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Transport Infrastructure Ireland

## TII Publications



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# Design of Road Restraint Systems for Constrained Locations (Online Improvements, Retrofitting and Urban Settings)

**DN-REQ-03079**

May 2019

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**TII Publications**




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**Updates to TII Publications resulting in changes to  
Design of Road Restraint Systems for Constrained Locations (Online Improvements,  
Retrofitting and Urban Settings) DN-REQ-03079**

**Date:** May 2019

**Amendment Details:**

This document replaces the February 2017 version of DN-REQ-03079. The principle changes from the previous document include:

- a) The document is now a TII Publications (Standards) document following an interim period as a TII Publications (Technical) document.
- b) The title of the document has been updated from Guidance for Retrofitting Vehicle Restraint Systems on the Single Carriageway National Road Network to Design of Road Restraint Systems for Constrained Locations (Online Improvements, Retrofitting and Urban Settings).
- c) The document has been updated to cover the design of VRS at constrained locations as part of online improvements as well as VRS design for new or retrofitting of existing VRS at constrained locations on the legacy road network.
- d) The document has been updated to incorporate the Risk Assessment Procedure for assessing the need for VRS on online improvements within Section 5 of this document, this was previously Chapter 8 of DN-REQ-03034 Safety Barriers.
- e) The Risk Assessment Procedure referred to for assessing the need for VRS when installing new or retrofitting existing VRS on legacy single carriageway National Roads is now the Risk Assessment Procedure within Section 5 of this document.
- f) The concept of using Operational Speeds as opposed to Design Speeds on legacy roads where the road itself is not being upgraded i.e. VRS works only, has been introduced to this document.
- g) Reduced Clear Zones for lower Design/ Operational speeds have been introduced into DN-GEO-03036 Cross Sections and Headroom and are referred to within this document.

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# **1. Introduction**

## **1.1 Scope**

This Standard provides the requirements for the following in relation to Vehicle Restraint System (VRS) design:

- Assessing the need for VRS on online improvements to existing single carriageway legacy National Roads through the risk assessment procedure detailed in Section 5 (Previously Chapter 8 of DN-REQ-03034).
- Designing VRS for online improvements to existing single carriageway legacy National Roads where the design of a fully compliant VRS to DN-REQ-03034 The Design of Road Restraint Systems (Vehicle and Pedestrian) for Roads and Bridges may not be achievable.
- When considering retrofitting VRS on the single carriageway National Road network and site conditions and constraints are such that design compliance with DN-REQ-03034 may not be achievable.
- Assessing the need for VRS on National Roads in urban scenarios.

The Designer shall consider the VRS Design Process Flowchart provided in Section 2 of this document when confirming the design standard appropriate for the VRS design being considered. For new build projects, the Designer is directed to DN-REQ-03034 where the procedures outlined in this document do not apply.

This document should be read in conjunction with DN-REQ-03034 and the Forgiving Roadside Section of DN-GEO-03036 Cross Sections and Headroom.

## **1.2 Categories of Constraints**

Three broad categories of constraints that may not allow the design of a fully compliant VRS to DN-REQ-03034 are detailed within Table 1.1. A risk-based approach to designing solutions for such locations is presented within Sections 6 to 9 of this Standard.

**Table 1.1 Categories of VRS at constrained locations**

Category	Location description	Example Constraints
<b>A</b>	Constrained Locations on Online Improvements / Retrofitting (Away from Structure / Bridge Locations)	<ul style="list-style-type: none"> <li>• Lack of available working width or set-back</li> <li>• Inadequate space to accommodate the Length of Need</li> <li>• Land restrictions preventing a compliant design to DN-REQ-03034</li> <li>• Access / Junction requirements preventing a compliant design to DN-REQ-03034</li> <li>• Tie in locations on minor improvement schemes</li> </ul>
<b>B</b>	Online Improvements/ Retrofitting at Existing Structure / Bridge Locations	<ul style="list-style-type: none"> <li>• Historical parapets at road, rail and river bridge crossings</li> <li>• VRS at culvert crossings</li> <li>• Historical parapets with unknown containment values</li> <li>• Cultural heritage issues may prohibit modification or demolition of an existing parapet</li> <li>• Inadequate space to accommodate the Length of Need</li> <li>• Adjacent VRS is a pre-I.S. EN 1317 system with concrete or timber posts</li> </ul>
<b>C</b>	Urban Setting	<ul style="list-style-type: none"> <li>• VRS within urban settings without traffic calming</li> <li>• VRS at a location that is now within a speed limit zone but was not at the time of system installation</li> </ul>

### 1.3 Implementation

The assessment and design processes described within this Standard shall be applied for:

- Assessing the need for VRS at hazard locations on online improvement schemes to existing National Roads and minor improvement schemes as defined in DN-GEO-03030 Guidance on Minor Improvements to National Roads.
- Designing solutions for hazard locations on online improvement schemes to existing National Roads and minor improvement schemes as defined in DN-GEO-03030 where it has been assessed that a VRS is required but the site-specific constraints do not allow a compliant VRS design in accordance with DN-REQ-03034. For offline sections of such schemes e.g. where removing a sub-standard alignment, VRS shall be designed in accordance with DN-REQ-03034.
- Retrofitting or installing a new VRS at a location on the existing single carriageway National Road network where the site-specific constraints do not allow a compliant VRS design in accordance with DN-REQ-03034.
- Assessing existing VRS on single carriageway legacy National Roads for replacement or removal and the design of replacement VRS where the site-specific

constraints do not allow a compliant VRS design in accordance with DN-REQ-03034.

- VRS design for Local and Regional Roads being upgraded as part of a National Road scheme with lower design / operational speeds and site-specific constraints do not allow a compliant VRS design in accordance with DN-REQ-03034.
- Urban schemes where a VRS may be required due to a particular high-risk hazard or where assessing the need for existing VRS in an urban setting.

This Standard shall not be used for new build (offline/ green field) projects. VRS for such project shall be designed in accordance with DN-REQ-03034 and the Departures from Standard process shall be followed as relevant. The road design for online realignment schemes should also account for compliant VRS design to DN-REQ-03034 where practical. VRS design for significant online widening schemes, such as widening of Dual Carriageways, shall be in accordance with DN-REQ-03034 and the associated Departure from Standards process.

## 2. VRS Design Process Flow

An overview of the VRS design process is presented in the flowchart in **Error! Reference source not found.**. The flowchart shall be followed at the commencement of the project to confirm that the correct design standards and associated processes are being followed. There are three Standards which are primarily applicable to the design and documentation of VRS, namely:

- DN-GEO-03036 Cross Sections and Headroom – for considering the Principles of Forgiving Roadsides and the opportunities therein to remove or mitigate the need for a VRS.
- DN-REQ-03034 The Design of Road Restraint Systems (Vehicle and Pedestrian) for Roads and Bridges – for use on all new projects and where project constraints permit the provision of a compliant restraint system (e.g. where sufficient space is available for the requirements of this Standard).
- DN-REQ-03079 (This Standard) – for assessing the need for VRS on online improvement projects and the design of VRS on projects which fall within the types and categories described in DN-REQ-03079 where project constraints do not permit the provision of a compliant system (e.g. where sufficient space is not available for the requirements of this Standard) or where a risk assessment identifies that a VRS provision may not be warranted (e.g. in an urban scenario).

Once it has been established that the use of this Standard is applicable then the Designer shall follow all requirements herein. It should be noted that this flowchart is non-exhaustive and does not preclude the Designer from following any requirements set out in the stated design standards.

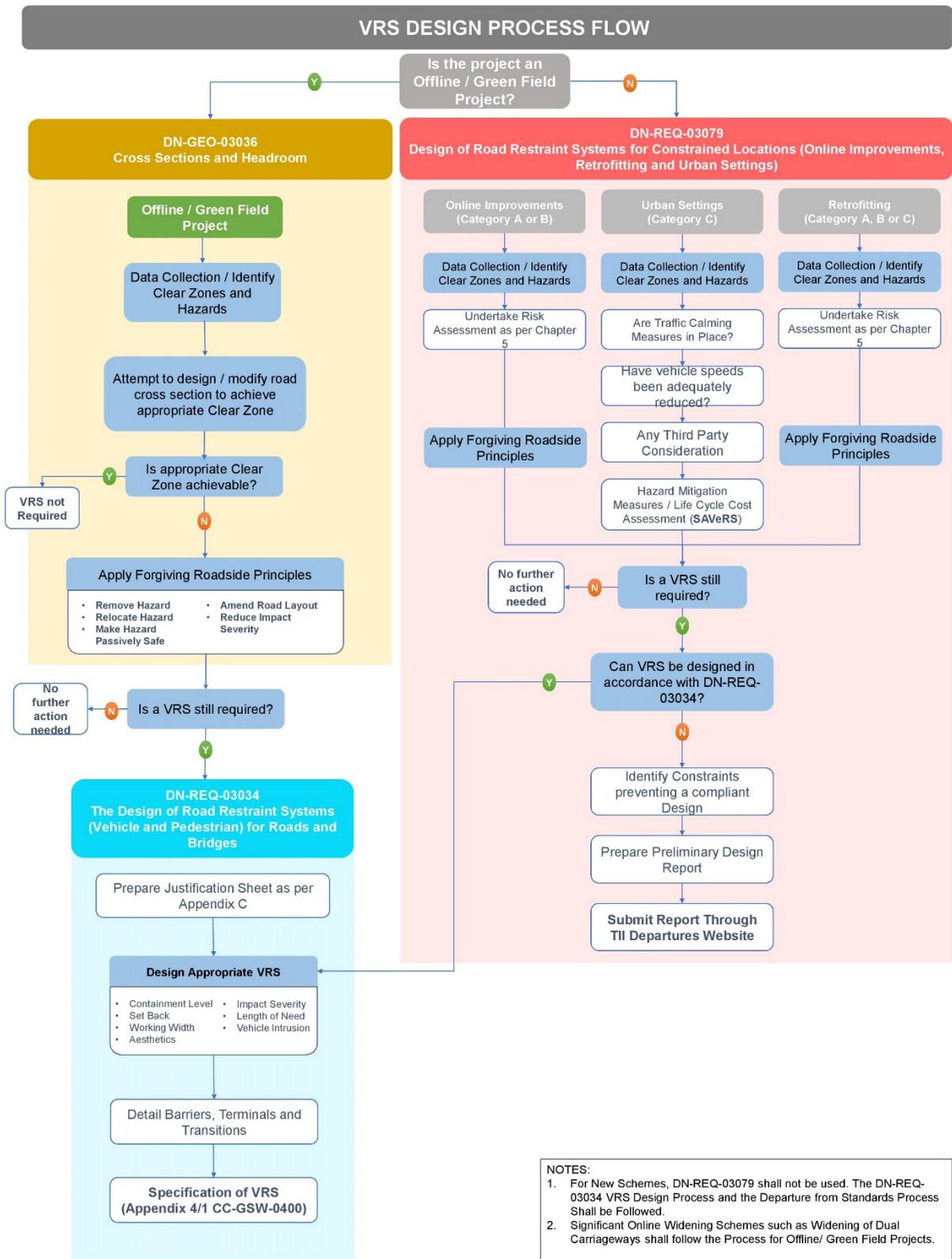


Figure 2.1 Detailed Flowchart for VRS Design Process

## 3. Definitions

### 3.1 General

For clarification, and for the purposes of this Standard, the following terms defined in IS EN 1317-1 apply:

- Vehicle restraint system
- Safety barrier
- Terminal
- Transition
- Vehicle parapet

The following terms defined in DN-REQ-03034 also apply:

- Hazard
- Clear Zone
- Set-back
- Length of Need
- Working Width
- Vehicle Intrusion
- Approach / Departure Lengths
- Bespoke parapet

The following terms defined in DN-GEO-03036 also apply:

- National Road
- Regional Road
- Local Road
- Rural Road
- Urban Road
- Central Reserve
- Cross Section
- Verge

Particular terms used in this Standard are defined as follows:

a) **Designer**

The organisation responsible for undertaking and/or certifying the design. Individuals within the organisation responsible for the design of a proposed VRS must have successfully completed the two-day TII Design of Vehicle Restraint Systems course run in conjunction with Engineers Ireland.

- b) **TII Bridge Management Section**  
The department within TII responsible for the management of bridge structures on the National Road network.
- c) **TII Network Management**  
The department within TII responsible for the management of the operation of the National Road network and managing the associated assets including the road pavement, structures, VRS and other ancillary road assets.
- d) **VRS Preliminary Design Report**  
A report for submission to TII outlining the VRS design options considered by the designer and the proposed preferred design solution. It shall describe the issues with compliance with the relevant parts of TII Publication (DN-REQ-03034) for the options considered and other relevant information as outlined in this document.
- e) **Constrained location**  
A location where site conditions and constraints do not allow a compliant VRS design in accordance with DN-REQ-03034.
- f) **Bespoke VRS**  
A VRS which is not a product and thus not compliant with IS EN 1317, but which has been subject to a detailed design for a specific situation and set of circumstances.
- g) **Structure**  
A structure within this document is an object with several elements such as a road bridge, rail bridge or culvert crossing.
- h) **New-build**  
Any project which involves a new length of road with a compliant cross-section. This may include green field projects or brown field online improvements.
- i) **Urban setting**  
An area of human development such as towns, cities or suburbs.
- j) **Third party considerations**  
Consideration of any individual or party, sensitive property or infrastructure that may be affected or could benefit by the installation of a VRS at a location. Where third party considerations apply, the objective of a VRS installation may be to protect vulnerable roadside property or people as opposed to protecting an errant vehicle and the occupants of an errant vehicle from a roadside hazard. Further information on Third Party Considerations can be found in Section 9.2.
- k) **Road Authority**  
The authority responsible for the road construction or improvement scheme.

