table 6.6 - Consequential Factor (Part One)

6.4.2 Network Disruption

The potential for a collision with a roadside hazard to result in some form of network disruption would commonly be considered. The disruption could be caused by the carriageway being blocked by the collapse of the impacted feature, or in some cases damage to highway infrastructure may result in lane and/or speed restrictions of more than one day. As such scoring of this factor would consider the possible disruption that may be caused by the removal and replacement of the damaged feature.

The disruption experienced as a result of the collision may impact another highway authority's route or a private access. This may be of particular relevance where the collapse may temporarily block the only access to a particular destination or result in the diversion of large number of vehicles from their established route. Values are given in Table 6.7.

PRIORITY RANK	RISK FACTOR SCORE
0 - No impact on network availability.	0
1 - If hazardous feature was damaged or collapsed this could give rise to network disruption for more than one day.	1

Table 6.7 - Consequential Factor (Part Two)

6.4.3 Cost of damage

The resultant cost of repair or replacement of the infrastructure at risk of impact may also be accounted for. The highway authority will need to make a judgement on the cost implications dependant on their own circumstances. Where the costs of repair or replacement are high this is likely to be a factor in any subsequent cost benefit analysis. Values are given in Table 6.8.

PRIORITY RANK	RISK FACTOR SCORE
0 - No significant cost implications.	0
1 - Significant cost of repair or replacement following collision.	1

Table 6.8 - Consequential Factor (Part Three)

6.5 RISK RANKING SCORE

The total Risk Ranking score is based on the addition of 4 different Factors (F) and can be used to evaluate the risk at a particular location:

$F_{LOCATION}$(Range 0-6) +
F_{LAYOUT} (Largest of two scores, Range 0-5 or 0-3) +
$F_{COLLISION}$ (Sum of two separate scores, Range 0-4) +
$F_{CONSEQUENTIAL}$ (Sum of three separate scores, Range 0-3).

This Risk Ranking score will help prioritise the need for intervention at a particular location. Recommended upper and lower bounds for the three risk classifications are given below:

TOTAL RISK RANKING SCORE	CATEGORY	OUTCOME
14 or more	Higher Priority	(see Table 5.2)
9-13	Medium Priority	
0-8	Lower Priority	

Table 6.9 - Resultant Risk Categories

Annex A includes a series of examples of situations where RRSs may be warranted; several of these examples have been categorised into the above categories using this risk ranking methodology.

7. Cost Benefit Analysis

Cost Benefit Analysis (CBA) expresses costs and benefits in a common currency, usually money, so that a comparison can be made between different options. It is a defined methodology for valuing costs and benefits that enable broad comparisons to be made between different risk reduction options on a consistent basis, giving a measure of transparency to the decision making process.

For the purpose of this Guidance the Benefit/Cost ratio (B/C) is defined as follows:

B/C = [Monetary value of Net Benefit (i.e. reduction in accidents)] / [Cost of Provision, maintenance and mitigation measures].

7.1 OPTION SELECTION

When determining an appropriate option, the Benefit/Cost ratio is a useful tool for assessing relative options for the provision of different RRSs, or other solutions, but is only one part of the assessment process.

The Designer can estimate the cost of provision of each option (C1, C2, C3, etc). This cost will be the total estimated cost of providing the option, including, for instance, the cost of measures to relocate a hazard, and then economically discounted (using standard principles) over an assumed life for the measure. The Net Benefit (for accidents) is defined as the reduced cost of accidents as a result of the proposed option.

7.2 COST ESTIMATES

Accident and casualty valuations are published annually in "Reported Road Casualties Great Britain" on the Department for Transport's website[9]. When comparing competing options at a single site it would be appropriate to consider true severity valuations rather than average valuations. When reporting the economic investment case of the chosen option it may be more appropriate and conservative to use average severity valuations, particularly when comparing against other projects elsewhere, unless there is strong evidence for the use of higher actual valuations e.g. consistently high severity injuries at the site or similar sites.

In estimating the cost of a RRS highway authorities have a number of options available to them. At the CBA stage it is unlikely that the design is sufficiently developed to quantify the actual lengths of the different products that will be used to meet the specification. If a design is developed to the necessary level of detail, the authority may have quotes from the system manufacturer/provider, actual costs from previous RRS work or from information resources such as SPONS.

Where the system has been specified and only the performance class is known the RRRAP uses assumed values for N2, H1 and H4 safety barrier and parapet. Typical indicative values range from £55 per metre for N1/N2 barrier to £370 per metre for H4a barrier (2011 prices).

[9] http://www.dft.gov.uk/pgr/statistics/datatablespublications/accidents/casualtiesgbar/

7.3 ACCIDENT FREQUENCY

When assessing the cost benefit of a proposed RRS normally only run-off road accidents would be considered in the assessment. When assessing non-RRS options the chosen treatment is likely to have an impact on other forms of accident as well and these may also be considered.

Where the situation is new and accident histories are not available an estimate will need to be made using professional judgement supplemented by data from similar situations elsewhere if possible.

8. Parapets

An alternative approach is required for parapets as TD 19 establishes minimum levels of provision which is not based primarily on detailed risk assessment. Additional advice on the method of assessment for existing parapets was also introduced by IAN 97/07. Both these documents if applied by highway authorities recommend considering increasing the level of protection above “minimum” where the risk is shown to be sufficiently high e.g. if shown by the RRRAP.

IAN 97/07 can be used to determine[10] when a parapet on an existing structure may need to be upgraded. Where the need for upgrading is demonstrated, the levels of containment in the lower half of Table 8.1 apply.

SCENARIO		Recommended Containment Class – Speed Limit (mph) < 50mph	Recommended Containment Class – Speed Limit (mph) =>50mph	FURTHER ADVICE
New Structure	On a new bridge or structure (including accommodation bridge) that is carrying a road, that is not over or adjacent to a railway.	N1 Minimum	N2 Minimum	Containment above these minima may be considered where supported by the RRRAP.
New Structure	On new bridges and structures (but not accommodation bridges) carrying a road over, or adjacent to, a railway.	H4a		The containment class can be reduced below the recommended Containment Class where the cost of provision is unreasonable.
New Structure	For accommodation bridges carrying a road over, or adjacent to, a railway.	N2		Containment above the N2 level may be considered if supported by risk assessment.
Upgrade of Existing Structure (where an upgrade is justified by the assessment in IAN 97)	On an existing bridge or structure carrying a road over, or adjacent to, a railway.	N2		The decision to upgrade to a containment class above the N2 level can be made by undertaking the assessment described in IAN 97/07.
Upgrade of Existing Structure (where an upgrade is justified by the assessment in IAN 97)	On an existing bridge or structure (including accommodation bridge) that is carrying a road that is not over or adjacent to, a railway	N1 Minimum	N2 Minimum	Where traffic flows on either road is less than 25,000 AADT the assessment in IAN 97/07 can be used to determine the required Containment Class. Where both roads carry over 25,000 AADT (two-way) containment above the minima may still be considered if supported by the RRRAP.

Table 8.1 – Recommended containment class for parapets[11]

[10] For the avoidance of doubt, this UK RLG Guidance document does not create a new requirement to assess existing parapets

This Guidance acknowledges that RRRAP is the primary assessment tool for structures with no rail interface but also recognises that in the vast majority of cases the formal use of the RRRAP may not be needed to quantify risk, further advice is given below. IAN 97/07 is the principal tool where an existing structure has a rail interface.

