Guidelines for
Vehicle Stability Analysis - Main Roads Internal Process

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1 PURPOSE

The purpose of this document is to provide guidance on the process to be followed to assess the stability of heavy vehicles on the approach to and through roundabouts as well as on loop ramps and other tight geometric elements.

It is primarily intended for use by designers in the Road & Traffic Engineering Branch, although the process may also be used by project managers in Main Roads to engage external consultants to provide the required input to Heavy Vehicle Services (HVS) staff.

2 BACKGROUND

2.1 Why undertake vehicle stability analysis?

Roundabouts are generally adopted as a form of intersection due to their car safety benefits (i.e., low speeds and improved impact angles). To achieve the desired safety improvements offered by a roundabout, speeds need to be controlled through the horizontal geometry, however at the same time designers need to ensure stability of trucks with a high centre of gravity (HCoG) is maintained. This is particularly relevant where approach speeds could be high. The geometry and movements in a roundabout include a series of reverse curves, which also often include changes in crossfall direction: these features induce destabilising effects on trucks with HCoG.

2.2 When should vehicle stability analysis be undertaken?

For this reason, Main Roads has mandated in its supplement to the Austroads document "Guide to Road Design Part 4B: Roundabouts" that all roundabouts meeting the following criteria should be assessed for stability using simulation software:

- Freeway and highway exit ramp approaches to roundabouts where the approach posted speed is 80km/h or greater, especially where the crossing road is under the main alignment. For these assessments the high speed roundabout approach treatment must also be assessed if adopted.
- Rural roundabouts where the approach posted speed is 80km/h or greater. The approach treatment should also be included in the assessment if adopted.
- All roundabout approaches where the posted speed is 70 km/h and no approach treatment has been provided.

The assessment is based on estimating the Load Transfer Ratio (LTR), which is a measure of the proportion of the vehicle's load carried by the tyres on the outside of a curve. An LTR of 1.0 implies that 100% of the load is carried by the outside tyres and the vehicle will tip over.

Main Roads requires HCoG trucks to negotiate the roundabout at 30km/h without exceeding a LTR of 0.6.

2.3 Development of a process to assess vehicle stability

With the advent of Computer programs to model vehicle stability, Main Roads WA have undertaken the Stability Analysis of several roundabout designs using external consultants. This required Main Roads to provide 3D road alignment data to the consultant for analysis and has proven to be time consuming and costly.

Recently, a more cost effective collaboration has been developed between Road and Traffic Engineering and Heavy Vehicle Services to undertake Vehicle Stability Analyses internally.

The process involves Designers in the Road and Traffic Engineering Branch to prepare and provide 3D road alignment data for analysis and staff in Heavy Vehicle Services to carry out the analysis and provide a report of the results.

3 ROLES & RESPONSIBILITES

The following Main Roads' staff should be contacted in the event that project managers wish for a vehicle stability analysis to be undertaken internally.

Role	Responsibility
Principal Design Manager – Dave Nicholls	Prove advice on appropriate treatments for controlling speeds at roundabouts and format of required information for input to the stability analysis assessment.
Heavy Vehicle Road Use Research Analyst – Virang Vyas	Provide advice on appropriate design vehicle, undertake stability analysis and provide report.

4 RTE PROCESS

4.1 Receive a brief from the Project Manager

The project manager should provide a brief to the designer which includes the following information:

- The location of the intersection
- The vehicle movements to be analysed.
- The vehicle speeds to be assessed for rollover risk.
- Any background information or rollover history.

Advice should be obtained from HVS branch (HVRURA) on the design vehicle(s) to be assessed.

4.2 Create vehicle centreline alignments

This should be done in 2D CAD using vehicle swept paths in AutoTurn or AutoTrack to determine the design vehicle centre line path through the movement. The drawing should be to scale and on a coordinate system. Refer to the example shown in Figure 1 over the page.