## 3.2 Design/Operational Speed

Throughout this Standard are various references to Design/ Operational speed. The Design/ Operational Speed shall be determined based upon the following:

- For all new road schemes (new builds, road realignments and minor improvements) where a new or revised road cross section is being provided, the Designer shall use the design speed as calculated using DN-GEO-03031 Rural Road Link Design.
- For retrofitting works where the existing road cross section is not being changed i.e. VRS works only, the Designer may use the operational speed for the section of road under consideration. Indicative operational speeds for use when designing VRS on legacy national roads under this Standard **only** are included in Appendix A. The operational speed shall be rounded up to the next closest design speed band as set out in Chapters 1 and 10 of DN-GEO-03031. See Section 4.1 for the requirement of the Designer to confirm the appropriateness of the Operational Speed for the VRS Design under consideration.

## 4. Clear Zone for Reduced Design/ Operational Speeds

As vehicle speeds reduce, the space required for drivers to recover if they lose control and leave the road carriageway also reduces. Clear Zone widths, appropriate for a range of Design/ Operational Speeds, which are to be maintained adjacent to National Roads, are defined in DN-GEO-03036 Cross Sections and Headroom. These include Clear Zone widths for roads with lower Design/ Operational speeds which can be applied to the legacy National Road network where appropriate and used in conjunction with this standard for assessing the need for VRS at such locations.

It should be noted that the Clear Zone widths indicated are intended for use on rural sections of National Roads, or Local and Regional Roads being upgraded as part of a National Road scheme and are not intended for application to typical urban scenarios. The installation of a VRS in urban locations should be avoided wherever possible as detailed in Section 9 of this standard for Urban Settings (Including Minor Works Schemes within Reduced Speed Limits).

Where hazards cannot be removed, mitigated or modified to achieve the required Clear Zone width as per DN-GEO-03036, the Designer will be required to follow the risk assessment procedure outlined in Section 5 of this Standard to verify if a VRS is required. Should the risk assessment process indicate that a VRS is required, it shall be designed in accordance with:

- DN-REQ-03034 where site constraints and space permit a compliant VRS design; or
- DN-REQ-03079 (this standard) at constrained locations where a compliant VRS design is not achievable, as per the design procedure for the appropriate category of constraint detailed within this standard.

### 4.1 Operational Speed

#### 4.1.1 Application

Indicative operational speeds for National Roads which can be used when assessing the need for and designing VRS under this Standard **only** are included in Appendix A. The indicative operational speeds provided shall only be used for legacy sections of the national road network i.e. non-engineered legacy roads which include some or all of the following characteristics:

- sub-standard vertical and horizontal curves;
- reduced cross section widths;
- sub-standard accesses and junctions;
- reduced verges and hard strips.

The operational speed indicated is based on a quality assessment of the route categorised in approximately 1km sections. These are to be considered as a starting point for consideration in the initial design process and shall be rounded up to the nearest design speed within Chapter 1 or Chapter 10 of DN-GEO-03031 Rural Road Link Design.

Operational speeds shall not be applied to sections of road with a designed road cross-section, the governing speed for VRS assessment/ design shall be the mandatory speed limit. Operational speeds shall not be applied for VRS assessment / design for dual carriageways or motorways.

#### 4.1.2 Validation

Where VRS assessment/ design for constrained locations is being undertaken in accordance with this Standard, the Designer shall validate the indicative operational speed included in Appendix A for the

specific VRS location within the 1km section. This should be completed as part of the site survey already required as part of the Risk Assessment Procedure for assessing the need for VRS as detailed in Section 5. The site survey shall:

- confirm the location of the proposed VRS location within the 1km section during the site survey required under this Standard;
- assess if the proposed VRS is at the end of a straight section of road which is followed by a severe bend or series of bends within the 1km section which may affect the operational speed in Appendix A;
- assess if the proposed VRS is at a location coming out of a severe bend or series of bends which may affect the operational speed in Appendix A;
- assess if there any obvious features or hazards in the road environment that would cause a driver to travel at a speed in excess of/ below the indicative operational speed.

The route shall be driven a minimum of 3 times in each direction using a GPS enabled camera to establish the average operating speed of the road taking cognisance of the following:

- The full 1km section shall be driven, with the driver commencing from a location a minimum of 600m in advance of the start of the hazard location.
- Where obvious obstructions to traveling at the operating speed are encountered, the drive through shall be repeated e.g. where slow-moving vehicles, vehicles exiting/ entering the road, cyclists, animals etc. impede the drive through.

The obtained average operating speed should be compared with the indicative operational speed in Appendix A.

## 5. Risk Assessment Procedure (formerly Chapter 8 of DN-REQ-03034)

### 5.1 General

A risk assessment procedure shall be undertaken by the Designer to assess the need for a VRS on a scheme involving online realignment or sections of minor improvement schemes where available working space may be at a premium such as the tie in locations. The procedure is also applied as part of the Design process for retrofitting VRS as described in the subsequent Sections of this Standard. The Designer's professional judgment is required in the risk assessment and in the inclusion or omission of barriers. The risk assessment procedure can also be used in scenarios other than online realignment for decision making purposes.

### 5.2 Risk Assessment Procedure

As part of the risk assessment procedure, the Designer shall complete a risk assessment sheet at the preliminary design stage using the template included in Appendix B and include it in the Preliminary Design Report. This risk assessment procedure shall also be completed at the detailed design stage.

The Designer shall undertake the following procedure for all hazards and record it in the risk assessment sheet:

- i) Establish if the hazard is within the Clear Zone and if it can be removed or mitigated;
- ii) Rank the hazard as per Appendix C;
- iii) Calculate the sinuosity of that section of road;
- iv) Assess the collision rate threshold for that section of road;
- v) Assess the risk of a vehicle leaving the road based on sinuosity ranking and collision rate ranking;
- vi) Assess the overall risk rating;
- vii) Undertake a site survey to confirm the need for a VRS.

The risk assessment stages described above are explained in more detail in Sections 5.3 to 5.8 below.

### 5.3 Hazard Location and Ranking

The Designer shall establish if the hazard is located within the Clear Zone as defined for various speeds in DN-GEO-03036.

Hazards shall be mitigated as per the principles of the Forgiving Roadside Section of DN-GEO-03036 where deemed feasible when considered in line with environmental, engineering and economic constraints.

If the hazard cannot be mitigated, the Designer shall assess if the hazard ranking is very high, high, medium or low and record it in the risk assessment sheet (Appendix C contains a non-exhaustive list of hazards to assist the Designer with the ranking). Where a hazard is not included in Appendix C, the Designer is required to use their engineering judgement to rank the hazard.

If Appendix C indicates the hazard ranking is very high for any hazard located within the Clear Zone, a VRS shall be provided regardless of the outcome of the risk assessment procedure.

## 5.4 Sinuosity

The sinuosity of a road is defined as the actual section length between two points on a road divided by the shortest path between them (see Figure 5.1). The sinuosity index shall be calculated by the Designer as follows:

$$\text{Sinuosity Index (SI)} = \frac{\text{Actual section length between A and B}}{\text{Shortest path between A and B}}$$

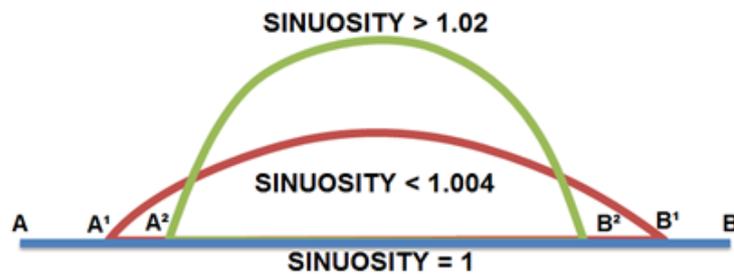


Figure 5.1 Sinuosity Index

The sinuosity index shall be calculated by the Designer on the approach to a hazard as set out below (in all cases the minimum approach length to the hazard considered shall be 200m):

Where the hazard is located within or at the end of a horizontal curve the sinuosity index shall be calculated by the Designer over the full length of that curve on the approach to the hazard (see Figure 5.2).

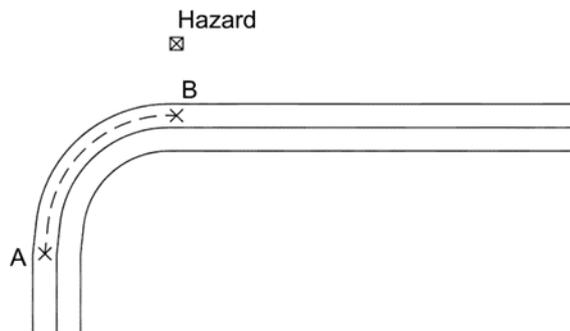
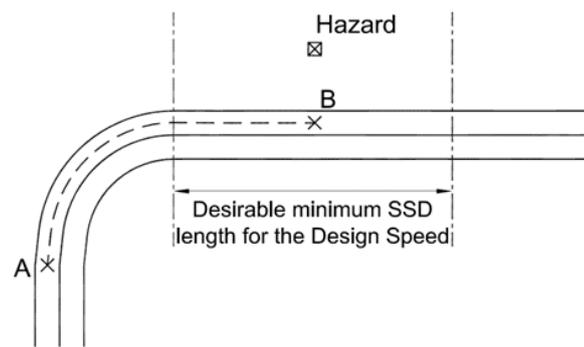


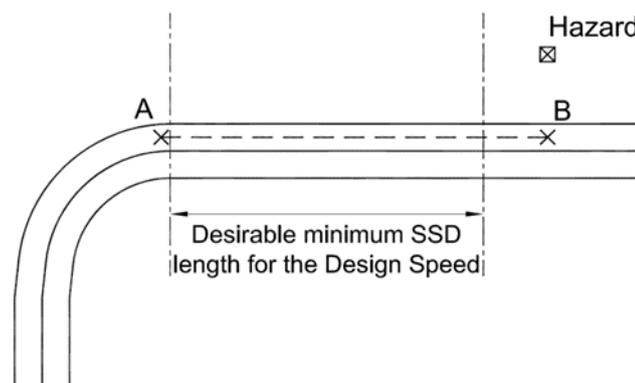
Figure 5.2 Case where the hazard is located within or at the end of a horizontal curve

Where the hazard is located on a straight or nearly straight section of road beyond a horizontal curve but within the Desirable Minimum Stopping Sight Distance (SSD) length for the design/operational speed of that road measured from the end of the curve, the sinuosity index shall be calculated by the Designer over the full length of the curve and the straight or nearly straight section of road up to the hazard location (see Figure 5.3).



**Figure 5.3 Case where the hazard is located on a straight or nearly straight section of road beyond a horizontal curve but within the Desirable Minimum SSD**

Consideration of the entire horizontal curve length need not be included in the sinuosity index calculation where the hazard is located on a straight or nearly straight section of road beyond the horizontal curve and beyond the Desirable Minimum SSD length for the design/operational speed of that road measured from the end of the curve. The Designer shall consider the curve length which lies within the 200m minimum length on the approach to the hazard only (see Figure 5.4).



**Figure 5.4 Case where the hazard is located on a straight or nearly straight section of road beyond a horizontal curve and beyond the Desirable Minimum SSD**

The Desirable Minimum SSD length shall be as per Table 1.3 (or Table 10.3 where appropriate) of DN-GEO-03031 for the particular design/ operational speed.

Nearly Straight sections shall be as per Figure 7.6 of DN-GEO-03031.

Sinuosity is divided into three sinuosity rankings as follows:

- High (H) - Sinuosity Index  $> 1.02$ ;
- Medium (M) –  $1.004 \leq \text{Sinuosity Index} \leq 1.02$ ;
- Low (L) - Sinuosity Index  $< 1.004$

Where the hazard is located on the inside of a bend or straight or located on the outside of a bend equal to or greater than 1000m radius, a 'Low' sinuosity ranking shall be assigned.

The Designer shall record the calculated sinuosity index and sinuosity ranking in the risk assessment sheet.

## 5.5 Collision Rate Ranking

The collision rate thresholds for a particular section of road shall be reviewed by the Designer using data compiled by Transport Infrastructure Ireland.

Collision rates have been calculated by TII, and then using the methodology described in GE-STY-01022, compared with historical rates and the following thresholds established:

1. Twice Above Expected Collision Rate;
2. Above Expected Collision Rate;
3. Below Expected Collision Rate;
4. Twice Below Expected Collision Rate.

Collision Rate Thresholds can be downloaded from <https://data.gov.ie/> under the Transport Infrastructure Ireland section of the Transport theme and shall be assessed for the section of road under consideration. The Designer shall confirm the accuracy of the information with the road authority.

The Designer shall assign a Collision Rate Ranking to the Collision Rate Threshold for the section of road under consideration as follows and record it in the risk assessment sheet:

- High (H) - Twice Above Expected Collision Rate;
- Medium (M) - Above Expected Collision Rate;
- Low (L) - Below Expected Collision Rate and Twice Below Expected Collision Rate.

## 5.6 Risk of a Vehicle Leaving the Road

The Designer shall take account of both the collision rate ranking and the sinuosity ranking for the section of road being examined and determine the risk of the vehicle leaving the road using the matrix in Table 5.1.

**Table 5.1 Risk of a Vehicle Leaving the Road**

Risk of a Vehicle Leaving the Road		Collision Rate Ranking		
		H	M	L
Sinuosity Ranking	H	H	H	M
	M	H	M	L
	L	M	L	L

*Note: H=High, M=Medium, L=Low*

## 5.7 Overall Risk Rating

The Designer shall compare the risk of a vehicle leaving the road against the Hazard Ranking using the matrix in Table 5.2 to determine the Overall Risk Rating for the location under consideration.

**Table 5.2 Overall Risk Rating**

Overall Risk Rating		Hazard Ranking		
		H	M	L
Risk of a Vehicle Leaving the Road	H	H	H	M
	M	H	M	L
	L	M	L	L

Note: H=High, M=Medium, L=Low

For each hazard location, a determination shall be made as follows:

- If the overall risk rating is High, the hazard shall be mitigated or a VRS shall be provided to meet the requirements of this Standard.
- If the overall risk rating is Medium, the hazard, if it is within 2m of the carriageway edge, shall be mitigated or a VRS shall be provided to meet the requirements of this Standard.
- If the hazard is located  $\geq 2m$  from the carriageway edge, the Designer shall assess the hazard level and the risk of the vehicle leaving the road on site and determine if a VRS is required.
- If the overall risk rating is Low, a VRS is not required.