8.1 JUSTIFYING A CONTAINMENT CLASS ABOVE THE MINIMIMUM LEVELS ON NEW STRUCTURES (STRUCTURES WITH NO RAIL INTERFACE)

The determining factor in providing a containment class higher than that given in Table 8.1 is the number of HGVs using the route and as such being exposed to the risk. The additional cost of higher containment may be justified when a significant proportion of the vehicles on the route would not be contained by a N1/N2 parapet. As N1/N2 provision is tested to contain a car, this would prevent incursion by most vehicles on a typical local highway authority route. As the number of HGVs on a route increases, a higher containment parapet becomes more justifiable in terms of the benefit it would provide for the additional cost.

TD 19 requires designers use the RRRAP to determine where the risk justifies the higher level of containment. Even using this method on a 60mph road with 5000 AADT there needs to be very good justification and a high risk to warrant even H1 containment. Considering low flow and low speed situations it is highly unlikely there is justification for the higher level of containment where there is a low number of HGVs (less than 20%[12]).

Where a highway authority route has (or is forecast to have) a HGV content of over 20%, it is recommended that RRRAP is used to test the need for a higher level of parapet containment. In order to do this the assumed speed will need to be set to the higher of 50mph or the route speed limit and the traffic flow set to the higher of 5000 AADT and the actual traffic flow on the route. It should be noted that in this situation the RRRAP will give conservative outputs.

In some circumstances there may be uncertainty that the lower containment class will be sufficient, e.g. at a site with slightly less than the 20% level of HGVs but with numerous other factors that may result in a higher risk of breach of the parapet. These sites can be initially assessed using the risk scoring technique described in Section 6 and further assessed using the RRRAP if necessary.

It should be noted that the additional cost of installing a higher containment or very high containment parapet on a new structure is minimal when compared to upgrading an existing structure to accommodate these parapets.

8.2 UPGRADING EXISTING PARAPETS (STRUCTURES WITH NO RAIL INTERFACE)

IAN 97/07 can be used to determine when the upgrade of an existing parapet is justified and in some situations the required containment class. In certain situations IAN 97/07 recommends designers use the RRRAP to determine what level of containment to provide. For the same reasons as Section 8.1

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[11] Different arrangements exist in Northern Ireland; see TD 19 Clauses 4.6 & 4.7.

[12] This conservative figure has been derived by inputting common factors into the RRRAP.

above the likelihood of a higher containment being justified is unlikely where there is less than 20% HGVs. It is recommended that designers initially aim to provide the minimum containment level and test the need for a higher level of containment using the RRRAP where there is a high HGV percentage.

Where an upgrade is justified and higher containment is required by the RRRAP, but the structure is not capable of supporting such a parapet the requirements of TD 19 clause 4.9 apply. Any proposal to provide a containment class less than the minimum level in Table 8.1 or that does not satisfy the RRRAP or IAN 97/07 requirements would normally be recorded and the highway authority may wish for it to be supported by a departure from standards (see Section 9.7).

8.3 PARAPET CONNECTIONS

When installing a new parapet or upgrading an existing parapet it is important that the connections to adjacent safety barriers are designed appropriately. Both strength and alignment can be considered using the advice of TD 19.

8.4 AESTHETICS OF PARAPETS

Many older structures will have a brick or stone parapets that serve an aesthetic purpose as well as providing containment. Where the need for upgrade has been determined using IAN 97/07 the use of a modern metal parapet may be inappropriate for such older structures. In such cases the advice given in Section 9.10.1 applies.

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9. Specifying systems

The nature of the routes where this Guidance will be applied will vary greatly. In many circumstances it may not be possible to provide a RRS that is fully compliant with the requirements of TD 19 and the product manufacturer's advice. In order to determine if a RRS can provide the solution at a specific site an initial exercise must be undertaken to determine whether it is possible to install a compliant system utilising the guidance in TD 19.

Guidance on the specification of the whole family of RRSs is given in Chapters 3, 5, 6, 7 and 10 of TD 19 and this is assumed to apply for the routes applicable to this Guidance. Designers are advised to consult this advice when considering if a RRS is feasible. Where this document refers to the results of the RRRAP designers should refer instead to the results of the relevant risk assessment outlined in 5.2.1 above.

The key information related to each type of RRS within TD 19 is repeated below along with a number of instances where the requirements can be relaxed. This text is highlighted to assist in the look-up of values. Details of the testing criteria for the following characteristics are given in BS EN1317-2:1998 and further advice on specification is given in Section 9.

9.1 SAFETY BARRIER

9.1.1 Containment Class

The default containment class levels recommended are:

On road with a speed limit of less than 50mph:	On Roads with a speed limit of 50mph or more:
• Normal Containment = N1	• Normal Containment = N2 • Higher Containment = H1 or H2 • Very High Containment = H4a

Where one of the following high risk hazards is present on a route with a speed limit of 50mph or greater containment higher than N2 would normally be specified:

- A road alongside a railway.
- A road crossing a dam.
- High Mast lighting columns within 10m of the carriageway.
- A major hazard that would result in a secondary incident.

9.1.2 Impact Severity Levels

The Impact Severity Level (ISL) for a barrier would not normally exceed Class B (see BS EN 1317-2). Impact severity is classified into three categories, A, B and C, with each category above A offering a reduction in vehicle occupant safety. Where the site is considered a high risk and the containment of an errant vehicle (such as a HGV) is the overriding concern, or where space is limited the ISL for a barrier can be greater than Class B.

Where the ISL level is greater than Class B the requirements of Clause 3.7 of TD 19 apply.

9.1.3 Working Width

In order for a RRS to be suitable for use at a particular location there must be sufficient space within the cross section to accommodate the system safely.

The definition of Working Width is

Working width = width of the restraint systems + its maximum dynamic lateral deflection + vehicle intrusion beyond the restraint system.

The levels of working width are contained within BS EN 1317-2:1998 and are repeated in Table 9.1 below

CLASSES OF WORKING WIDTH LEVELS	LEVELS OF WORKING WIDTH (M)
W1	W<=0.6
W2	W<=0.8
W3	W<=1.0
W4	W<=1.3
W5	W<=1.7
W6	W<=2.1
W7	W<=2.5
W8	W<=3.5

Table 9.1 - Levels of working width from BS EN 1317-2:1998

The dynamic deflection and the working width allow determination of the conditions for the installation of each safety barrier and also to define the distances to be provided in front of obstacles to permit the system to perform satisfactorily. The RRS location would preferably be such that the hazard being protected and any other obstructions along the barrier system length are not located within the working width. Whilst it is preferable that NMU routes are located completely beyond the working width of the system in practice this will not always be possible. This does not prevent provision of a RRS and would not significantly detract from the potential risk reduction provided by the barrier system unless the public are expected to gather regularly at this point. (see Table 5.1)

Road furniture and equipment must not be positioned in front (within the set - back) of a new or existing RRS and, in general, it would not normally be placed immediately in advance nor within the available Working Width of a new or existing RRS (as it can affect the way the RRS performs) unless the road furniture or equipment has been designed to be passively safe and, if hit, will not be displaced into the adjacent carriageway or give risk to a secondary event.

9.1.4 Set-back

The set-back is the lateral distance between the traffic face of a safety barrier and as appropriate:

i. Nearside: the back of the nearside hardstrip or hardshoulder
ii. Nearside: the kerb face for roads without a nearside hardstrip or hardshoulder
iii. Offside: the trafficked edge of the edge line or the kerb face where there is no edge line

When providing a RRS the suggested minimum set-back is 1000mm in rural areas with a relaxation to an absolute minimum set-back of 330mm in urban areas and a relaxation to 600m in rural areas. Where the set-back to be provided will be lower than 600mm the designer should carefully consider the possibility of side to side impacts and head-on impacts involving vehicles shying from the barrier especially if the existing lane width is 3.5m or below. Reduced setback may also have an impact on cyclists, pedestrians, maintenance activities and those attempting to open the door of their vehicles when stopped adjacent to the barrier.