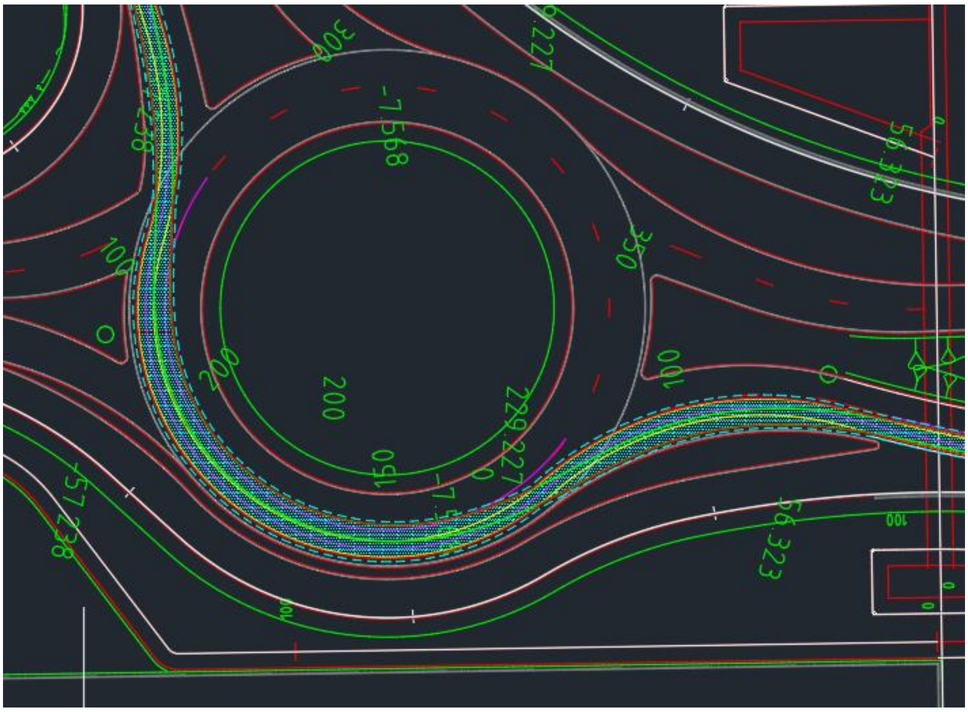

Figure 1: Centreline path through a roundabout with swept paths

4.3 Create 3D vehicle alignment and camber strings

Create a 3D terrain model from the design. This should include enough information to define the road surface accurately including crossfall and superelevation.

Using the vehicle centreline, create an alignment string with chainages at 2m intervals. Create a second parallel string with matching chainage points at 1-2m offset (within the lane) to define the vehicle camber throughout the manoeuvre. Refer to the example shown in Figure 2.

Drape the two strings on the alignment to obtain levels. Report the XYZ points of the vehicle CL and camber string and export to Excel.