Each determination shall be recorded in the risk assessment sheet along with the reason for providing or not providing the VRS.

## 5.8 Site Survey

The Designer shall visit the site as part of this risk assessment procedure to confirm the need or otherwise for a VRS at all locations considered. Where considering retrofitting existing VRS, this survey can also incorporate the VRS condition survey described in the following sections.

## 5.9 VRS Design

If the Risk Assessment Procedure indicates that a VRS is required, the Designer shall:

- Complete the VRS design in accordance with the requirements of DN-REQ-03034; or
- Follow the VRS design process described in Section 6 where the VRS is located at a constrained location and falls within one of the categories listed in Section 1.

## 6. Design Process for Constrained Locations

### 6.1 Introduction

This Section provides information on the general design process to be adopted for VRS at Constrained Locations falling within the categories noted in Section 1. For online improvements where it has been assessed that a VRS is required using the Risk Assessment Procedure in Section 5, and a fully compliant design to DN-REQ-03034 cannot be achieved in the scenarios and categories noted in Section 1, the process below can also be followed. The initial Data Collection and Assessment step included in Figure 6.1 below will already have been undertaken at this stage for such scenarios.

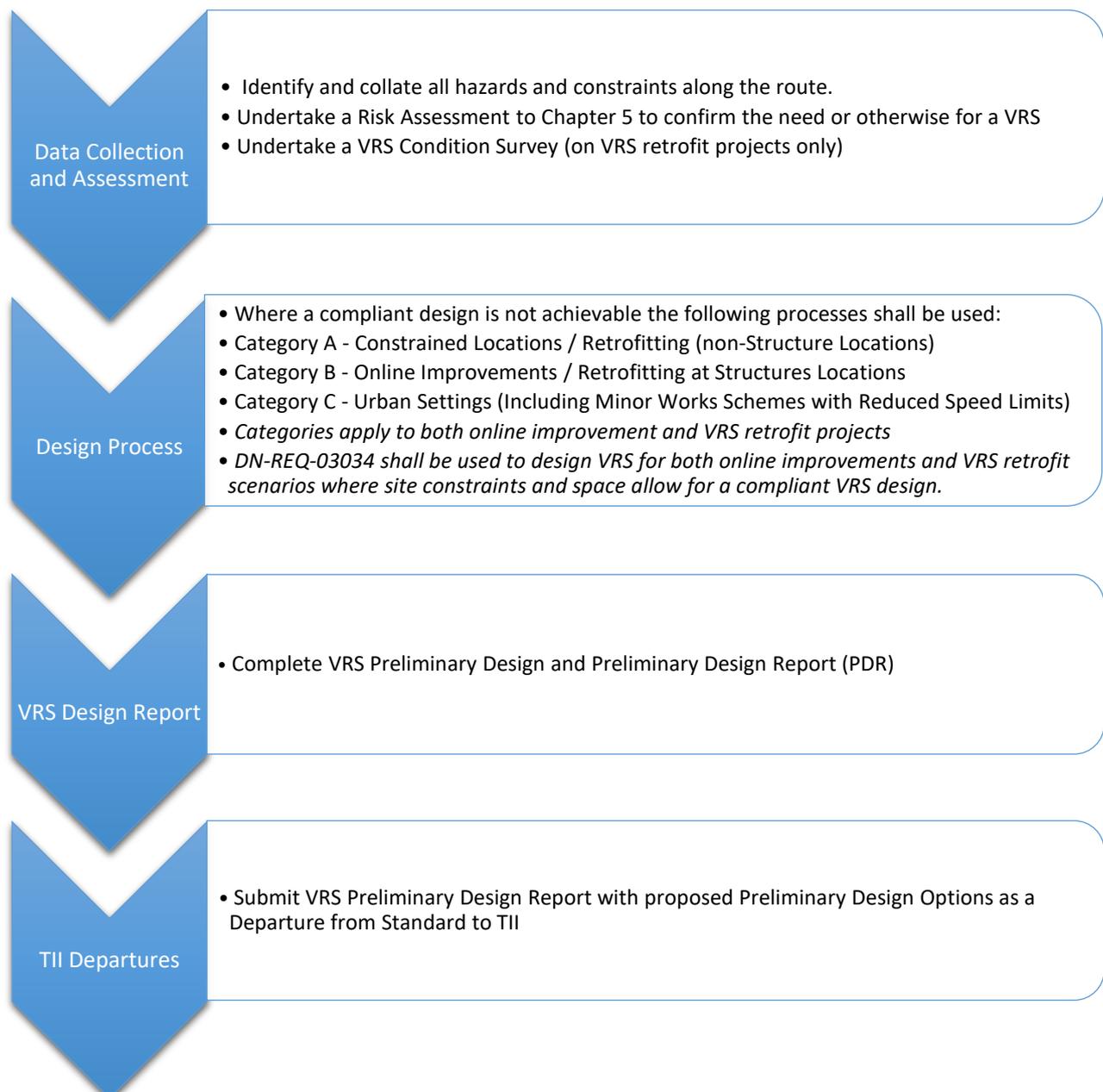


Figure 6.1 Retrofitting VRS Process Flowchart

## 6.2 Data Collection and Assessment

### 6.2.1 Apply the Principles of Forgiving Roadsides

Following the collation of all site and constraint information, the Designer shall assess whether the hazard can be removed, relocated or mitigated within the available cross section. In instances where the hazard cannot be removed or mitigated, a VRS may be considered, pending the completion of a formal Risk Assessment as detailed in the next section.

### 6.2.2 Risk Assessment

In accordance with the Section 5 Risk Assessment Procedure and Appendix B, a formal Risk Assessment should be undertaken wherever a VRS installation or removal is under consideration. The initial assessment and site survey may result in a design solution which proposes the removal of the existing VRS or provides a justification for not including a VRS. It may be that the VRS cannot be installed in accordance with DN-REQ-03034 due to limited space or other reasons outlined under the constraints section of this document. The outcome of the Risk Assessment shall form the basis of subsequent Preliminary Design Options for consideration by TII.

### 6.2.3 VRS Condition Survey

Where a VRS already exists, a site survey shall be undertaken to assess the condition of the existing installation and to confirm its adequacy for the given location and hazard treatment. The VRS condition survey should record the following information as a minimum and include suitable photographs:

- Hazards at the location (existing and new)
- Length of VRS
- Approach to and departure from the hazards
- VRS type including I.S. EN 1317 compliance status if known (is it a CE marked system?)
- Post type
- Post stability
- Post spacing
- Post installation (driven, concrete foundation, socketed, surface mounted)
- Terminal type, upstream and downstream (are they I.S. EN 1317 Part 7 compliant?)
- Setback
- Working width
- Height of VRS
- Damage evident to the existing VRS
- Grade of bolts used compared with manufacturer's specification (if available)
- Bolt attachments
- Taper rate, if any
- Connections and Transitions to other VRS, if any
- Parapet type – masonry, reinforced concrete, steel or aluminium.
- VRS connection to parapet, if any.

- Possible vehicle intrusion.
- General condition of VRS (poor, fair, good)

Thereafter, this information is used to decide whether a replacement VRS is required for the location or whether localised repairs or alterations are appropriate.

A sample VRS condition survey template is provided in Appendix D and is available for download from the Downloads section of the TII publications website:

<http://tiipublications.ie/downloads/>

The completed VRS condition survey template should be included where relevant as part of the VRS Preliminary Design Report (PDR) submission to TII. Where multiple restraint systems on a route are being considered, the information gathered should be tabulated and analysed in order to prioritise repair and replacement programmes.

## 6.3 Preliminary Design Process

If, following the completion of the Data Collection and Assessment stage, a VRS is deemed to be the most appropriate hazard mitigation, the Designer shall consider whether the VRS can be provided in accordance with DN-REQ-03034. In most instances considered under this Standard, a compliant VRS cannot be provided and as such the Designer shall prepare Preliminary Design Options for each hazard location in accordance with the information provided for developing such options under each of the Categories, A, B and C detailed in this document. Once developed, these will form the basis for consultation and approval procedures with TII.

Sections 7 to 9 include worked examples for a number of possible scenarios. They have been prepared to support the development of bespoke and tailored solutions for each hazard and location. They have not been developed to provide the Designer with a specific design solution for a particular constraint. The number of site-specific constraints which could exist at any one hazard location on the National Road network means it is not practical to prescribe definitive solutions.

### 6.3.1 General Design Principles

The general principles applied to the design processes can be summarised as follows:

- Where the work is not part of an online improvement or other minor improvement scheme, consult with the road authority and/or TII as appropriate to confirm whether any improvement or refurbishment works are planned at the proposed project location, such as a pavement renewal or bridge rehabilitation scheme. If such additional works are planned, the Designer, in consultation with the road authority and/or TII as appropriate, shall consider whether it is appropriate to partly or wholly delay the project works for incorporation into the subsequent project. In some instances, the safety risk of taking this approach may be such that the proposed project cannot be delayed.
- For the proposed VRS location, analyse all site-specific constraints which may prohibit a compliant VRS design, such as setback, working width, visibility, etc.
- Develop suitable design options identifying the advantages and disadvantages of each option.
- Identify the preferred option with appropriate reasoning, including consideration of whole life cycle costs. This assessment can be undertaken in detail using the SAVeRS tool (refer Section 6.3.3 Whole Life Cycle Cost Analysis below).

- Prepare a VRS Preliminary Design Report (PDR) which includes the design options under consideration, a recommendation on the preferred solution, and any necessary Departures from Standard. Sample VRS PDR summary templates for each category of constraint are contained in Appendix E.
- Submit the VRS PDR as a Departure from Standard for assessment and approval by TII. The departure is for the approval to use this standard as it permits designs which may not be fully compliant but are risk assessed by the Designer as being the most appropriate solution given the site constraints.

### **6.3.2 Development of preferred design options**

To assist the Designer in developing a final preferred solution, a suite of possible design options is presented at the end of Sections 7, 8 and 9. There are three tables for each category which are provided as follows:

- Possible hazard mitigation measures as per the Forging Roadsides Section in DN-GEO-03036.
- Possible VRS design options.
- Other possible options where mitigation measures or VRS solutions are not possible to implement.

These tables describe the advantages and disadvantages of the various options and provide commentary on the limitations for incorporating each into a preferred design solution. A solution may be a combination of the listed options or Designers may need to develop other innovative solutions beyond those listed in the tables, depending on the site-specific characteristics. A final solution for a particular scenario will be dependent upon items such as the site-specific constraints, the results of the design process and approval from TII as appropriate.

Worked examples for various scenarios are also included in Appendix F.

### **6.3.3 Whole life cycle cost analysis**

The Designer shall consider the whole life cycle cost of design solutions when developing the preferred design option. This is particularly important when considering alternative mitigation measures to remove the need for a VRS.

While the initial cost of mitigation measures may be higher than the installation of a VRS e.g. purchasing additional land to allow removal of the hazard from the Clear Zone, the whole life costing of a VRS solution should be taken into account when considering the cost benefit analysis. To assist with this process, the SAVeRS tool shall be used. Using input parameters such as the road characteristics and collision data already embedded in the tool based on the region chosen, the SAVeRS tool can provide an estimate of the whole life costing of a VRS including construction, maintenance and repair costs of the system, plus potential injury costs based on the predicted crash rate calculated. The SAVeRS tool, guideline document and user manual can be downloaded from the Downloads section of the TII Publications website.

The Designer shall provide the cost benefit analysis of the proposed design options when submitting a VRS PDR to TII for approval. Appendix G contains sample input data for the use of the SAVeRS tool. This data has been used in Worked Example 4 in Appendix F.

## 6.4 VRS Preliminary Design Report (PDR)

The design procedures for works on the National Road network presented in this document require the preparation of a VRS PDR for submission to TII. If the project is a standalone VRS retrofit or new installation at a constrained location, then the VRS PDR shall be a standalone document. If the VRS being considered are part of a minor improvement scheme/ online realignment being designed in accordance with DN-GEO-03030, the VRS PDR can be included as a section of the overall scheme Preliminary Design Report.

The purpose of the VRS PDR is to list all proposed lengths of VRS for the project and where compliant VRS cannot be provided to summarise the design process followed to arrive at the preferred solution. The report shall:

- Identify the physical constraints, issues and site-specific challenges encountered at the VRS location being considered;
- For non-compliant VRS, present the potential design solutions which the Designer has considered in order to account for the existing hazards, including any Relaxations and Departures from Standard required and
- Thereafter, outline the methodology adopted to arrive at these design solutions in line with the processes presented in this document.

VRS PDR templates for each category of constraint are contained in Appendix E and are available for download from the TII publications website.

## 6.5 Departures

The VRS PDR shall be submitted through the TII departures website.

Where an existing VRS is being replaced, the Designer shall complete the VRS condition survey template contained in Appendix D and submit it to TII as part of the VRS PDR submission. Worked examples of VRS PDRs have been included in Appendix F.

## 7. Category A – Constrained Locations on Online Improvements / Retrofitting

Category A covers scenarios where existing or proposed site conditions along the route and away from major structures and bridges do not allow for the provision of a compliant design. This section outlines the potential constraints that could be encountered in such scenarios, the design process to be followed when considering retrofitting a legacy VRS or designing a new VRS at a constrained location and potential solutions that may be applied in typical situations.

### 7.1 Potential Site-Specific Constraints

There are a number of constraints which do not allow for a compliant design to DN-REQ-03034. A non-exhaustive list is as follows:

- Lack of working width or setback for a new VRS (see Figure 7.1).
- Installations within the working width or in front of the VRS (see Figure 7.2).
- Accesses and junctions preventing the full length of need of the system being achieved (see Figure 7.3).
- VRS at junctions (see Figure 7.4).