9.1.5 Minimum lengths

In order for the RRS to perform in the specified way a minimum length of barrier must be provided, this length is dependent on the containment class:

SAFETY BARRIER CONTAINMENT LEVEL	MINIMUM "FULL HEIGHT" LENGTHS OF SAFETY BARRIER[13]	
	In advance of hazard	Beyond hazard
Normal (N1 or N2)	30m	7.5m
Higher (H1 or H2)	30m	10.5m
Very High (H4a)	45m	18m

Table 9.2 – Minimum lengths of barrier from TD 19

In some instances it may not be possible to provide these minimum lengths due to the presence of a side road, right of way, private driveway or emergency access. Although this may make the provision of a fully compliant RRS impractical the designer may wish to consider the probability of an errant vehicle reaching the hazard should these features be accommodated by a break in the barrier. Options for revising the road layout to accommodate both the access and the barrier would normally also be considered.

9.2 TERMINALS

The RRS layout must be carefully planned to minimise the number of approach ends to barriers, as the ends themselves are a hazard. There may be case for closing the gap between two adjacent sections of safety barrier if they are within 50m of one another.

In summary the minimum performance class requirements for terminals are:

On road with a speed limit of less than 50mph:

- P1 or greater.

On Roads with a speed limit of 50mph or more:

a) For terminals facing oncoming traffic[14] - P4. Ramped terminals must not be used.
b) For terminals not facing oncoming traffic – P1.

[13] It should be noted that some manufacturers may require longer lengths than those specified above.
[14] This includes both ends of an RRS on a two way single carriageway road.

The criteria and guidance for the provision of terminals is contained within Chapter 5 of TD 19.

9.3 TRANSITIONS

A transition is provided between all changes of type or performance class of RRSs to provide a gradual change in provision and remove the hazard an abrupt change in strength would introduce. The junction between two safety barriers having the same type, cross section and material and differing no more than one class of Working Width, is not considered a transition. The requirements of TD 19 Chapter 6 apply in full.

9.4 CRASH CUSHIONS

Crash cushions are generally provided to prevent a head-on impact with an isolated object, which cannot be protected in another way (e.g. with safety barrier). In general their use on low speed roads (less then 50mph) will be rare. The requirements of TD 19 Chapter 7 apply in full.

9.5 ARRESTER BEDS

Vehicle arrester beds are a form of vehicle restraint and their use is limited to specific circumstances, where it is necessary to decelerate a vehicle along long, steep descending gradients without causing significant damage to the vehicle, its occupants, other road users and adjacent buildings or property Although their use on low speed low flow roads is likely to be rare the requirements of TD 19 Chapter 10 apply in full.

9.6 VISIBILITY

Consideration may be given to the impact of any proposed system in respect of visibility, sightlines over and in front of safety barriers. In some cases the presence of a RRS may exacerbate an existing visibility problem and as a result increase the risk of shunt type accidents. When specifying a system any assumptions made on the maximum height allowable to maintain acceptable visibility can be built in to the specification so as that the contractor does not inadvertently provide a system that creates a visibility problem.

9.7 DEPARTURES AND RELAXATIONS

This appraisal process, or a highway authority’s adaption of it, will create a record of the decision making process and provide evidence for any future challenges to the appraisal outcome. The only situation where it may be necessary to record a departure is when the proposed RRS layout does not comply with:

- A mandatory requirement of TD 19 (unless superseded by the adoption of this Guidance),
- The design requirements of this Guidance,
- A system manufacturer requirement

It is recommended that each such situation is assessed by the designer and agreed by the highway authority taking into account the local circumstances; further guidance on departures has been produced by the UKRLG[15].

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[15] Departures for Local Highway Authorities – Published: TBC

9.8 DRAFTING OF SPECIFICATION

The RRS may be specified using the Highways Agency's Specification for Highway Works (SHW) and in particular a schedule created using Appendix 4/1 given in the Notes for Guidance for SHW. In general designers are required to specify the length of need for a RRS, the working width class (W1 to W8), the necessary containment performance class (N1, N2, H1, H4a and H4b) and the impact severity level. The displacement classes would normally be specified for terminals and crash cushions. A more detailed list of requirements is included in clauses 1.30 - 1.35 of the SHW. The designer or highway authority must not specify a system by name or manufacturer.

The designer must ensure that a system exists that meets the proposed specification. The Highways Agency maintains a list of approved road restraint products that have been tested and subsequently accepted for use on the trunk road network. This list is updated regularly and can be found on their website[16].

The testing criteria for RRSs are described in BS-EN 1317 Parts 1-4. In order for a system to be approved for use in the UK it must meet the requirements of these standards. Manufacturers are continually submitting new products for testing and approval. Some of these systems may not reach the Highways Agency's approved product list as they are deemed unsuitable for use on the Trunk Road network. This should not prevent their use by other highway authorities in the right circumstances. Highway authorities may wish to satisfy themselves that the system promoted for use by the manufacturer has passed the relevant BS-EN 1317 tests and mitigates the risk as envisaged by the risk assessment.

The highway authority would normally procure a competent contractor with staff with suitable training and experience to undertake the installation of any RRS, selection of a contractor in accordance with Sector Scheme 2B and 5B (see Appendix A of Manual of Contracts for Highway Works) would be one way of achieving this.

9.9 POWERED TWO WHEELERS

When specifying systems the designer should consider the number of motorcyclists using the route and the suitability of the system which will be provided. TD19 provides advice on this issue in section 3.41 & 3.42.

Further advice is given in the IHE Guidelines for Motorcycling (http://www.motorcycleguidelines.org.uk/home.htm).

9.10 ENVIRONMENTAL FACTORS

When considering the need for a RRS or specifying the type required there are a number of other environmental factors that need to be considered. The expected weather conditions e.g. snow drifting and the potential for build up or the installation of a RRS in a marine or coastal environment where products may be exposed to higher levels of corrosion.

Although the choice of product is a contractor decision the designer should ensure that his specification does not result in an inappropriate form of system

[16] http://www.standardsforhighways.co.uk/tech_info/en_1317_compliance.htm

being installed. For example where snow is regularly expected, the specifier, in addition to defining the required working width and containment level, should also specify that the profile of the system must not allow the build up of snow against it.

9.10.1 Aesthetics

In certain circumstances the decision to provide RRSs may be prejudiced by the potential visual impact. Reducing this impact by careful designer specification, especially in areas of outstanding natural beauty, may make provision of a system possible.

There is a variety of systems available that could help provide a solution that both meets the aesthetic demands of a site as well as the performance specification. Wooden clad N2 barrier compliant with BS EN 1317 is available with various working widths and could be particularly useful in rural situations. (Figure 9.1[17]) Several authorities have installed steel safety barrier and specified a protective system to minimise its visual impact, predominately in rural areas. (Figure 9.2) Where this is proposed the designer would need to discuss the appropriate type of coating to be used with the contractor and proposed product supplier. It may be necessary to include specific requirements to ensure that the RRS provided is suitable for such treatment.

Figure 9.1 – BS EN1317 wooden crash barrier

It should be remembered that any surface treatment of the barrier may need to be repeated at regular intervals which will incur costs over the design life of the product. Conversely a lack of maintenance could potentially result in a barrier becoming an eyesore. It is a legal requirement for future maintenance, including safe access for inspection and any tensioning, to be considered at the specification and system design stages.

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[17] Figures 9.1 & 9.2 reproduced courtesy of Norfolk County Council.

