

# **DERAILMENT RISK ASSESSMENT**

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## ABSTRACT

There is a large quantity of literature available on longitudinal train dynamics and risk assessment but nothing that combines these two topics. This thesis is focused at assessing derailment risks developed due to longitudinal train dynamics. A key focus of this thesis is to identify strategies that can be field implemented to correctly manage these risks. This thesis quantifies derailment risk and allows a datum for comparison. A derailment risk assessment on longitudinal train dynamics was studied for a 107 vehicle train consist travelling along the Monto and North Coast Lines in Queensland, Australia. The train consisted of 103 wagons and 4 locomotives with locomotives positioned in groups of two in lead and mid train positions. The wagons were empty hopper wagons on a track gauge of 1067mm. The scenarios studied include: the effect of longitudinal impacts on wagon dynamics in transition curves; and the effects of longitudinal steady forces on wagon dynamics on curves. Simulation software packages VAMPIRE and CRE-LTS were used.

The effects of longitudinal impacts from in-train forces on wagon dynamics in curves were studied using longitudinal train simulation and detailed wagon dynamics simulation. In-train force impacts were produced using a train control action. The resulting worst-case in-train forces resulting from these simulations were applied to the coupler pin of the wagon dynamics simulation model. The wagon model was used to study the effect of these in-train forces when applied in curves and transitions at an angle to the wagon longitudinal axis. The effects of different levels of coupler impact forces resulting from different levels of coupling slack were also studied. Maximum values for wheel unloading and L/V ratio for various curve radii and coupler slack conditions were identified. The results demonstrated that the derailment criteria for wheel unloading could be exceeded for a coupler slack of 50mm and 75mm on sharper curves, up to 400m radii.

A detailed study of the effect of steady in-train forces on wagon dynamics on curves also was completed. Steady in-train forces were applied to a three wagon model using VAMPIRE. Maximum and minimum values of wheel unloading and L/V ratio were identified to demonstrate the level of vehicle stability for each scenario. The results allowed the worse cases of wheel unloading and L/V ratio to be studied in detail.

Probability density functions were constructed for the occurrence of longitudinal forces and coupler angles for the Monto and North Coast Lines. Data was simulated for a coupler slack of 25, 50 and 75mm and force characteristics were further classified into the occurrences of impact and non-impact forces. These probability density functions were analysed for each track section to investigate the effects of coupler slack, track topography and gradient on wagon dynamics. The possible wagon instability in each of these scenarios was then assessed to give a measure of the potential consequences of the event. Risk assessment techniques were used to categorise levels of risk based on the consequences and likelihood of each event. It was found that for the train configuration simulated, the Monto Line has a higher derailment risk than the North Coast Line for many of the scenarios studied in this thesis. For a coupler slack of 25mm no derailment risks were identified, 50mm coupler slack derailment risks were only identified on the Monto track and the majority of derailment risks were identified for a 75mm coupler slack.

# **DERAILMENT RISK ASSESSMENT**

by

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**BEng Mech**

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## **STATEMENT OF ORIGINALITY**

To the best of my knowledge, this thesis is my own work and has not been published by any other source. Parts of this thesis have been published in papers which have been listed in the publications section.

Simon Wagner

## PUBLICATIONS LIST

Wagner, S. and Cole, C. 2003, "Modelling Train-Wagon Interaction on Curves", *Proceedings of the 18th International Association of Vehicle System Dynamics Symposium*, Kanagawa Institute of Technology, Atsugi, Kanagawa, Japan.

Wagner, S. and Cole, C. 2003, "Rollingstock Wheel Unloading Due to Coupler Impacts on Curve Transitions", *Central Region Engineering Conference*, (ed.) Wolfs, P, Central Queensland University, Rockhampton, Australia.

**NOMENCLATURE**

<b>Notation</b>	<b>Definition</b>
Dn	Step size (m)
H1 and H2	Overhang of wagon 1 and 2 (m)
H3	Coupler length (m)
n	Step
P1, P2, P3 and P4	Position 1,2,3,4 respectively
r	Radius (m)
$r_n$	Radius for step n (m)
1/r	Curvature (1/m)
X	X axis length (m)
X1 and X2	The X axis height due to coupler angle 1 and 2 respectively
Xn	The total X axis sum for step n (m), (Figure 3-12, p26)
Xn'	The X axis length for step n due to curvature (m), (Figure 3-12, p26)
Xn''	The X axis length for step n due to error (m), (Figure 3-12, p26)
Y	Y axis length, (m)
Y1 and Y2	The Y axis height due to coupler angle 1 and 2 respectively
Yn	The total Y axis sum for step n (m), (Figure 3-12, p26)
Yn'	The Y axis length for step n due to previous

	angle (m), (Figure 3-12, p26)
$Y_n''$	The Y axis length for step n due to curvature (m), (Figure 3-12, p26)
$Y_n'''$	The Y axis tangent length due to curvature for step n (m), (Figure 3-12, p26)
$\circ$	Angle (degrees)
$\mu$	Coefficient of friction
$\theta_1$ and $\theta_2$	The angle between the overhang and line between both bogie centre pins
$\theta_c'$	The angle created due to the difference in height of Y1 and Y2
$\theta_{c1}, \theta_{c2}$	Coupler Angle 1 and 2 respectively (degrees)
$\theta_n = \theta_n'$	Angle at the instant n (degrees), (Figure 3-12, p26)
$\theta_n''$	Angle between $Y_n'''$ and $X_n$ axis (degrees), (Figure 3-12, p26)
$\theta_1'$	Angle between the tangent at P2 and the line between P2 and P1 (degrees), Figure 3-15 on page 26.
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Angle between the tangent at P3 and the line between P3 and P2 (degrees), Figure

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## GLOSSARY

<b>Term</b>	<b>Definition</b>
AAR	Association of American Railways
Bogie	The primary chassis of a railway vehicle that holds the wheelsets
CABS	Coupler Angling Behaviour Software, developed by the AAR
CRE	Centre for Railway Engineering
CRE-LTS	Centre for Railway Engineering Longitudinal Train Simulator
Degrees Curvature	The angle for a arc of 100ft or 30.3m
DOF	Degrees of Freedom
Kilometridge	The track position based on the survey pegs that are placed along the track
L/V Ratio	Lateral/Vertical ratio of the wheelset
NUCARS	New and Untried Car Analytic Regime Simulation, a wagon dynamic simulator developed by the AAR.
pdf	Adobe Acrobat file format
Run-ins	Run-ins are developed due to the slack between couplers. It usually refers to impact forces that are developed during the transition from tensile to compressive forces
Run-outs	Run-ins are developed due to the slack between couplers. It usually refers to impact forces that are developed during the transition from compressive to tensile forces
Slack	The clearance between coupler knuckles once they are joined
Slack Action	Slack action refers to a series of impacts that are developed due to compressive to tensile forces and visa versa.

SRM	Safety Risk Model
WinBatch	Scripting user input utility software
WU	Wheel Unloading
UltraEdit	Text editor software
VAMPIRE	AEA Rail Technology Vehicle Simulator