Figure 7.1 Lack of working width or setback



Figure 7.2 Installations within the working width or in front of the VRS



Figure 7.3 Accesses and junctions preventing full length of need



Figure 7.4 VRS at Junctions

## 7.2 Design Process and Flow Chart

The design process to be followed when considering retrofitting VRS at locations on the National Road network where site-specific constraints do not allow a compliant design is presented in Figure 7.5. The process can also be used from Step 4 onwards for locations on online improvements where the Risk Assessment Procedure in Section 5 has shown that a VRS is required but a compliant design is not achievable.

The following sections propose steps to assist the Designer in developing the most appropriate design solution based on the site-specific constraints.

### Step 1: Consultation

The Designer shall consult with the Road Authority, TII Network Management and/or TII Roads and Tunnels Safety Section to determine if there are any minor improvement, road safety or maintenance schemes planned for the location. This may allow integration of the project with other scheduled works.

### Step 2: Hazard identification and Mitigation

The Designer shall undertake a site survey of the existing or proposed project in accordance with Section 6.2.3 and Appendix D to identify hazards that require protective measures, or are being protected by an existing VRS. For new-build schemes such as online realignments the designer shall base their assessment on a combination of the existing hazards and site constraints and those proposed as part of the new design. An assessment of the lands made available shall be undertaken as early as possible in such schemes and appropriate actions taken.

When a hazard has been identified, the Designer shall determine whether mitigation measures can be implemented to sufficiently reduce the risk or remove the hazard from the Clear Zone in order to remove the need for a VRS. VRS are also regarded as a hazard and have associated maintenance costs. A mitigation measure that removes the need for a VRS is always preferable over the installation of VRS.

The Forging Roadsides Section in DN-GEO-03036 provides information in relation to hazard mitigation listing the various solutions in order of preference; VRS installation should only be considered once all forms of mitigation have been explored and considered unsuitable.

### Step 3: Risk Assessment

The Designer shall undertake a risk assessment in accordance with Section 5 of this document, including desk top studies to calculate sinuosity and collision rates. This process can be used to:

- determine whether or not a VRS is required at the location based on current data, and
- inform the Designer of possible alternatives which should be considered.

The Designer shall submit the completed Risk Assessment undertaken in accordance with Section 5 to TII as part of the VRS PDR. Where the results of the Risk Assessment show that a VRS is not required at the location, the Risk Assessment sheet will form part of the main Preliminary Design Report. If the Risk Assessment findings indicate that a VRS is still required, the Designer shall proceed to the next step.

#### **Step 4: Design compliance**

Where it has been determined that a VRS is required, the Designer shall assess whether a DN-REQ-03034 compliant design can be implemented and if so the Designer shall proceed to design the VRS in accordance with DN-REQ-03034. If a compliant design cannot be implemented, the Designer shall identify the constraints preventing a compliant design.

In new build scenarios, there may be greater scope for the design to be adjusted to allow for a compliant VRS installation, for instance it may be possible to move accesses or junctions to allow for an appropriate approach/departure length to be installed.

#### **Step 5: Constraints identification**

The Designer shall assess what specific constraint, or combinations of constraints, are present on site and analyse them to determine whether a bespoke design solution can be provided which will reduce the collision and injury risk for an errant road user. The options should be considered in line with the requirements outlined in the sample VRS PDR template contained in Appendix E.

#### **Step 6: Development of Preferred Design Solutions**

The preferred design solution will be dependent on the various factors outlined in the previous section. The information in this section is provided to assist the Designer in developing the most appropriate solution for the site-specific circumstances.

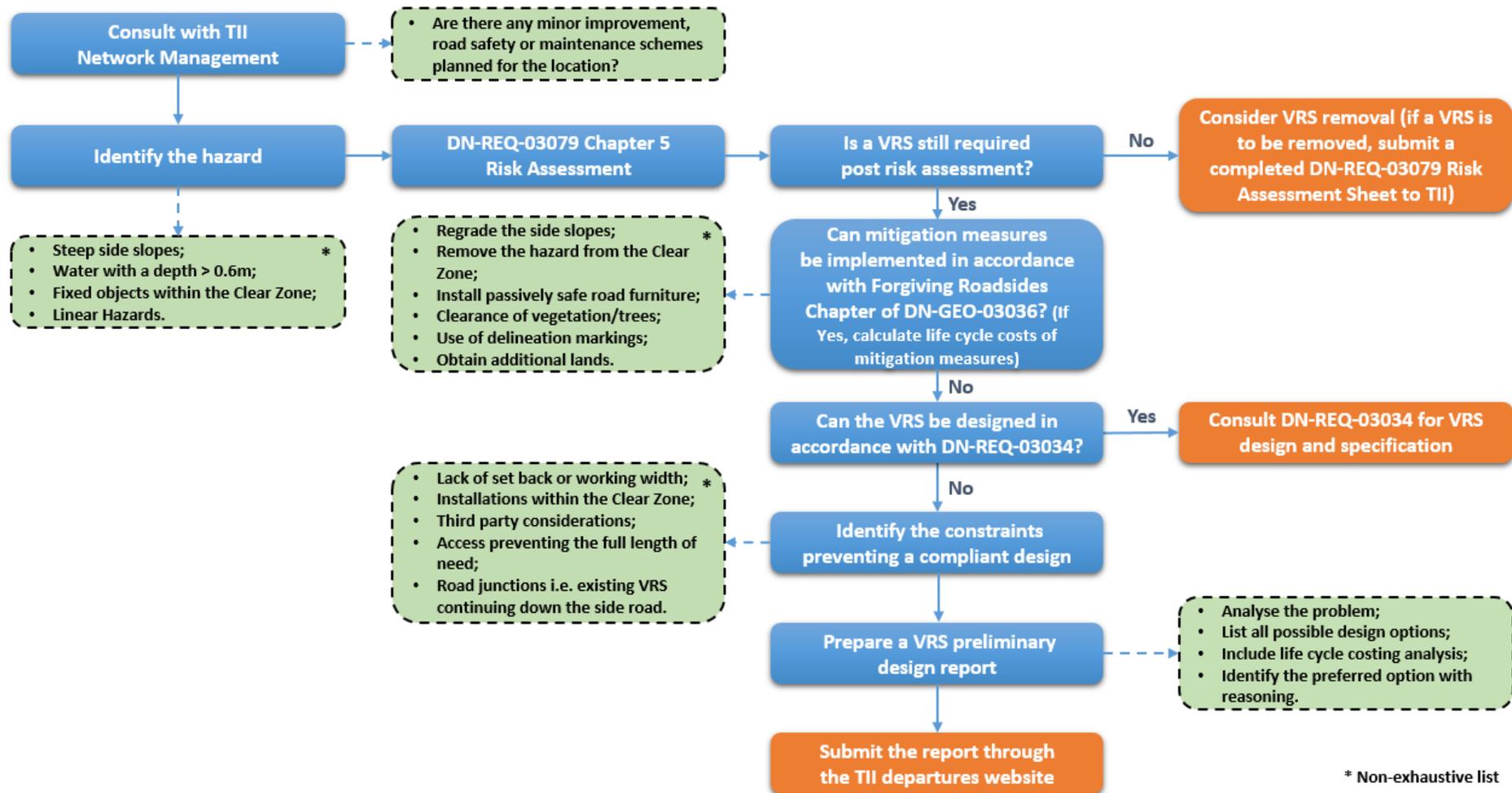
Tables 7.1 to 7.3 provide a list of possible design options for VRS at constrained locations. The Designer may develop and propose solutions other than those included in the tables.

#### **Step 7: VRS PDR**

The VRS PDR provides a summary of the Designer's assessment of the VRS location and details of the proposed design options developed. The Designer's preferred solution with reasoning, including details of the whole life cycle cost analysis shall also be included.

The VRS PDR shall be submitted through the TII departures website.

A worked example of a VRS PDR for VRS at constrained locations is included in Appendix F for information.



Note: For online improvements, this design process can be used where it has been assessed a VRS is required but a compliant VRS Design is not achievable.

Figure 7.5 VRS preliminary design process flowchart - Constrained Locations

**Table 7.1 Possible design solutions for Constrained Locations on Online Improvements / Retrofitting (Away from Structure / Bridge Locations)– Mitigation measures**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Revise the road layout or cross-section to lower the risk	<p>May reduce the overall risk ranking of the location and remove the requirement for a VRS.</p> <p>May facilitate removal of the hazard to create a forgiving roadside without the need for a VRS.</p>	<p>Additional lands will most likely need to be purchased to facilitate this solution.</p> <p>High initial costs to purchase land and to design and construct solution.</p>	Life cycle costs of a VRS solution (including installation, maintenance, repair, accident and injury costs) should be considered versus the purchase of additional land.
Regrade side slopes so as they are not considered a hazard to an errant vehicle in line with DN-REQ-03034	The need for a VRS may be mitigated creating a forgiving roadside.	<p>May require the purchase of additional land to accommodate gentler slopes.</p> <p>Knock on effects to existing drainage etc. would need to be accounted for.</p>	<p>Land available may be limited.</p> <p>Life cycle cost analysis should be considered.</p>
Remove the hazard from the Clear Zone	The need for a VRS may be mitigated creating a forgiving roadside.	May not be feasible e.g. natural watercourse or steeply sloping terrain adjacent to the road may be the hazard.	Third party consultations may be required e.g. removing a utility pole or burying services.
Install passively safe road furniture	The need for VRS may be mitigated creating a forgiving roadside.	May be expensive to remove existing and replace with passively safe in the retrofit scenario.	A life cycle cost analysis (including installation, maintenance, repair, and accident and injury costs) should be considered versus using non-passively safe furniture with a VRS.
Clearance of vegetation/trees within the Clear Zone	Need for VRS may be mitigated creating a forgiving roadside.	The rate of growth of vegetation may require regular maintenance which could increase the annual cost.	<p>Life cycle costs (including installation, maintenance, repair, accident and injury costs) should be considered versus the cost of removing the vegetation.</p> <p>Ecological/environmental impacts should be considered.</p>

**Table 7.2 Possible design solutions for Constrained Locations on Online Improvements / Retrofitting (Away from Structure / Bridge Locations) – VRS Solutions**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Higher containment VRS	A higher containment level may allow installation of the VRS in locations where a lack of space is the constraint.	Increased impact severity of collision Potentially higher installation costs.	A life cycle cost analysis should be considered as part of proposal.  Mandatory limitations on impact severity levels as detailed in DN-REQ-03034 should be considered.
Bespoke VRS solution	VRS can be designed to provide appropriate protection.  Aesthetic requirements can be accounted for in design.	May be an expensive solution.	Require approval for use by TII.  A life cycle cost analysis should be provided as part of proposal.
Crash cushions (end to end crash cushion/terminal)	Could be used to protect isolated hazards such as a single tree or utility pole instead of VRS which would require approach and departure lengths.	May be aesthetic issues depending on the location.  Initial cost of installation may be high.  Crash cushions are still a hazard.  May not restrain a vehicle.	A life cycle cost analysis should be provided as part of proposal.
Use of innovative products that may be available on the market to suit certain conditions	May be designed to suit site-specific circumstances.	May not be CE marked.	Require approval for use by TII.  A life cycle cost analysis should be provided as part of proposal.

**Table 7.3 Possible design solutions for Constrained Locations on Online Improvements / Retrofitting (Away from Structure / Bridge Locations) - Other Solution where mitigation / VRS not possible**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Delineation marker posts, warning signage and road markings.	Alert the road user to the hazard.	The hazard is highlighted to the road user but is not protected.	<p>Only permitted where all other solutions have been shown to be unachievable within the VRS PDR i.e. mitigation and/ or protection of the hazard not possible.</p> <p>Solution should be used in conjunction with other solutions e.g. high containment kerbs in conjunction with delineation markers and appropriate warning signage and road markings.</p> <p>Approval for use should be obtained from TII.</p> <p>Not suitable for high speed locations.</p> <p>Life cycle cost analysis should be provided as part of proposal.</p>
High containment kerbs.	<p>May be suitable for use in lower speed locations in place of a VRS.</p> <p>Less visually intrusive.</p>	Lower containment level, not suitable for use in high speed locations.	<p>Only permitted where all other solutions have been shown to be unachievable within the VRS PDR.</p> <p>Solution should be used in conjunction with other solutions e.g. delineation markers and appropriate warning signage and road markings.</p> <p>Approval for use should be obtained from TII.</p> <p>Not suitable for high speed locations.</p> <p>Life cycle cost analysis should be provided as part of proposal.</p>

## 8. Category B - Online Improvements / Retrofitting at Existing Structures

Category B includes VRS at road bridges, rail bridges and culvert crossings. This section outlines the potential constraints that could be encountered in such scenarios, the design process to be followed and potential solutions that may be applied in typical situations.

Category B will likely provide greater issues when dealing with legacy network issues than for new build scenarios.

A major risk of pocketing may exist where VRS are connected to bridge parapets. The potential for pocketing occurs due to a sudden change in stiffness between the parapet and connecting VRS resulting in the rigid parapet end penetrating the vehicle.

VRS constraints at structures usually relate to historical bridge parapets and the transition from the adjacent VRS to the bridge parapet itself. Other site-specific constraints in relation to VRS design that fall into Category A may also be present at structures. The design process described in this section however is specific to VRS at structures. The Designer may need to combine some of the design processes from Category A and Category B to deal with all constraints at a particular location.

The potential exists for issues to arise where accesses or junctions are located in close proximity to structures. This will impact on the possibility to provide adequate approach and departure lengths for the VRS / parapet.

### 8.1 Potential Constraints at Structures

Figure 8.1 below shows an example of a river bridge crossing on the National Road network with constraints common to many similar crossings.



Figure 8.1 VRS at river bridge crossing

Typical VRS design challenges include:

- Historical parapets with unknown containment values;
- No direct connection or transition between the adjacent VRS and the bridge parapet, (see Figure 8.1); and
- Adjacent VRS is a pre-I.S. EN 1317 system with concrete posts (see Figure 8.2).