Figure 9.2 – Innovative crash barrier coloured to minimise visual impact

Designers have the ability to specify any special requirements, via Appendix 4/1 of the works specification, for the required RRS. In specifying a specific material for the barrier the designer must ensure that a compliant system is actually available. Generally options would be left open unless the designer has recorded a strong argument to specify a particular appearance of barrier.

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10. Options not covered by TD 19

The family of RRSs described in Section 5.3 are all compliant with a relevant part of BS EN 1317. In some circumstances it may be beneficial to provide a non-compliant rigid system to prevent a vehicle reaching a certain point, hazard or asset. Such systems could be parking bollards or security barriers and these are not tested and certified to BS EN 1317. Generally these systems are not designed to guarantee the safety of the vehicle occupant, but when used in the appropriate locations can be a low risk/low cost alternative to RRSs.

10.1 BOLLARDS

The usual function of bollards is to assist with the prohibition of parking or stopping up a highway.

When used to prohibit parking the spacing adopted would normally be based on preventing the length of parallel parked vehicle (a spacing of 3-3.5m is suggested) as it would be unusual for a vehicle to drive up a kerb at right angles. The spacing may need to be reduced to 1.5m where there are wide footways or attractors such as shops and right angle parking may be attempted. Initial adoption of a 3m spacing would allow the gaps to be in-filled at a later date if the original spacing was proved to be in-effective.

Bollards can be used where vehicles are persistently obstructing footways or dropped kerbs. In these situations the placement of bollards would need to be carefully considered so that they do not cause problems for the visually impaired. The minimum footway/cycleway width would normally be considered when installing bollards because bollards can be a hindrance to free non-motorised user movements. It is particularly noted that whilst parked cars on footways or verges maybe a fluctuating problem, the use of bollards provides a permanent hindrance to Non-motorised User (NMU) longitudinal movements.

10.1.1 Bollards used as an alternative to vehicle restraint

In low speed environments, where vehicles are only expected to be manoeuvring (or travelling at equivalent speeds) bollards may only present a minor hazard with a collision resulting in minor or no injuries. They can be used as low cost measure to prevent a vehicle reaching a more dangerous hazard, which could result in serious or fatal injuries. As BS EN 1317-2 compliant systems are relatively expensive and only tested at very shallow angles, bollards can prove to be a more practical solution for dealing with low speed rear or frontal impacts. See BS 6180:1999 and Section 10.1.2 below for further details.

Where bollards are used as a primary vehicle restraint (e.g. on very low speed roads with off-carriageway hazards such as water or steep embankments) the spacing of centres can be set as 1.5m to allow the bollards to act as designed to prevent car incursion.

Where other substantial street furniture is present such as lighting columns, costs may be reduced by omitting a bollard where the other street furniture performs a similar role to the bollard as well as its primary role. The overall spacing of repeating furniture such as lighting columns and bollards may be considered together to achieve similar 'modular' co-existent spacing's to minimise overall costs.

10.1.2 Bollard Design

Bollards can cause substantial damage to vehicles and can be costly to maintain if frequent inadvertent impacts occur. Designers may wish to consider models that incorporate reflective strips near the top to reduce these risks. Additionally vehicle swept paths near junctions, accesses and delivery points can be measured to further reduce the likelihood of inadvertent damage. Isolated single bollards may not be conspicuous and their use would normally be avoided. The surrounding area would usually be taken into consideration to ensure the type of bollard is sympathetic. Where a local authority has streetscape guidance, this should be consulted.

Bollards capable of stopping or diverting a moving vehicle up to 2500kg at 10mph are described by BS 6180:1999. This standard is ideal where accidental impact is foreseeable. Where a security concern has been identified and this may result in deliberate vehicular incursion refer to Section 10.2.

The Health and Safety executive (HSE) have produced a leaflet "Workplace transport site safety information sheet WPT08" for bollards. Traffic Advisory Leaflets 4/97 and 4/93 respectively describe the design of rising bollards and discuss issuing surrounding pavement parking.

10.2 VEHICLE SECURITY BARRIERS

The British Standards Institution (BSI) has produced Publicly Available Specifications (PASs):

- PAS 68:2010 "Impact test specifications for vehicle security barriers"
- PAS 69:2006 "Guidelines for the specification and installation of vehicle security barriers"

Many systems are available that are either promoted or considered suitable for use as vehicle security barriers. As their characteristics differ in both function and form, a comparative means of assessing their performance is required. PAS 68 has been prepared to address the needs of organisations who want assurance that vehicle security barriers will provide the level of impact resistance they are aiming for. PAS 68 identifies impact test methods, tolerances, test vehicle type and vehicle performance criteria that need to be met in order to conform to PAS 68. The document cites a classification system for the performance of vehicle security barriers and their supporting foundations when subjected to a single horizontal impact.

PAS 69 provides guidance on the selection, installation and use of vehicle security barriers to ensure that they are selected and placed as effectively as possible. PAS 69 highlights the issues to be addressed when considering the use of traffic calming and vehicle restraint systems as part of an overall security regime.

Whilst the design and intention of normal RRSs is normally obvious the merits of retaining accurate and secure records for vehicle security barriers are heightened, particularly if future designers are considering barrier changes or highway layout changes. Decisions would normally be recorded and records retained for audit purposes and periodic review.

Vehicle security barriers are normally part of an integrated security solution which may include, adjacent perimeter protection, CCTV, alarm monitoring and guard force activity.

Vehicle security barriers by their nature may prove a hazard to the law abiding public and public vehicles. These risks can be considered in an assessment by a road safety engineer or road safety auditor. In some situations a traditional RRS may be warranted in front of the vehicle security barrier, although the possibility of the vehicular security barrier being bypassed by use of deliberate over-riding of any ramped ends would need consideration.

Traffic Advisory Leaflet 1/11 “Vehicle Security Barriers within the Streetscape” provides more details.

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11. Sources of Information

11.1 CORE INFORMATION

The following table lists the principal sources of information relevant to the design of RRSs, along with their online location.

TITLE	REFERENCE	AUTHOR	REVISION /DATE	LOCATION
Road Restraints Risk Assessment Process (RRRAP)	-	HA	Regularly updated	http://www.dft.gov.uk/ha/standards/tech_info/rrrap.htm
Requirements for Road Restraint Systems	TD 19/06	HA	2006	http://www.dft.gov.uk/ha/standards/tech_info/index.htm
Cross-Sections and Headrooms	TD 27/05	HA	2005	
Highway Link Design	TD 9/93	HA	1993	
Interim Advice Note – Assessment and upgrading of existing vehicle parapets.	IAN 97/07	HA	2007	
Specification for Highway Works – Road Restraint Systems (Vehicle and Pedestrian)	Series 0400	HA	Nov 2007	
HA Accepted EN1317 Compliant Road Restraint Systems List (updated regularly)	-	HA	-	http://www.standardsforhighways.co.uk/tech_info/en_1317_compliance.htm
Parts 1 -8 Road Restraint Systems	BS EN 1317	BSi	-	https://bsol.bsigroup.com/
Passive safety of support structures for road equipment (including UK National Annex)	BS EN 12767	BSi	2007	
Barriers in and about buildings. Code of Practice	BS 6180	BSi	1999	https://bsol.bsigroup.com/
Impact test specifications for vehicle security barriers	PAS 68:2010	BSi	2010	https://bsol.bsigroup.com/
Guidelines for the specification and installation of vehicle security barriers.	PAS 29:2006	BSi	2006	https://bsol.bsigroup.com/