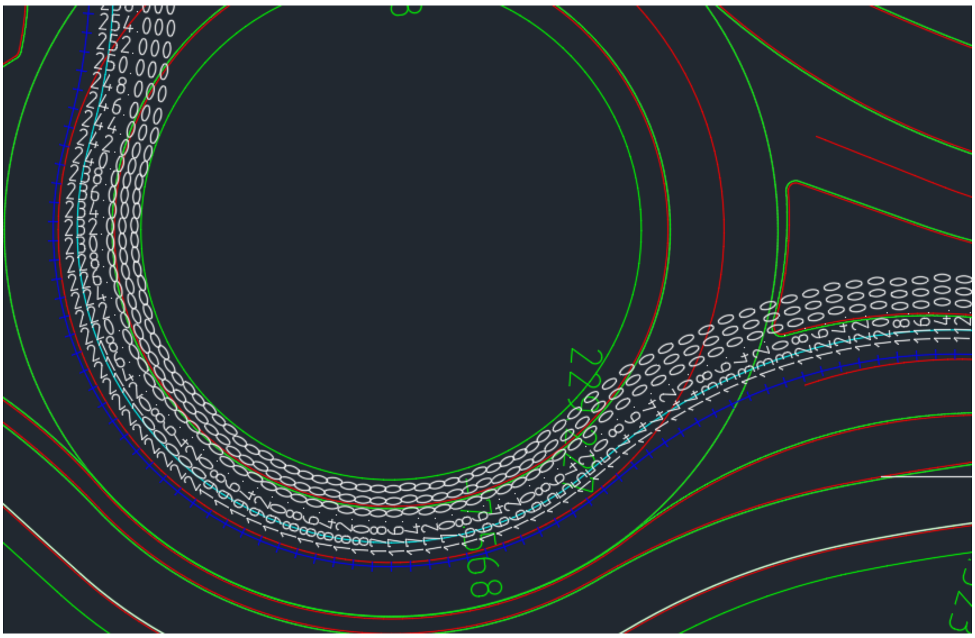

Figure 2: Centreline string and parallel offset string

5 HVS PROCESS

5.1 Receive design data and scope of analysis from RTE

The design data consists of the vehicle alignment and crossfall / superelevation information. The scope should include the number of vehicle movements and speeds to be modelled. In addition, the Maximum Load Transfer Ratio target (usually LTR 0.6) should be agreed on.

5.2 Determine and prepare the vehicle or vehicles to be modelled

This would typically be the highest risk vehicles permitted to operate on the section of road. The Project Manager in conjunction with HVS should determine the vehicles to be modelled

5.3 Carry out the stability analysis

The stability analysis is to be carried out using Universal Mechanism simulation software.

5.4 Prepare analysis outputs

The output should include a table and graph relating the Load Transfer Ratio (LTR) to the vehicle location. Refer to the examples shown in Figures 3 and 4.

	A	B	C
1	**Time (second)**	**Distance**	**Vehicle LTR**
2	28.12047195	234.6955	0.568903506
3	28.14047241	234.8662	0.573803186
4	28.16047287	235.0372	0.574815273
5	28.18047333	235.2081	0.577029049
6	28.20047188	235.3789	0.583529532
7	28.22047234	235.5496	0.592311323
8	28.24047279	235.7201	0.600963235
9	28.26047325	235.8907	0.609190285
10	28.2804718	236.0612	0.61697185
11	28.30047226	236.2318	0.623608887
12	28.32047272	236.4023	0.62821579
13	28.34047318	236.5728	0.630037844
14	28.36047173	236.7432	0.628466368
15	28.38047218	236.9134	0.623369753
16	28.40047264	237.0834	0.615005374
17	28.4204731	237.2531	0.603779078
18	28.44047356	237.4225	0.590319812