**Figure 8.2 No connection to bridge parapet**

Figure 8.3 below represents a railway bridge crossing typical of those found on the National Road network. Issues associated with such locations include:

- Pre-I.S. EN 1317 parapet which may need to be replaced;
- No transition included from the VRS to the bridge parapet;
- An unapproved connection detail which does not appear to transition suitably from the semi-rigid barrier to the rigid concrete parapet (see Figure 8.4); and
- Adjacent VRS is a pre-I.S. EN 1317 system which may include timber posts.



**Figure 8.3** VRS at railway bridge crossing



**Figure 8.4** Unapproved connection detail

Figure 8.5 below provides an example of a culvert crossing on the National Road network. The constraints from the photograph which are common to many similar culvert crossings are:

- No end terminals provided;
- VRS has no working width;
- The length of need of the hazard is not catered for;
- The VRS height above the carriageway is too low; and
- The VRS is a pre-I.S. EN 1317 system with timber posts.



**Figure 8.5 VRS at culvert crossing**

Further site constraints that could impact upon the provision of a compliant design to Standard that may be encountered at structures include:

- Masonry parapets not designed to DN-REQ-03034;
- Cultural heritage issues may prohibit modification or demolition of an existing parapet;
- Insufficient lands available to provide the required approach and departure lengths; and
- Accesses or junctions located adjacent to the structure that may not allow the required approach and departure lengths.

## 8.2 Design Process and Flow Chart

The design process to be followed when considering retrofitting VRS at structures on the National Road network is presented in flowchart format in Figure 8.6. Its aim is to assist the Designer in developing the most appropriate design solution so as to overcome the constraints outlined above and any other site-specific issues that may exist. The following sections provide a breakdown of the steps involved.

### Step 1: Consultation

As with Category A, the Designer shall consult with the Road Authority, TII Network Management and/or the TII Roads and Tunnels Safety Section to determine if there are any minor improvement, road safety or maintenance schemes planned for the location. This may allow integration of VRS works with other scheduled works. Additionally, the Designer shall contact the TII Bridge Management Section to determine if the structure is included in a capital refurbishment programme. This may allow integration of VRS works with other planned bridge refurbishment works.

### Step 2: Hazard Identification and Mitigation, Step 3: Risk Assessment, Step 4: Design Compliance and Step 5: Constraints Identification

These steps are identical to those described in Category A and shall be followed for the Category B scenarios.

## Step 6: Design options

The Designer should develop appropriate design options to overcome the site-specific constraints in consultation with the TII Bridge Management Section. The options should be considered in line with the requirements outlined in the sample VRS PDR contained in Appendix E.

The preferred design solution will be dependent on various factors including:

- The hazard being protected;
- The type of structure;
- The site-specific constraints;
- Land available;
- Other planned works;
- Heritage issues; and
- The existing parapets and VRS.

Tables 8.1 to 8.3 list possible design options for VRS at structures which are provided to assist the Designer in developing the most appropriate solution for the site-specific characteristics.

A possible solution to protect an existing concrete parapet may be to run a VRS with adequate setback and working width across the structure in front of the vehicle parapet as there may be space available in the hard shoulder to do so. However, if there is only a narrow hard strip, a compliant VRS design may not be achievable in front of the bridge parapet. In cases like this a higher containment VRS with a reduced working width could possibly be installed.

Modifying masonry parapets to include a reinforced concrete core with masonry cladding to enable a VRS connection to the approach and departure of the structure may be a suitable solution. The following Standard Construction Details (SCDs) have been developed to assist designers in such scenarios:

- CC-SCD-00412 Safety Barrier to Concrete Parapet, Sheet of 1 of 3 – Transition Details.
- CC-SCD-00413 Safety Barrier to Concrete Parapet, Sheet of 2 of 3 – Connection Details.
- CC-SCD-00414 Safety Barrier to Concrete Parapet, Sheet of 3 of 3 – Foundation Details.

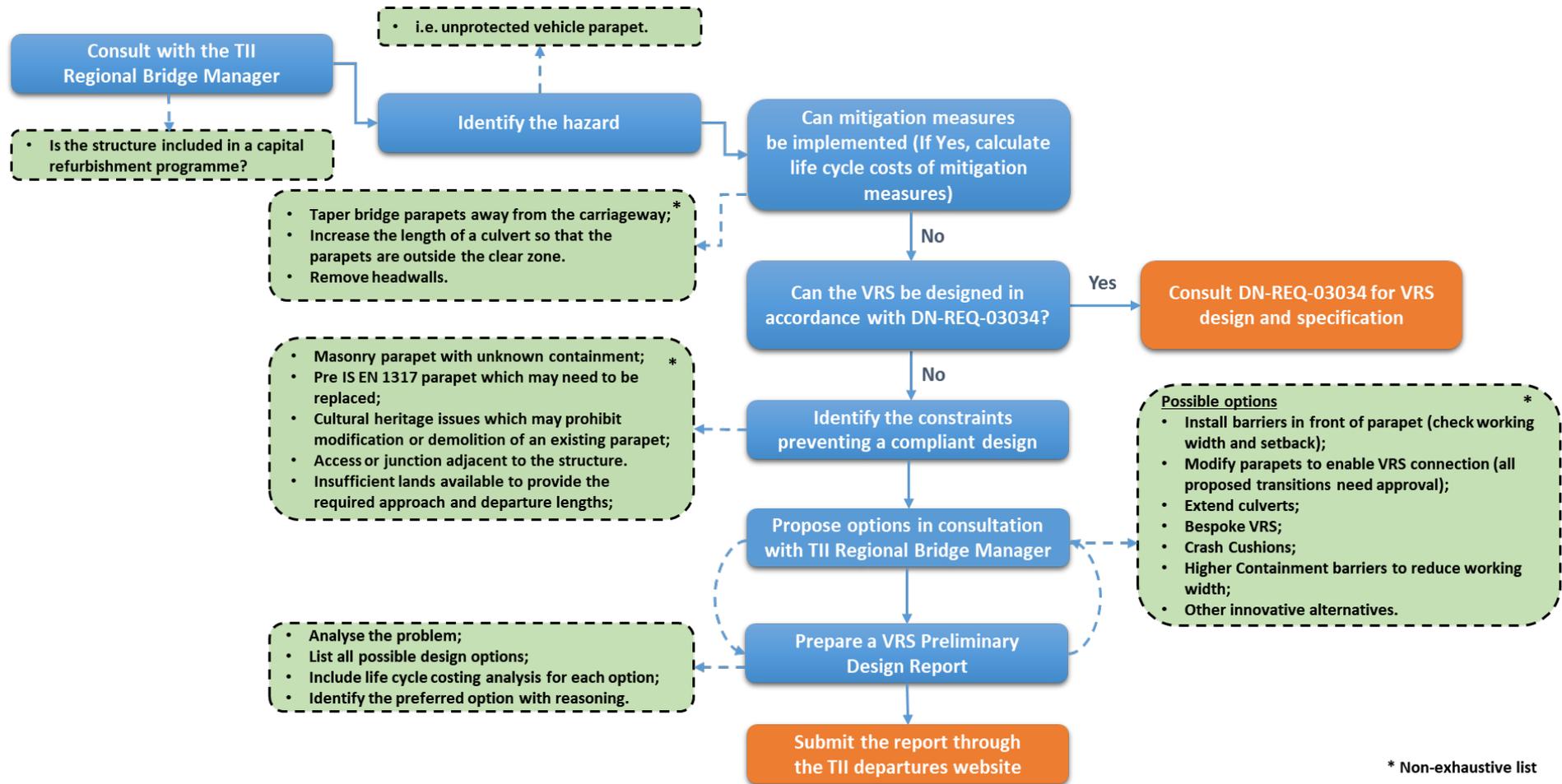
## Step 7: VRS PDR

The VRS PDR provides a summary of the Designer's assessment of the VRS location with details of the design options developed and the Designer's preferred solution, as agreed with the TII Bridge Management Section, including the whole life cycle cost analysis.

All connections from a VRS to a bridge parapet shall require a suitable transition. Where the preferred solution includes an untested transition detail, this shall be submitted to TII at **detailed design stage** for assessment under the TII Transition Assessment Procedure DN-REQ-03081, following approval of the preliminary design solution by TII.

The VRS PDR shall be submitted through the TII departures website.

A worked example of a VRS PDR for VRS at Structures is included in Appendix F for information.



\* Non-exhaustive list

Figure 8.6 VRS preliminary design process flowchart - Existing Structures

**Table 8.1 Possible design solutions for Online Improvements / Retrofitting at Existing Structures Locations – Mitigation Measures**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Taper bridge parapets away from the carriageway.	<p>Hazard of parapet ends reduced.</p> <p>The need for VRS may be mitigated thus creating a forgiving roadside.</p>	<p>The tapered parapets are still a hazard and it may not be possible to taper outside the Clear Zone.</p> <p>May be an expensive solution for a retrofit scenario.</p> <p>May require the purchase of additional land to facilitate construction.</p>	<p>Should not be used if it is possible to install a suitable VRS on the approach and departure to the bridge and connect to the parapet using a suitable transition.</p> <p>Length of need should be accommodated on the approach and departure.</p> <p>Land available may be limited.</p> <p>Heritage structures may restrict works.</p> <p>Life cycle cost analysis should be provided as part of the proposal.</p>
Increase the length of a culvert so that the parapets are outside the Clear Zone.	<p>The need for a VRS may be mitigated thus creating a forgiving roadside</p>	<p>May be an expensive solution for a retrofit scenario.</p> <p>May require the purchase of additional land to facilitate construction.</p>	<p>Land available may be limited.</p> <p>Heritage structures may restrict works.</p> <p>May require a Section 50 application.</p> <p>Life cycle cost analysis should be provided as part of the proposal.</p>
Remove the culvert headwalls and create a passively safe end to a pipe culvert.	<p>The need for a VRS may be mitigated thus creating a forgiving roadside.</p>	<p>The solution may leave an unprotected edge which would be a hazard for pedestrians.</p>	<p>Not suitable for larger culverts.</p> <p>Should not be used where deep-water present.</p> <p>Should not be used where pedestrian activity is likely.</p>

**Table 8.2 Possible design solutions for Online Improvements / Retrofitting at Existing Structures Locations – VRS Solutions**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
<p>Install VRS in front of the existing bridge parapet, suitable solution for locations where sufficient width exists across the bridge deck.</p>	<p>Parapet works not required.</p> <p>VRS protects driver from hazard of parapet and parapet ends.</p> <p>The need for a connection between the parapet and a VRS on the approach to and the departure from the structure is removed.</p>	<p>Maintenance of VRS required.</p> <p>May take from aesthetics of bridge.</p> <p>May not have space to maintain working width and setback of VRS across the structure.</p> <p>Additional works may be required to anchor the VRS posts if bridge deck unsuitable e.g. old masonry arch bridges.</p> <p>Pedestrian activity may be affected.</p> <p>VRS will be closer to the road than the existing parapet.</p>	<p>Working width and setback of VRS should be accommodated.</p> <p>It may not be possible to suitably install VRS posts in the bridge deck.</p> <p>May not be suitable for a location of natural beauty.</p> <p>May not be suitable for a heritage structure.</p> <p>Cyclists and pedestrians need to be accommodated where appropriate.</p> <p>Existing uses e.g. parking in hard shoulder for access to recreation area need to be considered.</p> <p>A life cycle cost analysis should be provided as part of proposal.</p>
<p>Modify masonry parapets to include RC core with masonry cladding to enable VRS connection to approach and departure. May be incorporated either end of the parapets for longer bridges where the existing parapet provides sufficient containment.</p> <p>(See CC-SCD-00412 to CC-SCD-00414).</p>	<p>Parapet ends are protected.</p> <p>Suitable connection and transition can be designed.</p> <p>Full length of need can be facilitated.</p> <p>A RC core with masonry cladding solution can sustain aesthetics.</p>	<p>Initial cost of installation may be high.</p> <p>Expensive bridge upgrade works may be required.</p>	<p>All proposed untested transitions/connections require submission to TII for approval through the departures website.</p> <p>For shorter span bridges, full parapet reconstruction may be required across the full bridge span.</p> <p>Heritage structures.</p> <p>A life cycle cost analysis should be provided as part of the proposal.</p>

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Full parapet replacement to include full length of need on approach and departure.	<p>Parapet ends are protected.</p> <p>Full length of need on approach and departure can be provided.</p> <p>Suitable transition can be provided.</p> <p>May be suitable for urban locations where full length of need may not be required due to lower speeds.</p>	<p>May be an expensive solution for a retrofit scenario.</p> <p>Expensive bridge upgrade works may be required to connect reconstructed parapet.</p>	<p>Requires TII approval.</p> <p>Heritage Structures.</p> <p>A life cycle cost analysis should be provided as part of the proposal.</p>
Bespoke VRS solution.	<p>Parapet can be designed to provide appropriate protection.</p> <p>Aesthetic requirements can be accounted for in design.</p>	<p>May be an expensive solution.</p>	<p>Requires TII approval.</p> <p>A life cycle cost analysis should be provided as part of proposal.</p>
Install crash cushions at exposed parapet ends.	<p>Protects the parapet ends.</p> <p>Expensive bridge upgrade works may be avoided.</p>	<p>Length of need may not be accommodated on approach and departure.</p> <p>Only protects against collision risk at parapet ends.</p> <p>Will not improve the performance of the existing parapet.</p> <p>May take from aesthetics of bridge.</p> <p>May prove an expensive solution.</p>	<p>Heritage structures.</p> <p>Requires TII approval.</p> <p>A life cycle cost analysis should be provided as part of the proposal.</p>
Higher containment VRS.	<p>Working width for smaller vehicles will be reduced and may allow installation in front of an existing parapet where space constraints exist.</p> <p>May allow installation on approach and departure where space constraints exist (a suitable connection/transition to the parapet would still be required).</p>	<p>Increased impact severity of collision with higher containment VRS.</p> <p>Potentially higher installation costs.</p> <p>May take from aesthetics of bridge.</p>	<p>Bridge structure may not be capable of accommodating additional loading of higher containment VRS.</p> <p>Life cycle cost analysis should be provided as part of the proposal.</p>

**Table 8.3 Possible design solutions for Online Improvements / Retrofitting at Existing Structures Locations – Other Solutions where mitigation/VRS not possible**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
<p>Delineation Markers, warning signage and road markings.</p>	<p>Alerts the road user to the hazard.</p>	<p>The hazard is highlighted to the road user but is not protected.</p>	<p>Only permitted where all other solutions have been shown to be unachievable within the VRS PDR i.e. mitigation and/ or protection of the hazard not possible.</p> <p>Should only be used in conjunction with other solutions e.g. high containment kerbs in conjunction with delineation markers and appropriate warning signage and road markings.</p>

## 9. Category C - Urban Settings (Including Minor Works Schemes with Reduced Speed Limits)

Category C includes VRS in urban settings or speed limit zones where the speed limit may have been reduced subsequent to the installation of the VRS. The design process outlined in this section involves a risk-based decision-making process for use when considering the removal or provision of a VRS at such locations, while highlighting the potential constraints that could be encountered. Information in relation to potential solutions that may be applied in typical scenarios is also provided. The design process may also be used for justification for not installing VRS in an already congested and narrow urban National Road scenario. As a general principle, VRS should not be installed on national roads in urban scenarios unless warranted by exceptional or third party risks.