Passive Safety UK Guidelines for Specification and Use of Passively Safe Street Furniture on the UK Road Network.	-	Passive Safety UK	2010	http://www.ukroads.org/passivesafety/
Departures from Standard: Procedures for Local Highway Authorities	-	UKRLG	2011	http://www.ukroadsliaisongroup.org/index.htm
Highway Risk and liability claims: A Practical Guide to Appendix C of The Roads Board report "Well Maintained Highways – Code of Practice for Highway Maintenance Management"	2nd Edition	UKRLG	July 2009	http://www.ukroadsliaisongroup.org/liaison/practice.htm
Managing the accidental obstruction of the railway by road vehicles.	-	DfT	Feb 2003	http://www2.dft.gov.uk/pgr/roads/network/policy/obstructionrailways/index.html
Guidelines for Motorcycling	Version 1.1	IHE	Nov 2007	http://www.motorcycleguidelines.org.uk/home.htm
Vehicle Security Barriers within the Streetscape	TAL 1/11	DfT	Mar 2011	http://www.dft.gov.uk/publications/tal

Table 11.1 - Core Reference Documents

11.2 OTHER INFORMATION SOURCES

As well as the documents detailed in Table 11.1 there are a number of other sources of relevant information.

SOURCE	OWNER	LOCATION
Local Transport Note 2/09 – Pedestrian Guardrailing	DfT	http://www2.dft.gov.uk/pgr/roads/tpm/ltnotes/ltn209pedestrian.pdf
Transport Advice Portal – VRS	IHT	http://www.tap.iht.org/en/topic/safety/vehicle-restraint-systems/
Reported Road Casualties (updated annually)	DfT	http://www.dft.gov.uk/pgr/statistics/datatablespublications/accidents/casualtiesgbar/rrcgb2009
ALARP – Suite of Guidance	HSE	http://www.hse.gov.uk/risk/theory/alarp.htm

Sector Training Schemes – Appendix A of Specification for Highway Works.	HA	http://www.dft.gov.uk/ha/standards/mchw/vol1/pdfs/appendix_a.pdf
Workplace transport site safety information sheet WPT08.	HSE	http://www.hse.gov.uk/pubns/wpt08.pdf
Traffic Advisory Leaflet 4/97	DfT	http://www.dft.gov.uk/publications/tal
Traffic Advisory Leaflet 4/93	DfT	http://www.dft.gov.uk/publications/tal
The travel of Errant vehicles after leaving the carriageway.	HA	http://www.standardsforhighways.co.uk/tech_info/errant_vehicle.htm
Sign Structures Guide	IHE	http://www.theihe.org/news/ihie-in-action/ihie-sign-structures-guide/

Table 11.2 - Secondary Reference Documents

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Annex A
Case Studies

Note: These case studies have been included to illustrate the range of diverse situations that exist, the type of factors that may be considered and include some examples where indicative risk scores have been assigned using Method C. Accident data was not available for these sites and the case studies are not intended to be a critical appraisal of the highway authorities' decisions.

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RRS Case Study No.1

A residential road backs almost directly onto to the motorway hardshoulder and is separated by a close boarded boundary fence. An open box beam barrier has been installed to prevent vehicles from failing to stop at the end of the road from crashing through the fence onto the motorway. The motorway is almost at the same level as the residential road and there is only a short section of verge between the fence line and the back of the hard shoulder.

The residential road is wide and lightly trafficked, which is most likely the reason why a turning head has not been provided at this location. There is also no kerb in front of the barrier, which means the barrier would be the first point of contact should a motorist miss-judge where the edge of the carriageway is. The barrier also acts as a visual deterrent.

This site could be assessed using Method A or Method C. Indicative scores for Method C prior to barrier installation are included below.

Factor	Priority Rank	Risk Factor Score
Location	0 - All other roads	0
Layout	0 - Straight alignment and/or complies with TD9	0
	2 - High likelihood of lane changing, overtaking, positioning manoeuvres or avoiding action.	3
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	7 – Lower Priority Site

Although the first feature (the fence) severity score would likely be ‘1’, it would not prevent incursion onto the motorway. Any incursion onto the motorway would likely be a high severity incident.

Although a low priority site, the serious nature of a possible incursion onto the motorway has still prompted the installation of a RRS which due to the short length would incur a low cost. While the barrier that has been installed is not designed for straight-on collisions, the relatively low speed of the road means that it is most likely a sufficient provision to prevent cars from going through the fence and onto the motorway. There might be an issue with the suitability of the barrier in preventing the same from happening in the case of a large vehicle. However, given the nature of the road, it is probably unnecessary to provide a barrier capable of containing a HGV.

Alternative methods of restraint in scenarios like this could be the use of either high kerbs and/or bollards. The RRS offers some physical restraint and a visual deterrent. Some form of reflective material may reduce the risk further.

RRS Case Study No.2

The above photograph shows a turning head at the end of a residential road that backs onto a canal. The gradient of the road and the subsequent turning head falls gently towards the canal. A number of bollards have been installed in the grass verge separating the public highway and the towpath. Between the bollards hangs a loose chain. No bollards exist towards the right side of the turning head; however, due to the way the bollards have been spaced, a small vehicle could just fit through the gap between them. In the event of this happening, the loose chain would provide a warning to the motorist, but little restraint.

This location could be scored using Method A or C. Indicative scores for Method C (Risk Scoring), prior to measures being introduced, are included below.

Factor	Priority Rank	Risk Factor Score
Location	0 - All other roads	0
Layout	0 - Straight alignment and/or complies with TD9	0
	2 - High likelihood of lane changing, overtaking, positioning manoeuvres or avoiding action.	3
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	7 – Lower Priority Site

Although the score indicates the site is a lower priority the installation of some form of RRS reduces the risk yet further. The bollards are a cost effective method of reducing the risk. While there are more compliant restraint solutions available than the bollards, such as the provision of a steel barrier, the picturesque nature of the area means that visually intrusive solutions are not always appropriate. With that said, improvements could be made such as ensuring the bollards are spaced within 1.5m.

In icy conditions, the gradient of the turning head falling towards the canal could make it difficult for motorists to stop before the edge of the public highway. Additionally, the dark colour of the bollards and the lack of reflective strips mean that visibility of the hazard could be poor during the hours of darkness.

RRS Case Study No.3

The photographs below show a T-junction on a lightly trafficked 30mph road that runs alongside a canal. Over the length of the main road, a simple wooden post and metal rail system has been in place for a long period of time. This is evident from the extensive wear and tear, wood rot and rust that are all present along the length of the barrier. The first photograph shows the approach to the junction from the side road. The gradient of the side road slopes up towards the main road impairing perception of the canal. However, the lighting column does provide some limited reduction in 'see through'.

In the second photograph, either due to a past collision or simply down to wear, the post and rail system has been reduced with only some of the wooden posts remaining. As a remedial measure, stone benches and a single new bollard have been installed to provide some form of restraint. The low kerbs remain the same as along the rest of the road and there is even a dropped section in between the two benches. As illustrated in the first photograph, the space between the new benches and the bollards is significant and could allow a vehicle to pass through unobstructed. It is also questionable whether the existing wooden bollards would provide any real restraint in their current condition.

This site could be assessed using Method A or Method C. Indicative scores for Method C are included below.

Factor	Priority Rank	Risk Factor Score
Location	1 - Rural U & B roads and urban C roads	1
Layout	0 - Straight alignment and/or complies with TD9	0
	2 - High likelihood of lane changing, overtaking, positioning manoeuvres or avoiding action.	3
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	8 – Lower Priority Site

In this lower priority scenario, there is an obvious need to compromise between a compliant RRS and aesthetics. The potential reduction in risk achieved by upgrading to a fully compliant RRS may be hard to justify in terms of expenditure. Due to the low speed of the roads concerned, the careful selection of closely spaced bollards could offer the necessary restraint without impeding significantly upon visual quality. In terms of non-RRS measures the introduction of give-way markings would provide a visual cue to motorists approaching the main road that they should slow down. This would help prevent drivers from overrunning the junction and being unable to stop before entering the canal.