Figure 3: Sample output from stability analysis software showing LTR

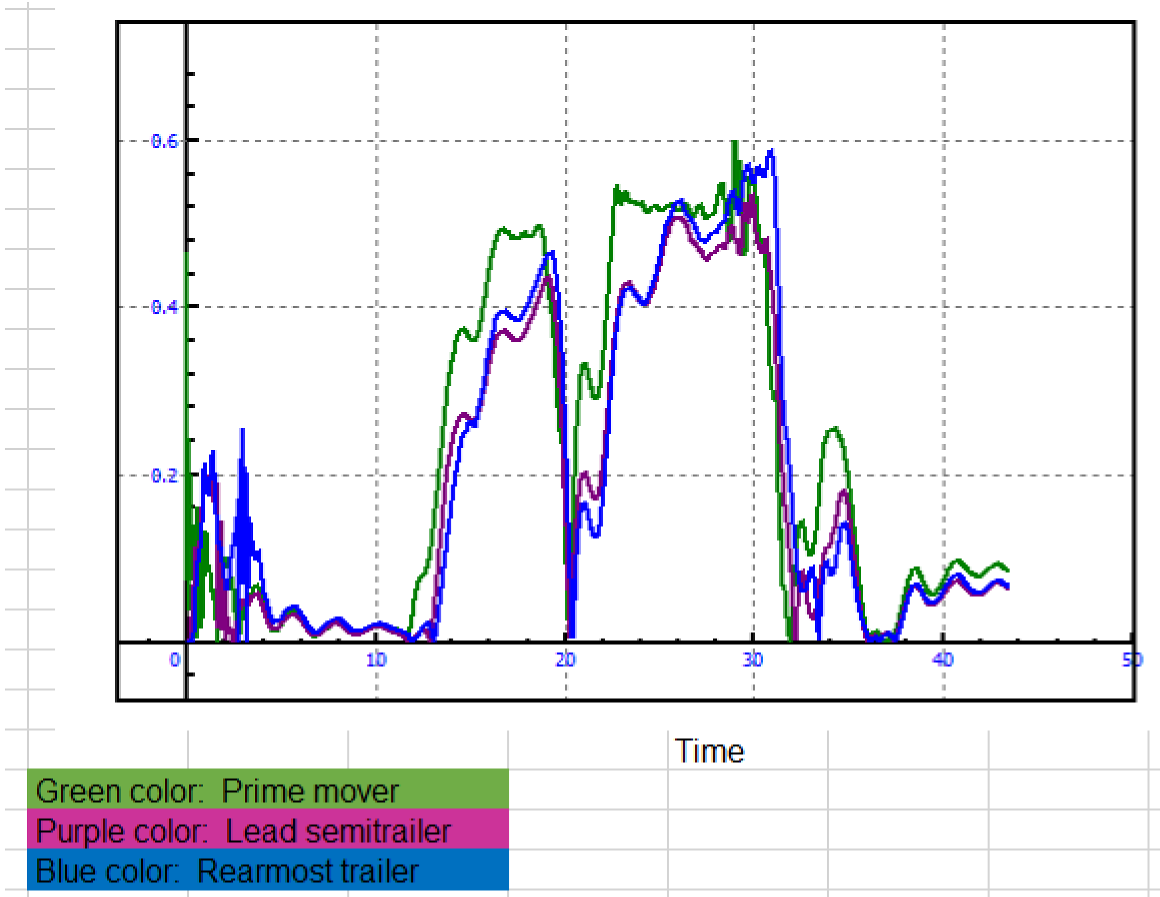

Figure 4: Graphical output from stability analysis software for various vehicle types

6 THE VEHICLE STABILITY ANALYSIS REPORT

The following information should be included in the vehicle stability analysis report.

6.1 Vehicle modelling assumptions

It should be noted that there are many factors that affect vehicle stability, including suspension, tyre pressure, vehicle loading and vehicle coupling type etc. HVS take these factors into consideration when carrying out the assessment.

For roundabouts refer to Section 4.10 of the Main Roads' Supplement to Austroads Part 4B: Roundabouts.

6.2 Load Transfer Ratio (LTR) and vehicle speed

The Load Transfer ratio (LTR) is a measure of the change in vehicle weight transfer from the centre of the vehicle to the outside wheels during lateral acceleration. This varies from 0 to 1 (vehicle rolls over).

The generally accepted maximum LTR value for turning vehicles is 0.6. The speed at which this figure is reached should be greater than the design speed of the turning vehicle for a given manoeuvre.

For a guide to truck turning speeds refer to Austroads Guide to Road Design Part 4A, Appendix B

6.3 Report content

The report to the Project Manager, in addition to the LTR graphs for each movement and vehicle speed, should include a plan for each movement as per Figure 2.

Commentary from HVS should also be included with regard to test vehicles and loading chosen along with the considered risks.

A recommendation may be included as to what mitigation strategies may be considered to reduce the risk of rollover.

7 REDUCING THE RISK OF VEHICLE ROLLOVER

The following mitigation strategies may be used to reduce the risk of vehicle rollover.

7.1 Mitigation strategies

- Modifying the intersection geometry to increase vehicle turn path radii
- Increasing the superelevation around the curve or remove adverse crossfall.
- Removing or reducing rapid changes in grade
- Put in measures to reduce the approach speeds to intersections or roundabouts.
- Install truck rollover warning signs.

Note that installing warning signs should be a last resort with geometric methods to reduce rollover risk being preferred.

For Roundabout treatments refer to the Main Roads' Supplement to Austroads Part 4B – Table 4.10.1: Design Features Affecting HCoG Truck Stability.

8 REFERENCES AND RELATED DOCUMENTS

Document Number	Description
D17#491152	MRWA Supplement to Austroads Guide to Road Design – Part 4B