### 9.1 Potential Issues in Urban Settings or Speed Limit Zones

The main issues that may be encountered in urban settings are related to the actual need for a VRS. The Designer shall assess the hazard that is being protected by the VRS and determine whether the hazard remains following the introduction of a reduced speed limit and traffic calming measures. Figures 9.1 and 9.2 show locations where a VRS was installed when the speed limit was 100km/h but has subsequently been reduced.



Figure 9.1 VRS within urban settings



Figure 9.2 VRS within speed limit zones

## 9.2 Design Process and Flow Chart

The design process to be followed when considering VRS in urban settings or speed limit zones is presented in flowchart format in Figure 9.3. The following sections provide a breakdown of the steps involved.

### Step 1: Consultation

As per approach defined within Category A, The Designer shall consult with the Road Authority, TII Network Management and/or TII Roads and Tunnels Safety Section to determine if there are any minor improvement, road safety or maintenance schemes planned for the location. This may allow integration of VRS repair/replacement or removal works with other scheduled works.

### Step 2: Hazard identification

The Designer shall visit the site to undertake a site survey of the existing VRS and surrounding conditions in accordance with Section 6.2.3 and Appendix D to identify the hazards that are currently being protected and any additional hazards that may require protection by a new VRS. In some circumstances, the hazard originally requiring protection may in fact no longer exist, for instance trees or street furniture that may have died or been removed over time.

### Step 3: Traffic calming measures

The Designer should note whether traffic calming measures are in place at the VRS location. Traffic calming measures could include, but are not limited to:

- Speed limit reduced to 50 or 60 km/h;
- Segregated turning lanes;
- Reduced carriageway width;
- Gateway set up;
- Hatched central reserve.

If traffic calming measures have been introduced such as a reduced speed limit, the Designer should assess on site if vehicle speeds have actually been reduced sufficiently to justify VRS removal.

#### **Step 4: Third party considerations**

The Designer should assess whether there are any third party considerations that could require the installation of a VRS. The priority of the VRS in these circumstances may be to protect the third party consideration from an errant vehicle as opposed to protecting the road user from a roadside hazard. Third party considerations could include, but are not limited to:

- Playgrounds;
- Playing pitches;
- Schools;
- Monuments;
- ESB sub stations;
- Pedestrians under a bridge.

If the risk assessment finds that the hazard no longer remains as a result of traffic calming measures and there are no third party considerations that could require a VRS, the Designer should consider removing the VRS. The Designer shall submit a record of their completed risk assessment (Steps 2 – 4) with appropriate reasoning for removal of the VRS to TII.

If the risk assessment finds that the hazard remains or there are third party considerations, the Designer shall proceed to the next step.

#### **Step 4: Mitigation measures**

The Designer should assess whether the hazard can be mitigated so as to remove the requirement for a VRS. Mitigation measures in urban settings or speed limit zones may include:

- Relocating hazards outside of the reduced Clear Zone for urban areas;
- Piping and backfilling of drainage ditches.

If deemed possible, mitigation measures should be implemented to remove the need for a VRS thereby creating a Forgiving Roadside. The Designer should assess the costs of mitigation measures versus the whole life cycle cost of a VRS solution. The VRS PDR submitted to TII for approval should indicate that the mitigation measure is the preferred option.

Where it is not possible to mitigate the hazard, the Designer should move to the next stage in the process.

#### **Step 5: Design compliance**

When it has been determined that a VRS is required and the hazard cannot be mitigated, the Designer should assess whether a DN-REQ-03034 compliant design can be implemented. If a compliant design cannot be implemented the Designer should identify the constraints preventing the design.

#### **Step 6: Constraints identification**

The Designer should identify any constraints that could prevent a compliant design and installation of a VRS to DN-REQ-03034. Constraints include:

- Domestic/commercial/agricultural accesses;
- Street furniture;
- Cultural heritage;

- Headstones/monuments;
- Town/village name installations;
- Pedestrian/cyclist facilities.

The Designer should assess what specific constraint or combination of constraints are present on site and analyse them to determine whether a bespoke design solution can be provided which will minimise the collision risk for an errant road user. The options should be considered in line with the requirements outlined in the sample VRS PDR template contained in Appendix E.

### **Step 7: Development of Preferred Design Solutions**

The preferred design solution will be dependent on various factors at a specific location including:

- the hazard type at the location;
- whether the VRS is still required or not post traffic calming measures;
- whether or not there are third party considerations to be accounted for in the design;  
and
- the presence of any of the various constraints listed in the previous section.

Tables 9.1 to 9.3 include information to assist the Designer in developing the most appropriate solution for the site-specific circumstances.

### **Step 8: VRS PDR**

The VRS PDR provides a summary of the Designer's assessment of the VRS location with details of the design options developed and the Designer's preferred solution with reasoning, including details of the whole life cycle cost analysis.

The VRS PDR shall be submitted through the TII departures website:

Worked examples of VRS PDRs have been included in Appendix F for information.

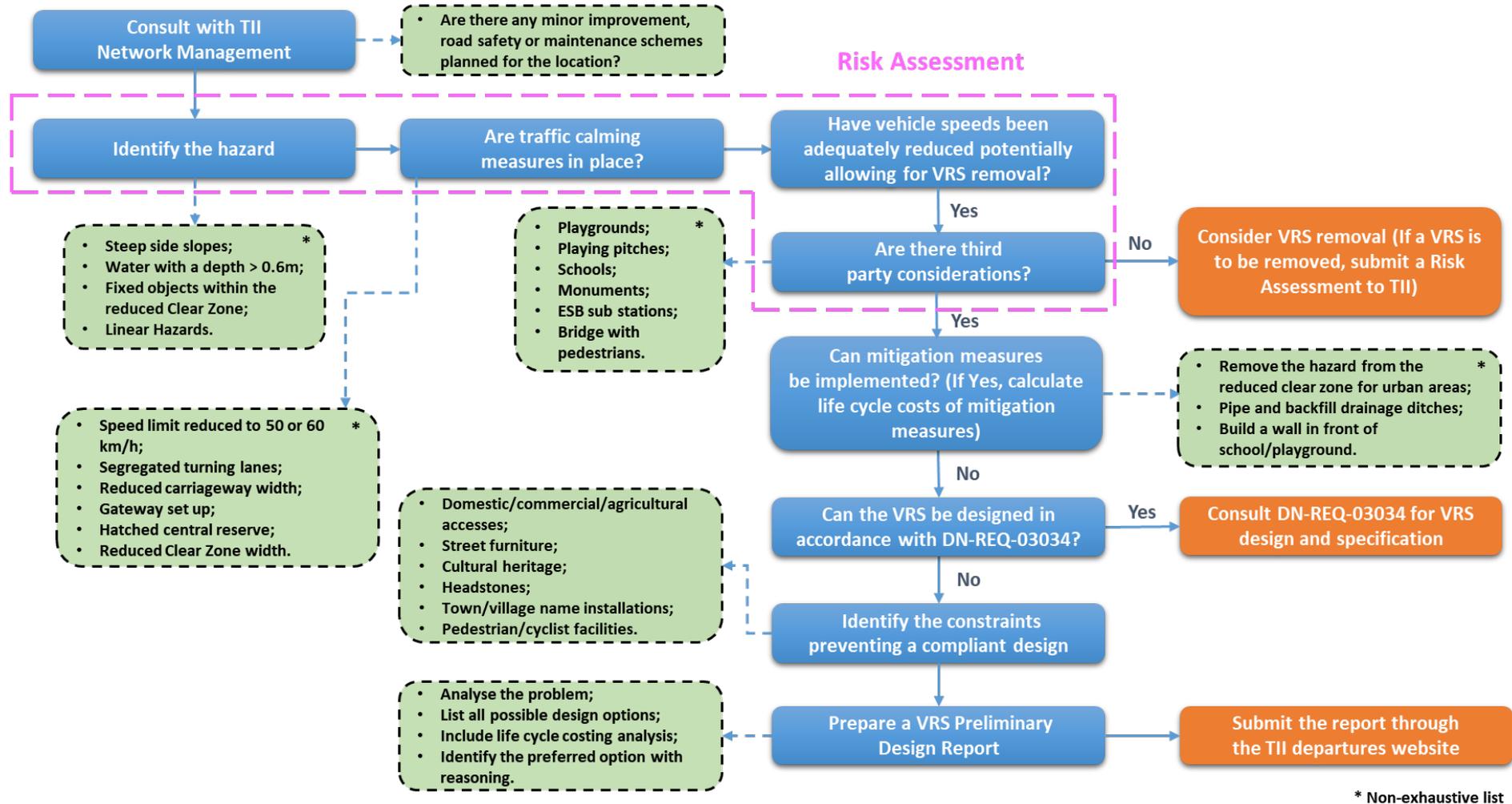


Figure 9.3 VRS preliminary design process flowchart – Urban Settings

**Table 9.1 Possible design solutions for VRS in urban settings – Mitigation Measures**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Removal of VRS	The VRS, being a hazard in itself, is removed. Reduced collision risk to road users.	Cost of removal	The roadside feature should no longer be considered a hazard following completion of a risk assessment. Approval for use shall be obtained from TII prior to removal.
Relocate hazards outside of reduced Clear Zone for urban areas	Hazards removed from the Clear Zone. Reduced collision risk to road users.	May require the purchase of additional land, making it an expensive solution. Land may not be available in an urban situation.	Approval for use shall be obtained from TII.
Pipe and backfill drainage ditches	The hazard of a level difference is removed. Reduced collision risk to road users.	Could lead to flooding if predicted flows not catered for.	Approval for use shall be obtained from TII A life cycle cost analysis of mitigation should be considered.

**Table 9.2 Possible design solutions for VRS in urban settings – VRS Solutions**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
Bespoke VRS solution	VRS can be designed to provide appropriate protection. Aesthetic requirements can be accounted for in design.	May be an expensive solution.	Approval for use shall be obtained from TII. A life cycle cost analysis should be provided as part of the proposal.
Crash Cushions (end to end crash cushion/terminal)	Could be used to protect isolated hazards such as trees or utility poles instead of a VRS which would require approach and departure lengths.	May be aesthetic issues depending on the location. Installation costs may be high. Crash cushions are still a hazard. Crash Cushions may not fit in limited available space.	A life cycle cost analysis should be provided as part of the proposal.
Higher Containment VRS	Working width for smaller vehicles may be reduced and may allow installation in a limited space. Life cycle costs (including injury costs) may be reduced.	Increased impact severity of collision Potentially higher installation costs.	A life cycle cost analysis should be provided as part of the proposal.

**Table 9.3 Possible design solutions for VRS in urban settings - Other Solutions where mitigation/VRS not possible**

Solution	Advantages	Disadvantages	Limitations on/Requirements for use
<p>Delineation Markers (not a standalone solution, should be used in conjunction with other solutions, see limitations)</p>	<p>Alerts the road user to the hazard.</p>	<p>The hazard is highlighted to the road user but is not protected.</p>	<p>Only permitted where all other solutions have been shown to be unachievable with back up information within the VRS PDR i.e. mitigation and/ or protection of the hazard not possible. Not suitable for high speed locations. Approval for use should be obtained from TII. Should be used in conjunction with other solutions e.g. high containment kerbs with appropriate warning signage. A life cycle cost analysis should be provided as part of the proposal.</p>
<p>High Containment kerbs</p>	<p>May be suitable for use in lower speed urban locations in place of VRS. Less visually intrusive.</p>	<p>Lower containment</p>	<p>Approval for use should be obtained from TII. Not suitable for high speed locations. Should be used in conjunction with other solutions e.g. in conjunction with delineation markers and appropriate warning signage and road markings.</p>

# **Appendix A**

## Operational Speeds

Indicative operational speeds for use when assessing/ designing VRS on legacy National Roads **only** are available for download from the Downloads section of the TII Publications website.