RRS Case Study No.4

The main road shown in this example is a busy 30mph A class Road. Running alongside it is a major river with a significant drop from the road to water level. There are also numerous side roads that provide access to a built-up residential area.

Separating the river and the carriageway is a wide footway and verge. While standard kerbs have been used along the road, they do sit at quite a high level, which provides a warning for an errant vehicle in the form of deflection. The second level of restraint comes from the numerous mature trees in the verge. In the majority of cases, these trees will stop a vehicle that leaves the highway and prevent it from reaching the river. However, collisions with trees are likely to result in serious or fatal injuries, even at 30mph. As shown in the second photograph, pedestrian guard railing once ran behind the tree line. However, the photograph and the inset photograph show that the growth of the surrounding trees and foliage has significantly impaired the effectiveness of the barrier at a number of points along the route.

This site could be assessed using Method A or Method C. Indicative scores for Method C are included below. This demonstrates that installation of a RRS could be justified in terms of reducing the risk to an errant vehicle. The barrier system could protect against impact with the trees as well as the hazard of a vehicle entering the water, the barrier would need to be installed so that the lighting columns were also protected.

Factor	Priority Rank	Risk Factor Score
Location	3 - Urban A Roads	6
Layout	0 - Straight alignment and/or complies with TD9	0
	1 - Some potential for lane changing, overtaking, positioning manoeuvres or avoiding action.	2 (this score would be zero away from the junctions)
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	12 – Medium Priority Site

RRS Case Study No.5

In this example, there is a substantial brick parapet in place across a bridge that spans a canal. On the approaches to the bridge however, there is only a simple concrete post and rail barrier in place, which has deteriorated over time and looks to have been impacted in a collision; it is expected that this would have little or no ability to contain an errant vehicle. On one approach the A class road is national speed limit and has a straight alignment, on the other approach the speed limit is 30mph.

On the approach shown in the top picture the embankment is sufficiently high to justify appraisal and the canal also presents a hazard to an errant vehicle. On the opposite side of the carriageway, a lane exists adjacent to the parapet that leads down to the canal tow path; a situation that is common to canal bridges. Retaining access to the towpath in this way does allow an unobstructed path for an errant vehicle leaving the carriageway to reach the canal and an unprotected parapet end. Leaving such a gap would be justified to retain pedestrian access or in some cases vehicular access. This site could be assessed using Method A or Method C. Indicative scores for Method C are included below.

A fully compliant solution would be to provide a safety fence up to the parapet end and relocate the pedestrian and vehicular access to behind the barrier, outside the working width. This option is likely to be prohibitively expensive. Alternatively barrier could be provided on only the highest risk approaches. Any new RRS design should consider the lighting columns and trees on the embankment also.

Factor	Priority Rank	Risk Factor Score
Location	2 - Rural A roads and urban B roads	3
Layout	0 - Straight alignment and/or complies with TD9	0
	0 - No reason for lane changing/manoeuvres.	0
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	7 – Lower Priority Site

RRS Case Study No.6

The photograph below shows a car park that has been built adjacent to a railway line. Three methods of restraint exist. The first is the kerbing, which provides the motorist with an indication of whether they are getting too close to the edge of the pavement and prevents vehicles from making contact with the crash barrier and potentially causing damage to the body work of their car.

The second method of restraint is the crash barrier. While these barriers are not specifically designed for straight-on collisions, the low speed of vehicles in the car park means that it should be sufficient to prevent cars from proceeding any further in the event of a collision.

The third method of restraint is the mesh fencing along the boundary line of the car park. It would provide little or no additional vehicle restraint should such a collision occur and the TCB barrier was breached. With that said however, the primary purpose of the fencing is to provide restraint for pedestrians to ensure they do not walk onto the railway line.

Although this site is strictly a road rail interface this scenario is not covered by the DfT document 'Managing the accidental obstruction of the railway by road vehicles'. It can be assessed using Method C – Risk Scoring, indicative scores are included below. To account for the fact that a vehicle may reach the railway line the second part of the collision factor (severity) has been scored as a '2'.

Factor	Priority Rank	Risk Factor Score
Location	0 - All other roads	0
Layout	0 - Straight alignment and/or complies with TD9	0
	2 - High likelihood of lane changing, overtaking, positioning manoeuvres or avoiding action.	3
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	7 – Lower Priority Site

Method C may indeed underestimate risk at this particular location as provision of a simple barrier seems a cost effective way of protecting the other car park infrastructure from damage as well as reducing the risk of an errant vehicle from reaching the rail line.

The only realistic improvement that could be made to the existing situation would be to move the crash barrier further back from the kerb edge. As it is very close to the kerb face, it may be possible for some cars to make contact with the crash barrier before their tyres touch the kerb face. However, the risk would need to be balanced as this may mean the lighting columns would be within the barrier working width.

RRS Case Study No.7

The photograph below show a heavily trafficked dual carriageway A-road, with a 30mph limit that passes over a wide river with a walkway along the bank. The section shown has no crash barrier on the approach to the parapet and a footway down to the canal is provided. The other three approaches to the structure are protected and this approach presents the least risk as the route down to the river is on the inside of the bend and the river is some considerable distance from the edge of carriageway. This location could be risk assessed using Method A or C, indicative scores for Method C – Risk Scoring is given below.

Factor	Priority Rank	Risk Factor Score
Location	3 - Urban A Roads	6
Layout	0 - Straight alignment and/or complies with TD9	0
	0 - No reason for lane changing/manoeuvres.	0
Collision	1 - Series of individual hazards less than 50m apart or a longitudinal hazard that might be reached.	1
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	9 – Medium Priority Site

Although the hazard can be considered longitudinal rather than a spot hazard, this element of score has been reduced from 2 to 1 due to the large distance to the river. The scoring shows that this is a medium priority site. Considering the embankment as the primary hazard would result in a similar score, with different component parts.

There would be a potential reduction in risk if a barrier was provided, however this would be difficult to achieve without limiting or preventing access to the riverside. Given the distance between the river and the edge of the carriageway it appears acceptable to provide no barrier at this location.

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RRS Case Study No.8

The above photograph shows an extremely sharp bend situated close to the end of a long straight residential road. Directly behind the bend is a residential property. Located on the footway in front of the property are a number of bollards and a ‘sharp deviation of route’ sign.

The bollards may have been installed to prevent parking at the corner or they may have been installed to stop vehicles that leave the carriageway should the driver fail to negotiate the corner. As vehicles could be travelling along this road at speeds up to 30mph, a collision with a bollard would be hazardous. This location could be assessed using Method A or Method C. Indicative scores for Method C are included below.

Factor	Priority Rank	Risk Factor Score
Location	2 - Rural A roads and urban B roads	3
Layout	5 - Five steps below desirable minimum R with superelevation of 5%	5
	0 - No reason for lane changing/manoeuvres.	0
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	1 - Percentage of KSI for primary feature 20 -30%	1
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	11 – Medium Priority Site

These scores show that the location is a medium risk; installation of a RRS may reduce the risk further. The highway authority has introduced signing and road markings on the approach to the bend and the bollards also have reflective strips increasing driver’s awareness of the corner at night. This solution seems preferable to a RRS at this location as a compliant system would be difficult to accommodate, unsightly and potentially ineffective at the probable angle of impact.