# **Appendix B**

Risk Assessment Sheet

 <b>Risk Assessment Sheet for Vehicle Restraint Systems</b>							Date:		Completed By:			
							Location ID/Description:					
							Site Survey Conducted (Y/N):					
Hazard Type, Start and End Co-ordinates	Is Hazard within the Clear Zone? (Y/N)	Can the Hazard be Mitigated? (Y/N)	(1) Hazard Ranking	Sinuosity Index (SI)	(2) Sinuosity Ranking	(3a) Collision Rate Threshold	(3b) Collision Rate Ranking	(4) Risk of a Vehicle Leaving the Road	(5) Overall Risk Rating	Distance of Hazard (m)	VRS to be Installed (Y/N) Start and End Coordinates	Reasons for Installing / Not Installing the VRS
1												
2												
3												
4												
5												
6												
7												

**L = Low, M = Medium, H = High**

(1) Hazard Ranking as per Appendix C

High/Very High (H) as per Appendix C  
Medium (M) as per Appendix C  
Low (L) as per Appendix C

(2) Sinuosity Ranking

High (H) > 1.02  
Medium (M) = 1.004 ≤ SI ≤ 1.02  
Low (L) < 1.004

(3a) Collision Rate Threshold

- (1) Twice above Expected Rate
- (2) Above Expected Rate
- (3) Below Expected Rate
- (4) Twice Below Expected Rate

(3b) Collision Rate Ranking

High (H) = Twice above Expected Rate  
Medium (M) = Above Expected Rate  
Low (L) = Below Expected Rate and Twice Below Expected Rate

(4) Risk of a Vehicle Leaving the Road	Collision Rate Ranking		
	H	M	L
Sinuosity Ranking	H	H	M
	M	H	L
	L	M	L

(5) Overall Risk Rating	Hazard Ranking		
	H	M	L
Risk of a Vehicle Leaving the Road	H	H	M
	M	H	L
	L	M	L

# **Appendix C**

## Hazard Ranking

Hazard Ranking	Hazard Description
<b>Very High</b>	<ul style="list-style-type: none"> <li>• High volume of Road/Railway Crossings</li> <li>• Power/Chemical/Industrial Plant</li> <li>• High volumes of off-road vulnerable road users</li> <li>• Structures not designed for accidental collision loading</li> <li>• Building with risk of collapse</li> <li>•</li> </ul>
<b>High</b>	<ul style="list-style-type: none"> <li>• Lighting Columns that are not passively safe.</li> <li>• Tubular Steel Signposts &gt;89mm diameter by 3.2mm thick, or equivalent strength.</li> <li>• Wooden Poles or Posts with Cross Sectional Area &gt; 25,000mm<sup>2</sup> that do not have breakaway features.</li> <li>• Trees having a girth of 314mm or more measured at 0.3m above the ground.</li> <li>• Concrete posts with Cross Sectional Area &gt; 15,000mm<sup>2</sup>.</li> <li>• All fences (including timber post and rail fences) except those to CC-SCD-00320 or CC-SCD-00321.</li> <li>• Playgrounds/Monuments and other locations of high socio-economic value.</li> <li>• Water of likely depth &gt; 0.6m.</li> <li>• Bridge Parapets, Bridge Piers, Abutments, Railing Ends, Gantry Legs</li> <li>• Location where errant vehicle may encroach onto road/railway which crosses or runs parallel to road.</li> <li>• Substantial fixed objects e.g. walls extending above the ground by more than 150mm with projections or recesses &gt; 100mm and running parallel to the road.</li> <li>• Underbridges or retaining walls &gt;0.5m high supporting the road, where a vehicle parapet or vehicle/pedestrian parapet of the required performance class is not provided.</li> <li>• Industrial sites with potential for explosion or chemical spill.</li> <li>• Rock cutting with rough face.</li> <li>• Steep Embankment Slopes, steeper than 1:2 and ≥1.0m height.</li> <li>•</li> </ul>
<b>Medium</b>	<ul style="list-style-type: none"> <li>• Steep Embankment Slopes, steeper than 1:2 and between ≥0.5m and &lt;1.0m height.</li> <li>• Embankment Slopes between 1:2 and 1:3 (inclusive) and ≥2m height.</li> <li>• Slopes to ditches.</li> <li>• Drainage Items such as culvert headwalls and transverse ditches that are not detailed to be traversed safely.</li> <li>• Hazardous topographical features outside the Clear Zone as detailed in DN-GEO-03036.</li> <li>• Single cross culvert opening exceeding 1000mm measured parallel to the direction of travel.</li> <li>• Culvert approximately parallel to the roadway that has an opening exceeding 600mm measured perpendicular to the direction of travel.</li> <li>• Steep sided cuttings or earth bunds (steeper than 1:2) within the Clear Zone.</li> <li>• Multiple cross culvert openings exceeding 750mm each, measured parallel to direction of travel.</li> <li>• Linear V-ditches alongside the scheme.</li> <li>• Environmental Barriers.</li> <li>•</li> </ul>
<b>Low</b>	<ul style="list-style-type: none"> <li>• Shallow Slopes, between 1:3 and 1:5 gradient and ≥6m in height.</li> <li>• Embankment Slopes between 1:2 and 1:3 (inclusive) and between 0.5m and 2m height.</li> <li>• Substantial fixed objects e.g. walls extending above the ground by more than 150mm with projections or recesses ≤ 100mm and running parallel to the road.</li> <li>•</li> </ul>

## **Appendix D**

VRS Condition Survey



## VRS Condition Survey

VRS ID/Description:	Date:	Inspected by:
<b>Site Survey Notes</b>		
Hazards		
Approach to and departure from hazards		
VRS type (including I.S. EN 1317 compliance status if known)		
Post type		
Post stability		
Post spacing		
Post installation		
Terminal Upstream		
Terminal Downstream		
Setback		
Working width		
Height of VRS above pavement (< 1.5m setback)		
Height of VRS above ground (> 1.5m setback)		
Grade of bolts used compared with manufacturer's specification		
Bolt attachments		
Taper rate, if any		
Parapet type – masonry, reinforced concrete, steel or aluminium		
VRS connection to parapet, if any		
Possible vehicle intrusion		
Damage including description		
Observations		

Signed: \_\_\_\_\_

## VRS Condition Survey



## **Appendix E**

Sample VRS PDR Summary  
Template

**Category A – VRS PDR Template**

<b>VRS ID / Location:</b>		<b>VRS Preliminary Design Report Summary VRS at Constrained Location</b>	
<b>Description:</b>	Insert Image	Insert Image	Insert Image
<b>Length:</b>			

<b>Consultation</b>	<b>Outcome</b>
<b>TII Network Management</b>	
<b>Identify the Hazard(s)</b>	<b>Summary</b>

Analysis	
Need for VRS (reference DN-REQ-03079 - Risk Assessment):	Is the VRS still required post risk assessment?
Can mitigation measures be implemented (Yes/No)?	If "Yes" include proposals and projected life cycle costs:
Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?	If "No" identify the constraints:
Design/Operational Speed:	Road Cross-Section & Traffic Volumes:

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
Option 1:		

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
<b>Option 2:</b>		
<b>Option 3:</b>		

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis
<i>Provide details of the Designer's proposed solution</i>	<i>Provide reasoning as to why this option was chosen over others</i>	<i>Provide details of the life cycle cost analysis undertaken as part of the preferred solution decision</i>

**Category B – VRS PDR Template**

<b>VRS ID / Location:</b>		<b>VRS Preliminary Design Report Summary VRS at Structures</b>	
<p><b>Description:</b></p> <p><b>Length:</b></p>	<p>Insert Image</p>	<p>Insert Image</p>	<p>Insert Image</p>

<b>Consultation</b>	<b>Outcome</b>
<b>TII Bridge Management Section</b>	
<b>Identify the Hazard(s)</b>	<b>Summary</b>

Analysis	
Can mitigation measures be implemented (Yes/No)?	If "Yes" include proposals and projected life cycle costs:
Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?	If "No" identify the constraints:
Design/Operational Speed:	Road Cross-Section & Traffic Volumes:

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
Option 1:		
Option 2:		
Option 3:		

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis
<p><i>Provide details of the Designer's proposed solution</i></p>	<p><i>Provide reasoning as to why this option was chosen over others</i></p>	<p><i>Provide details of the life cycle cost analysis undertaken as part of the preferred solution decision</i></p>

**Category C – VRS PDR Template**

<b>Barrier ID / Location:</b>		<b>VRS Preliminary Design Report Summary VRS in Urban Settings</b>	
<b>Description:</b>	Insert Image	Insert Image	Insert Image
<b>Length:</b>			

<b>Consultation</b>	<b>Outcome</b>
<b>TII Network Management</b>	
<b>Identify the Hazard(s)</b>	<b>Summary</b>
<b>Traffic Calming Measures</b>	<b>Description</b>
<b>Third Party Considerations</b>	<b>Description</b>

<b>Analysis</b>	
<b>Are traffic calming measures in place (Yes/No)?</b>	<b>Have vehicle speeds been adequately reduced (Yes/No)?</b>
<b>Are there third party considerations (Yes/No)?</b>	<b>Is the VRS still required (Yes/No)?</b>
<b>Can mitigation measures be implemented (Yes/No)?</b>	<b>If “Yes” include proposals and projected life cycle costs:</b>
<b>Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?</b>	<b>If “No” identify the constraints:</b>
<b>Design/Operational Speed:</b>	<b>Road Cross-Section &amp; Traffic Volumes:</b>

<b>Design Options Considered (Attach drawings as required)</b>	<b>Relaxations and Departures</b>	<b>Observations</b>
<b>Option 1:</b>		

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
<b>Option 2:</b>		
<b>Option 3:</b>		

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis
<i>Provide details of the Designer's proposed solution</i>	<i>Provide reasoning as to why this option was chosen over others</i>	<i>Provide details of the life cycle cost analysis undertaken as part of the preferred solution decision</i>

## **Appendix F**

VRS PDR Summary – Worked  
Examples

**Worked Example 1 – Category A, VRS at a constrained location**

<b>VRS ID / Location:</b> N56DL-01 (N56DL_100066_S1_B4)		<b>VRS PDR Summary</b> <b>VRS at Constrained Location</b>	
<p><b>Description:</b>                  A short section of existing untensioned corrugated VRS on timber posts with a ramped terminal upstream and full height fish tail terminal downstream.</p> <p><b>Length:</b>                  15m</p>			

Consultation	Outcome
<b>TII Network Management</b>	Following consultation with AN Other on 11/08/2016 it has been established that there are no minor improvement, road safety or maintenance schemes planned for this location.
Identify the Hazard(s)	Summary
Steep embankment slope and water of likely depth >0.6m	Steep slope into deep water to the west.
Substantial fixed object extending above the ground by >150mm	A low stone wall approximately 600m in length but with no piers.
Substantial fixed object extending above the ground by >150mm	There are 2 indented tourist laybys.

Analysis	
<b>Need for VRS (reference DN-REQ-03079 - Risk Assessment):</b>	<b>Is the VRS still required post risk assessment?</b>
Hazard within the Clear Zone: Yes Hazard ranking: High Sinuosity: Medium Collision rate threshold: Above expected rate (Medium) Risk of a vehicle leaving the road: Medium Overall risk rating: High	Yes The overall risk rating for this section of road is “high”, therefore, a VRS should be installed to meet the requirements of DN-REQ-03034 or the hazard should be mitigated.
<b>Can mitigation measures be implemented (Yes/No)?</b>	<b>If “Yes” include proposals and projected life cycle costs</b>
No. It will not be possible to obtain additional lands to create a forgiving roadside due to the proximity to the body of water.	N/A
<b>Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?</b>	<b>If “No” identify the constraints</b>
No	The minimum setback of 1.2m where the hard shoulder is <1.0m wide will not be achievable for approximately 50m.
<b>Design/Operational Speed:</b>	<b>Road Cross-Section &amp; Traffic Volumes:</b>
The posted speed limit is 100 km/h. There are Speed Enforcement Zones to the north and south of this section of road which may have a speed reducing effect on traffic.	Single carriageway, narrow hard strip and grass or hardstanding verge of varying width. 2015 AADT = 5,293 ( <a href="#">TII Traffic Data</a> ) (Closest counter available: N56 North of Donegal, Drumrooske, Co. Donegal) The N56 forms part of the Wild Atlantic Way tourist driving route which is expected to result in significant increases in traffic, particularly visiting traffic during tourism seasons.

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
<b>Option 1:</b>		
Install new modular T110 end terminal tested to prEN 1317-7 with no connection to existing wall.	The slope hazard and trees are not fully protected at the upstream end. The existing wall is within the Clear Zone and would be left unprotected.	A T110 end terminal tested to prEN 1317-7 will protect the end of wall hazard. The linear face of the wall should deflect errant vehicles back towards the road. The layby indents are considered momentary. This solution is sympathetic to the scenic location.
<b>Option 2:</b>		
Install approximately 400m of additional VRS.	The minimum setback of 1.2m where the hard shoulder is <1.0m wide will not be achievable for approximately 50m. The hazard will not be protected where the VRS breaks at the laybys.	This would have a visual impact on the scenic nature of the location. Breaks in the VRS would be required for two number layby recesses and one access to the water, which will require additional terminals to be installed. The presence of the VRS including the terminals will reduce visibility from the laybys for exiting traffic. The minimum required setback will not be achievable as hard strip narrows to < 1.0m in places. The space for pedestrians (particularly where close to lay-bys) will be significantly reduced by the presence of a VRS.
<b>Option 3:</b>		
N/A	N/A	N/A

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis										
<p><b>Option 1:</b> Install a new modular T110 Terminal with no connection to the existing wall.</p> <p>Install delineators/reflectors at/along the wall to highlight its presence in low light conditions.</p> <p>Install new signs to highlight the laybys to road users.</p>	<p>The hazard could not be mitigated to remove the need for a VRS.</p> <p>The linear face of the existing wall should deflect errant vehicles back towards the road.</p> <p>The layby indents are considered momentary and the additional measures of appropriate signage and road markings are designed to reduce this risk to an acceptable level.</p> <p>The solution is sympathetic to the scenic location with a reduced level of steel VRS.</p> <p>This is the most cost-effective option based on SAVeRS analysis.</p>	<p>The whole life cycle (20 year) cost of installing and maintaining 400m of VRS is as follows:</p> <table data-bbox="1563 408 1995 531"> <tr> <td>N2 W2</td> <td>€180,000</td> </tr> <tr> <td>N2 W5</td> <td>€190,000</td> </tr> <tr> <td>H2 W4</td> <td>€205,000</td> </tr> <tr> <td>2 W6</td> <td>€205,000</td> </tr> </table> <p>Due to the proximity of the body of water it will not be possible to obtain additional lands in order to create a forgiving road side.</p> <p>The whole life cycle (20 year) cost of installing and maintaining a modular P4 terminal is as follows:</p> <table data-bbox="1576 770 1982 802"> <tr> <td>P4 Terminal</td> <td>€50,000</td> </tr> </table>	N2 W2	€180,000	N2 W5	€190,000	H2 W4	€205,000	2 W6	€205,000	P4 Terminal	€50,000
N2 W2	€180,000											
N2 W5	€190,000											
H2 W4	€205,000											
2 W6	€205,000											
P4 Terminal	€50,000											

**Worked Example 2 – Category B, VRS at structures**

<b>VRS ID / Location:</b> N70KY_10079_S2_B49		<b>VRS PDR Summary</b> <b>VRS at Structures</b>	
<p><b>Description:</b>                  The existing VRS begins on the northbound approach to the Inny River Bridge, continuing as far as the bridge itself but does not connect directly to the parapet.</p> <p><b>Length:</b> 50m</p>			

Consultation	Outcome
<b>TII Bridge Management Section</b>	Following consultation with AN Other on 11/08/2016 it has been established that the structure is not included in a capital refurbishment programme.
Identify the Hazard(s)	Summary
Bridge parapets	Unprotected vehicle parapet
Water of likely depth > 0.6m	The Inny River flows under the structure.