The railings shown to the extreme right of the picture are at the top of a railway embankment for the West Coast Mainline. Vehicles travelling towards the corner from the opposite direction are less likely to be surprised by the sudden turn as they have only travelled a short length of the residential street with on street parking; as such their speed is likely to be lower. This situation would need to be assessed using Method B.

RRS Case Study No 9

The photographs below show a main road that slopes down in a cutting to pass underneath a canal bridge. As a result, the side roads that adjoin it are at a much higher level and create a sheer drop at the containment walls. On either side of the main road, there is either no restraint or only restrain provided by existing trees / foliage to prevent vehicles from dropping down from the side roads onto the main line. This risk may increase in icy conditions when stopping become more difficult.

This site could be assessed using Method A or Method C. Indicative scores for Method C are included below. This assessment shows that even without a RRS the risk appears to be low, although the introduction of a RRS would reduce the risk further still. Installation of a system at this location may be visually intrusive and not be justified in cost terms. Additional planting of bushes may be desirable as an alternative.

Factor	Priority Rank	Risk Factor Score
Location	0 - All other roads	0
Layout	0 - Straight alignment and/or complies with TD9	0
	2 - High likelihood of lane changing, overtaking, positioning manoeuvres or avoiding action.	3
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	2 - Percentage of KSI for primary feature >30%	2
Consequential	0 - No secondary events likely.	0
	0 - No impact on network availability.	0
	0 - No major cost implications.	0
	Total Priority Score	7 – Lower Priority Site

RRS Case Study No. 10

At this railway bridge, there is limited footway provision on the bridge itself and a pedestrian footbridge has been provided alongside the parapet to allow pedestrians to cross safely. While the above image shows that there is suitable footway at end of the bridge, it significantly narrows towards the other end. Pedestrian guardrail has therefore been installed to prevent pedestrians using the bridge and divert them over the footbridge. Clearly the separation of pedestrians from the vehicular traffic increases the space available to improve the road alignment and reduces the risk of the vehicle leaving the carriageway. This situation would need to be assessed using Method B.

The second photograph also shows the use of high kerbs, which helps prevent vehicles from leaving the carriageway and ultimately reduces the likelihood of them reaching the parapet. Kerbs of this nature are only appropriate where speeds are 30mph or less, as higher speeds can result in vehicles rolling over on contact with them.

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RRS Case Study No 11

The photograph below shows a fast moving and heavily trafficked 3 lane, 40mph, dual carriageway on the approach to a motorway. At the point shown traffic has the option to leave the route and rejoin the local road network.

Located in the footway, adjacent to brick boundary wall, is a high level lighting mast and the leg of a sign gantry. Of the two structures, the high level lighting mast poses the most risk to motorists as it is located downstream of a diverge taper where it is more likely that a vehicle will leave the carriageway. Nonetheless an impact with the gantry leg may damage the structure and result in a partial or complete collapse, especially if the collision involves a HGV. This would result in network disruption, potential secondary collisions and be expensive to repair.

A collision with the wall may guide an errant vehicle into either of the two point hazards making them more likely to be hit. The brick wall sits above a railway line. This location could be risk assessed using Method A or C, indicative scores for Method C are given below. Although there is a significant amount of lane changing at the diverge the taper and nose are broadly to standards warranting a score of 2 rather than 3.

Based on the results of the risk scoring exercise alone the site warrants additional appraisal and investigation into the possible options for reducing the risk. One such option would be to reduce the slip road to one lane, moving traffic away from the hazards. Installation of a compliant RRS may be problematic, although closure of one lane may assist in accommodating a barrier system.

Factor	Priority Rank	Risk Factor Score
Location	3 - Urban A Roads	6
Layout	0 - Straight alignment and/or complies with TD9	0
	1 - Some potential for lane changing, overtaking, positioning manoeuvres or avoiding action.	2
Collision	2 - Longitudinal Hazard that is highly likely to be reached resulting in harm or a spot hazard downstream of a feature which may guide the vehicle towards the hazard.	2
	1 - Percentage of KSI for primary feature 20 -30%	1
Consequential	1 - When damaged or collapsed the feature could rise to the risk of secondary vehicular accidents.	1
	1 - If hazardous feature was damaged or collapsed this could give rise to network disruption.	1
	1 - Significant cost of repair or replacement following collision.	1
	Total Priority Score	**14 – Higher Priority Site**

Annex B
Calculating Curve Design Speed

The Curve design speed can be calculated from the road standards using the following formula:

$$V_{design} = \sqrt{127.R.(e + f)}$$

R = curve radius in metres
e = super-elevation or crossfall in metres per metre
f = side friction factor
and the resultant V_{design} is in km/h.

Several studies aimed at determining the maximum side-friction factors (f) that are comfortable for drivers have been conducted. Some of the results from these studies (AASHTO, 1994) are tabulated below and these results can be used to select the appropriate f value to calculate the Curve design speed.

SPEED (KM/H)	COMFORTABLE SIDE-FRICTION FACTOR
40	0.21
50	0.18
55-80	0.15
> 110	0.10

The side-friction factors that are employed in the design of horizontal curves should accommodate the safety and comfort of the intended users.[18]. The side-friction factor is associated to the SCRIM value at a particular site

[18] This value is not an appropriate value for surfacing design purposes. Because highway curves are designed to avoid skidding conditions with a margin of safety, the coefficient of friction values of pavements should be substantially higher than the value of f.

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Annex C
Further Accident Data Analysis