Analysis	
<b>Can mitigation measures be implemented (Yes/No)?</b>	<b>If “Yes” include proposals and projected life cycle costs:</b>
No. It will not be possible to obtain additional lands to protect and errant road user from the level difference to the adjacent land on the approach to the structure.	N/A
<b>Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?</b>	<b>If “No” identify the constraints:</b>
No	Masonry parapet with unknown containment. Pre IS EN 1317 parapet which may need to be replaced.
<b>Design/Operational Speed:</b>	<b>Road Cross Section &amp; Traffic Volumes:</b>
The posted speed limit is 100 km/h.	Single carriageway with narrow hard strip and grass or hardstanding verge of varying width. 2015 AADT = 2,599 ( <a href="#">TII Traffic Data</a> ) (Closest counter available: N70 Between Caherciveen and Glenbeigh, Gortaforia, Co. Kerry)

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
<b>Option 1:</b>		
Replace the existing VRS on a like-for-like basis with an IS EN:1317 compliant design	A departure regarding the VRS length (<45m, excluding hazard length) will be required.	None
<b>Option 2:</b>		
Following an initial consultation with the TII Bridge Management Section a full redesign of the existing VRS to include an approved transition and connection to a reconstructed parapet may be appropriate.	None envisaged if an approved transition and connection to the reconstructed parapet is detailed as part of the redesign.	This option would include for the removal of the existing VRS. The upstream terminal would be upgraded to prEN 1317-7 T110 (P4) performance class. A 2m section of the parapet would be demolished and replaced with a reinforced concrete

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
		parapet. This would enable the upstream and downstream terminals of the VRS to directly connect to the parapet.
<b>Option 3:</b>		
Install a crash cushion on the approach to the bridge parapet.	None envisaged	Will address the collision risk of the parapet end but will not address the collision risk associated with the level difference to the adjacent land.

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis
<p><b>Option 2:</b> This option includes for the removal of the existing VRS. The upstream terminal will be upgraded to P4 performance class. The downstream terminal will transition and connect to a newly constructed reinforced concrete parapet. The design will require input and approval from the TII Bridge Management Section.</p>	<p>Option 1 will not directly connect to the structure. This could result in pocketing and could increase the severity of injury in the event of a collision.</p> <p>Option 3 will not protect an errant road user from the level difference to the adjacent land on the approach to the structure.</p>	<p>Whole life cycle (20 year) cost of installing and maintaining a VRS as well as constructing the reinforced concrete parapet is as follows:</p> <p>N2 W2, P4/T110 Terminal &amp; Parapet Construction: €95,000</p> <p>2 W4, P4/T110 Terminal &amp; Parapet Construction: €90,000</p>

**Worked Example 3 - Category C, VRS in urban settings**

<b>VRS ID / Location: N21LK_10078_S1_B24</b>		<b>VRS PDR Summary VRS in Urban Settings</b>	
<p><b>Description:</b>                  A pre-IS EN 1317 VRS located within a traffic calming zone at Croagh, Co. Limerick</p> <p><b>Length:</b>                  20m</p>			

Consultation	Outcome
<b>TII Network Management</b>	Following consultation with AN Other on 11/08/2016 it has been established that there are no minor improvement, road safety or maintenance schemes planned for this location.
Identify the Hazard(s)	Summary
Water of likely depth >0.6m	A stream, within the Clear Zone, runs parallel to the carriageway.
Culvert approximately parallel to the roadway that has an opening exceeding 600mm measured perpendicular to the direction of travel	A culvert headwall is located within the Clear Zone.

Third Party Considerations	Summary
N/A	N/A

Analysis	
<b>Need for VRS (reference DN-REQ-03079 - Risk Assessment):</b>	<b>Is the VRS still required post risk assessment?</b>
Hazard within the Clear Zone: Yes Hazard ranking: High Sinuosity: Low Collision rate threshold: Twice below expected rate (Low) Risk of a vehicle leaving the road: Low Overall risk rating: Medium	Yes The overall risk rating for this section of road is medium, therefore, the Designer shall provide a VRS or mitigate the hazard if it is within 2m of carriageway edge.
<b>Are traffic calming measures in place (Yes/No)?</b>	<b>Is the hazard still present following traffic calming measures (Yes/No)?</b>
Yes	Yes, the hazard is located inside the reduced Clear Zone width for a 60 km/h road.
<b>Can mitigation measures be implemented (Yes/No)?</b>	<b>If “Yes” include proposals and projected life cycle costs:</b>
Yes	Remove the VRS, pipe the stream and backfill to existing ground level. Projected life cycle cost = €2,000
<b>Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?</b>	<b>If “No” identify the constraints:</b>
No	Adjacent accesses do not allow the full length of need to be achieved.
<b>Design/Operational Speed:</b>	<b>Road Cross-Section &amp; Traffic Volumes:</b>

Analysis	
60 km/h	Single carriageway with a reduced cross section due to traffic calming measures. 2015 AADT = 16,076 ( <a href="#">TII Traffic Data</a> ) (Closest counter available: N21 Between Adare and M20 Jn, Nouborough, Co. Limerick)

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations
<b>Option 1:</b>		
Replace the existing VRS on a like-for-like basis.	Potential departure required for the VRS length (if <45m excluding the length of hazard to be protected).	There is concern that the existing VRS does not protect the full extent of the hazard.
<b>Option 2:</b>		
Full redesign of the existing VRS.	Potential departure required for the VRS length (if <45m excluding the length of hazard to be protected).	This option will include for the removal and replacement of the existing VRS. Both upstream and downstream terminals will be upgraded to P1 performance class and tapered away from the carriageway at 1:20.
<b>Option 3:</b>		
Remove the VRS, pipe the stream and backfill to existing ground level.	None required	This option will mitigate both the hazard of the drainage ditch and the VRS itself, creating forgiving roadside. Initial consultation with the local authority suggests piping and backfilling the drainage ditch is a feasible option.

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis						
<p><b>Option 3:</b> Remove the VRS, pipe the stream and backfill to existing ground level.</p>	<p>Options 1 and 2 will introduce a hazard (the VRS) to protect a hazard. This may not be warranted due to the traffic calming measures that have been introduced which included the lowering of the posted speed limit to 60 km/h.</p> <p>Option 3 will result in the removal of the road side hazard, thereby providing a forgiving road side for errant road users.</p>	<p>The whole life cycle (20 year) cost of installing and maintaining a VRS is as follows:</p> <table data-bbox="1473 379 2040 464"> <tr> <td>N2 W2</td> <td>€25,000</td> </tr> <tr> <td>N2 W4</td> <td>€25,000</td> </tr> </table> <p>The whole life cycle (20 year) cost of piping and backfilling the stream is as follows:</p> <table data-bbox="1473 555 2040 587"> <tr> <td>Piping and backfilling</td> <td>€ 2,000</td> </tr> </table>	N2 W2	€25,000	N2 W4	€25,000	Piping and backfilling	€ 2,000
N2 W2	€25,000							
N2 W4	€25,000							
Piping and backfilling	€ 2,000							

**Worked Example 4 - Category A, example where hazard mitigation is the proposed preferred option based on a life cycle cost analysis**

<b>VRS ID / Location:</b> N20CK-01 (N20CK_100025_S1_B1)		<b>VRS PDR Summary</b> <b>VRS at Constrained Location</b>
<p><b>Description:</b>                  A section of the N20 bounded by mature trees within the Clear Zone.</p> <p><b>Length:</b>                  400m</p>		

Consultation	Outcome
<b>TII Network Management</b>	Following consultation with AN Other on 11/08/2016 it has been established that there are no minor improvement, road safety or maintenance schemes planned for this location.
Identify the Hazard(s)	Summary
Trees having a girth 314mm or more measured at 1m above the ground.	Mature tree lined verge to the east on the outside of a right-hand curve.

Analysis	
<b>Need for VRS (reference DN-REQ-03079 - Risk Assessment):</b>	<b>Is the VRS still required post risk assessment?</b>
Hazard within the Clear Zone: Yes Hazard ranking: High Sinuosity: High Collision rate threshold: Below expected rate (Low) Risk of a vehicle leaving the road: Medium Overall risk rating: High	Yes The overall risk rating for this section of road is high, therefore, a VRS should be installed to meet the requirements of DN-REQ-03034 or the hazard should be mitigated.
<b>Can mitigation measures be implemented (Yes/No)?</b>	<b>If “Yes” include proposals and projected life cycle costs</b>
Yes.	Obtain additional lands and remove the trees/vegetation to create a forgiving roadside. Projected life cycle cost = €200,000.
<b>Can the VRS be designed in accordance with DN-REQ-03034 (Yes/No)?</b>	<b>If “No” identify the constraints</b>
No	Vegetation clearance required to achieve set back and working width
<b>Design/Operational Speed:</b>	<b>Road Cross-Section &amp; Traffic Volumes:</b>
The posted speed limit is 100km/h.	Single carriageway with climbing lane, narrow hard strip and grass or hardstanding verge of varying width. 2015 AADT = 9,778 ( <a href="#">TII Traffic Data</a> ) (Closest counter available: N20 Between Buttevant and Charleville, Co. Cork)

Design Options Considered (Attach drawings as required)	Relaxations and Departures	Observations								
<b>Option 1:</b>										
Install a new VRS over the length of the hazard (approximately 400m).	None envisaged.	This option will require some tree and vegetation clearance in order to provide for adequate setback and VRS working width. The whole life cycle (20 year) cost for various VRS solutions has been calculated using the SAVeRS tool as follows: <table border="0" data-bbox="1563 692 1995 815" style="margin-left: auto; margin-right: auto;"> <tr> <td>N2 W2</td> <td style="text-align: right;">€386,302</td> </tr> <tr> <td>N2 W5</td> <td style="text-align: right;">€388,109</td> </tr> <tr> <td>H2 W4</td> <td style="text-align: right;">€404,005</td> </tr> <tr> <td>H2 W6</td> <td style="text-align: right;">€404,005</td> </tr> </table>	N2 W2	€386,302	N2 W5	€388,109	H2 W4	€404,005	H2 W6	€404,005
N2 W2	€386,302									
N2 W5	€388,109									
H2 W4	€404,005									
H2 W6	€404,005									
<b>Option 2:</b>										
Obtain additional lands and remove the trees/vegetation to create a forgiving roadside.	None envisaged.	The requirement for a VRS is removed. The life cycle cost of purchasing additional land, completing the vegetation clearance and maintaining the extended verge has been estimated at €200,000.								
<b>Option 3:</b>										
N/A	N/A	N/A								

Preferred Option	Reasoning	Whole Life Cycle Cost Analysis
<p><b>Option 2:</b> Obtain additional lands and remove the trees/vegetation to create a forgiving roadside.</p>	<p>Installing a VRS, which in itself can be considered a hazard, to protect a hazard will still pose a collision risk to an errant road user. The proposed mitigation is seen as the most cost effective long-term solution at the location when compared with the life cycle costs of a VRS installation. The proposed solution represents a safer solution for road users.</p>	<p>The lowest whole life cycle cost of installing and maintaining a VRS as per Option 1 (as calculated using the SAVeRS tool) is €386,302 for a N2 W2 VRS.</p> <p>The projected cost of obtaining additional lands, clearance of trees and vegetation and maintenance thereafter is estimated to be €200,000.</p> <p>(Refer to Appendix G for SAVeRS tool input data)</p>

## **Appendix G**

Sample SAVeRS Input Data for  
VRS Life Cycle Cost Analysis

SAVeRS Tool - Sample Input Data	
Crash model	
Ireland	Single Carriageway
Road Features	
Number of Lanes (per carriageway)	1
AADT (per carriageway)	6,744
HGV (Trucks & buses) Proportion (%)	5.9%
Traffic Growth per year (linear - average %)	1%
Road Section Properties	
Segment Length (m)	400
Curve Radius (m) - 1st Curve	300
Speed limit (*)	100
Gradient (%) (< 0 downhill)	0.12%
Outside Shoulder Width (m)	1.35
Inside shoulder width (m) (for motorways)	0
Lane Width (m)	3.3
Percentage of Rumble Strips (%)	0
Cost Benefit Analysis	
Start Year	2018
End Year	2037
Design years	20
Interest-inflation Rate	3.5%
Predicted Crash Conditions	
Reference Country	Ireland
Crash Distribution (Cars)	Germany Single Carriageway
Crash Distribution (HGVs)	RSAPV3 Undivided_fric=0.45-0.6
Severity Distribution	
Roadside Type	Verge
Hazard Type	Tree
Image	
	

Sample input data which was used in conjunction with the SAVeRS tool for calculating the life cycle cost of a VRS solution in Worked Example 4 in Appendix F for illustrative purposes.

The SAVeRS tool, guideline document and user manual can be downloaded from the Downloads section of the TII Publications website.





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