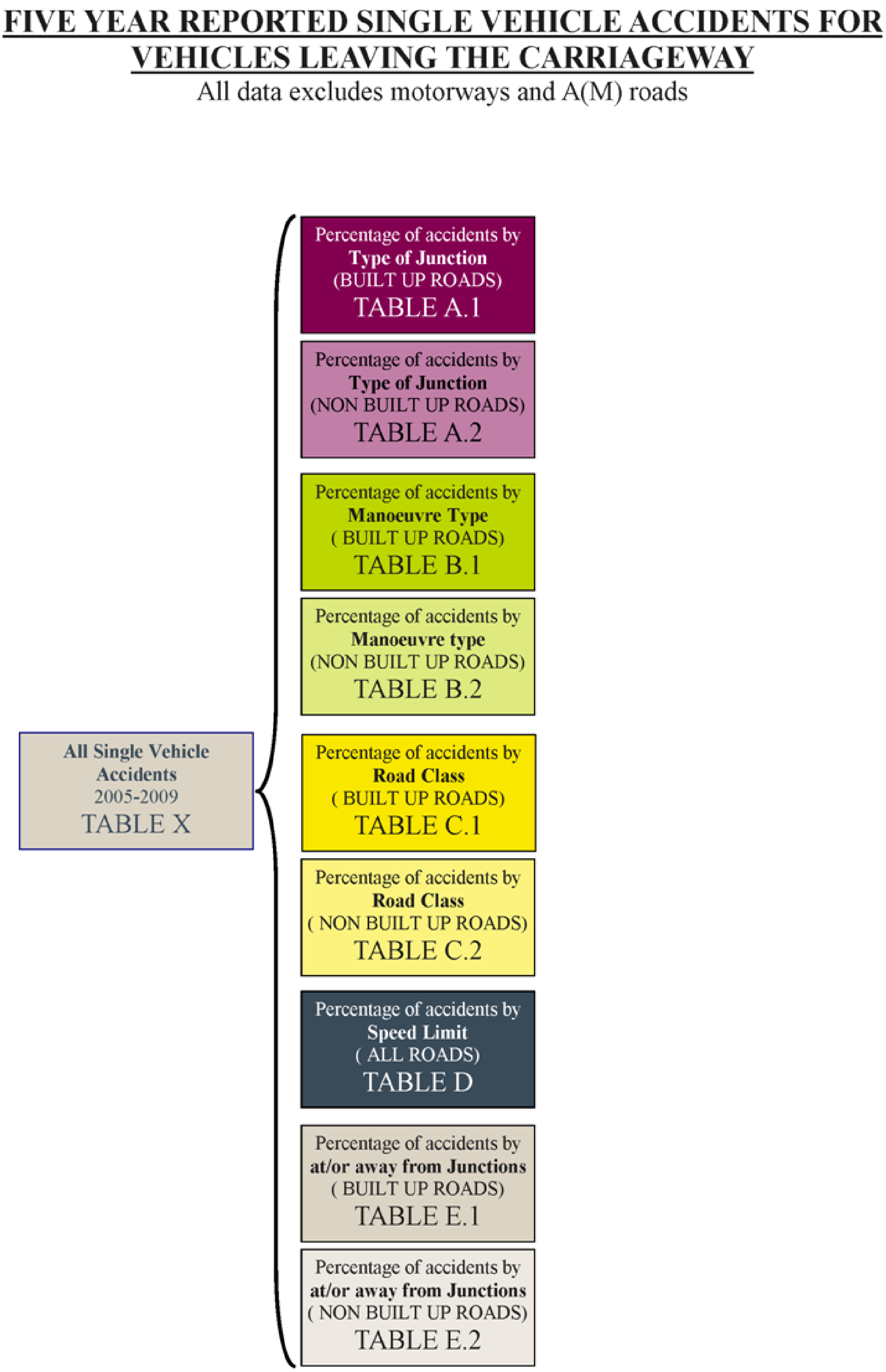

TABLE X

ALL SINGLE VEHICLE ACCIDENTS				
Fatal	Serious	Slight	All	KSI
5,581	51,358	208,806	265,745	56,939

TABLE A.1

SINGLE VEHICLE ACCIDENTS – BUILT UP BY JUNCTION TYPE (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
Roundabout	1.7	3.1	3.7	3.6	3.0
Mini Roundabout	0.3	0.5	0.6	0.6	0.5
T' or Staggered	18.0	24.1	23.5	23.5	23.5
Crossroads	4.3	6.1	5.7	5.7	5.9
Slip Road	0.3	0.3	0.4	0.3	0.3
Other Junctions / Accesses	3.1	4.9	5.7	5.5	4.8
ALL	**27.7**	**38.9**	**39.5**	**39.2**	**37.8**

TABLE A.2

SINGLE VEHICLE ACCIDENTS – NON BUILT UP BY JUNCTION TYPE (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
Roundabout	1.0	1.5	1.5	1.5	1.4
Mini Roundabout	0.0	0.0	0.0	0.0	0.0
T' or Staggered	3.3	2.0	1.8	1.9	2.1
Crossroads	0.5	0.3	0.2	0.2	0.3
Slip Road	1.0	0.6	0.6	0.6	0.6
Other Junctions / Accesses	1.4	0.8	0.7	0.7	0.8
ALL	**7.2**	**5.1**	**4.8**	**4.9**	**5.3**

TABLE B.1

SINGLE VEHICLE ACCIDENTS – BUILT UP
BY VEHICLE MANOEUVRE (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
Reversing	1.5	2.5	3.3	3.1	2.4
Parked	0.6	1.1	1.6	1.5	1.0
Waiting To Go-Held Up	0.1	0.5	1.0	0.9	0.4
Slowing or Stopping	0.7	2.5	4.6	4.2	2.4
Moving Off	2.0	3.1	4.6	4.2	3.0
'U' Turn	0.1	0.2	0.2	0.2	0.2
Turning Left	1.7	2.4	3.1	2.9	2.4
Turning Right	1.8	3.5	4.3	4.1	3.3
Changing Lane	0.3	0.3	0.3	0.3	0.3
Overtaking	0.9	2.5	2.3	2.4	2.4
Going ahead around bend	8.9	7.3	7.0	7.1	7.4
Going Ahead Other	36.4	47.1	41.5	42.5	46.1
Unreported or Unknown	0.0	0.0	0.1	0.1	0.0
ALL	**55.1**	**73.0**	**73.9**	**73.3**	**71.2**

TABLE B.2

SINGLE VEHICLE ACCIDENTS – NON BUILT UP
BY VEHICLE MANOEUVRE (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
Reversing	0.1	0.1	0.1	0.1	0.1
Parked	0.0	0.0	0.0	0.0	0.0
Waiting To Go-Held Up	0.0	0.0	0.0	0.0	0.0
Slowing or Stopping	0.2	0.4	0.5	0.5	0.3
Moving Off	0.1	0.1	0.1	0.1	0.1
'U' Turn	0.0	0.0	0.0	0.0	0.0
Turning Left	0.2	0.3	0.4	0.4	0.3
Turning Right	0.1	0.2	0.3	0.3	0.2
Changing Lane	0.6	0.2	0.3	0.3	0.2
Overtaking	1.0	0.6	0.5	0.6	0.6
Going ahead around bend	19.3	12.3	11.9	12.2	13.0
Going Ahead Other	23.0	12.7	11.7	12.1	13.7
Unreported or Unknown	0.0	0.0	0.0	0.0	0.0
ALL	**44.6**	**27.0**	**25.9**	**26.5**	**28.7**

TABLE C.1

SINGLE VEHICLE ACCIDENTS – BUILT UP BY ROAD CLASS (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
A Class excl. A(M)	25.6	28.2	25.8	26.2	27.9
B Class	8.1	9.0	8.9	8.9	8.9
C Class	5.1	6.7	7.3	7.1	6.5
Unclassified	16.6	29.2	32.1	31.2	27.9
ALL	**55.4**	**73.0**	**74.1**	**73.5**	**71.3**

TABLE C.2

SINGLE VEHICLE ACCIDENTS – NON BUILT UP BY ROAD CLASS (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
A Class excl. A(M)	27.4	14.7	13.8	14.3	16.0
B Class	6.7	5.0	4.8	4.9	5.2
C Class	4.9	3.1	3.0	3.0	3.3
Unclassified	5.6	4.2	4.3	4.3	4.3
ALL	**44.6**	**27.0**	**25.9**	**26.5**	**28.7**

TABLE D

SINGLE VEHICLE ACCIDENTS BY SPEED LIMIT (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
20mph	0.7	1.0	1.1	1.1	1.0
30mph	44.6	65.2	67.2	66.4	63.2
40mph	10.1	6.8	5.7	6.0	7.1
50mph	4.1	2.3	1.9	2.0	2.5
60mph	32.8	21.1	20.3	20.8	22.3
70mph	7.7	3.5	3.7	3.7	3.9

TABLE E.1

SINGLE VEHICLE ACCIDENTS – BUILT UP BY PROXIMITY TO JUNCTION (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
Not at Junction	27.7	34.1	34.5	34.3	33.5
On or within 20m of Junction	27.7	38.9	39.5	39.2	37.8
ALL	**55.4**	**73.0**	**74.1**	**73.5**	**71.3**

TABLE E.2

SINGLE VEHICLE ACCIDENTS – NON BUILT UP BY PROXIMITY TO JUNCTION (PERCENT)

Object Hit	Fatal	Serious	Slight	All	KSI
Not at Junction	37.5	21.8	21.1	21.6	23.4
On or within 20m of Junction	7.2	5.1	4.8	4.9	5.3
ALL	**44.6**	**27.0**	**25.9**	**26.5**	**28.7**

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