Vehicle Roll-over

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IRTE (Institute of Road Transport Engineers), one of the most respected names in UK transport, has always been recognised as an impartial voice of the industry.

IRTE publishes an industry-leading technical journal, Transport Engineer, every month. Now online www.transportengineer.org.uk contains a searchable editorial archive, daily online news updates, a supplier directory, e-zine newsletter, jobs, events, whitepapers and much more.

IRTE also hosts regular technical seminars and forums and works alongside the DfT to promote efficiency and best practice. Recent events include biofuels, trips and falls from vehicles, truck operation, fuel efficiency and the Road Safety Act.

IRTE's technical committee also produces regular industry guidance on key topics. See pages 14-15 for IRTE's range of guidence documents, all of which are free to download from www.soe.org.uk.

IRTE members come from a wide variety of transport-related roles. These include workshop managers, fleet engineers, transport managers, company directors, apprentices and technicians in the light and heavy goods vehicle and bus and coach sectors.

This publication is a result of work conducted by the IRTE Technical, Publications and Government Liaison Committee. If you are interested in becoming involved with the committee, please contact Ian Chisholm, Head of Operations & Communications on 020 7630 1111 or email ian.chisholm@soe.org.uk.

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ISBN: 978-0-9555685-6-5
Author: Nicholas Edwards Editor: David Jones Design and Guide Coordinator: Sarah Prest

Preface

In 2008, there were 9,040 reported accidents in the UK involving large goods vehicles (rigid and articulated). Almost 5% of these accidents related to vehicle roll-over. Although roll-over accounts for only a small proportion of vehicle accidents, it is the manner in which these occur and the outcome that is the concern. Vehicle roll-over also costs a great deal of money - recovering vehicles, repairing vehicles and roadways, replacing damaged or lost loads; incidents may result in serious injury or death of the driver or third parties.

Roll-over is particularly evident in the road transport industry, due to the physical nature of large goods vehicles (LGV) and passenger carrying vehicles (PCV). The shape and structure of LGVs and PCVs often leads to a high centre of gravity, which in turn increases the chances of the vehicle rolling over. Semi articulated LGVs are at higher risk than rigid, due to the coupling. Usually, the trailer is supported in three places, which reduces the stability of the vehicle.

Vehicle roll-over typically occurs during cornering, where centrifugal force, acting through a vehicle's centre of gravity, causes it to lean. The magnitude of the centrifugal force will increase as speed and turning angle increases.

'Roll-over Threshold' is the term for a truck's ability to resist roll-over. The lowest point of centrifugal acceleration, which causes the truck to tip over when travelling consistently along a curved path, derives this value. A vehicle's Roll-over Threshold can be directly affected by the way in which the vehicle is set-up (loads, tyre pressure, suspension etc.)

ESP switched off
Image supplied by Knorr-Bremse UK

Contents and appendices

Why do roll-overs occur?

Below is an outline of the primary reasons for vehicle roll-over to occur:

Adverse weather conditions

The most obvious weather condition associated with vehicle roll-over is high winds. The probability of a vehicle rolling over in high winds is increased in situations where there is a high centre of gravity.

As well as high winds, weather that affects the road surface (snow, rain, ice) can all contribute to vehicle roll-over, as the contact between the tyres and road surface is inhibited.
N.B. Some high-sided trailers are more susceptible to roll-over.

Avoidance

This type of incident is where the driver attempts to avoid a hazard in their path, and turn too abruptly, resulting in a possible over turn situation. The over turn situation is usually caused through the correction of the initial avoidance manoeuvre, resulting in cumulative pendulum action, which may increase or decrease as the vehicle continues in a straight line. This pendulum action is enhanced with high centre of gravity vehicles, such as double deck trailer units, car transporters, liquid or powder tankers etc.

Brakes

For a driver to have maximum control over a vehicle, it is very important the braking system be in correct working order. Anti-lock Braking Systems (ABS), Electronic Braking Systems (EBS) and Electronic Stability Programs (ESP) all help in preventing vehicle roll-over, as they can automatically adjust the braking pattern for each wheel, possibly giving the driver greater control.

N.B. The combined effects of ABS, EBS, ESP, yaw rate sensors and steering angle sensors can apply corrective action to assume control from the driver and reduce the chance of roll-over.

Cornering

As stated, a large proportion of vehicle roll-overs occur whilst cornering. Due to the higher centre of gravity, and low Roll-over Threshold, entering a corner at excessive speeds encourages the vehicle to lean and thus roll-over.

Why do roll-overs occur?

Driver error

There are a number of factors that can be attributed to driver error or insufficient training. Misjudging the magnitude of a corner can result in the vehicle entering a corner too fast. Lack of attention can also contribute to vehicle roll-over. Drowsiness, distraction or simply not assessing the path ahead can result in sudden awareness of danger, and therefore sudden action to avoid the danger. This can cause the driver to turn sharply, encouraging roll-over. There are also situations where the driver either runs onto the soft shoulder and gets pulled over by the run off, or impacts the kerb and load shift results in roll-over.

Excess speed

A recent study has indicated that excessive speeds increase the likelihood of vehicle roll-overs.

Jack-knifing

The primary reason for Jack-knifing to occur is equipment failure, wheels locking due to braking and poor grip from adverse driving conditions. Depending on the speed the vehicle is travelling, jack-knifing can result in vehicle roll-over.

Load

The majority of vehicle roll-overs occur due to factors associated with the load. This can be because the load is inadequately secured or loaded incorrectly. The height of the centre of gravity of the load directly affects the vehicle's centre of gravity – therefore altering the Roll-over Threshold.

Double-deck trailers are at greater risk of roll-over when it comes to loading, particularly if a larger percentage of the load, or a heavy load, is incorrectly placed on the top deck of the trailer.

Similarly, curtain-side bodies with air suspension and tall, unrestrained pallet loads relying on curtains for security can suffer from instant shift of the centre of gravity, as pallets rock about the centre line of the body. That shift is from the centre line to outboard of the suspension attachment centres – resulting in instant instability, with potential roll-over. There is often a failure to correct load distribution on multi-drop work, attributable to poor management or inadequate training.

Why do roll-overs occur?

Over steering

Over steering can occur due to a variety of reasons. Entering a corner at excessive speeds, or a sudden awareness of danger, are points previously mentioned that can result in over steer. However, over steer can also happen as a result of changing lanes too abruptly or over correcting – where the driver turns too much and follows this up with corrective steering that exceeds the stability of the vehicle. This results in a pendulum effect as described under “Avoidance”.

Road design

Road design can also contribute significantly to vehicle roll-over. Roundabouts, adverse cambers, slip roads, dual carriageway contra-flow lane changes and double bends can all contribute to roll-over, as they are not always designed with LGVs and PCVs in mind and are not always appropriately signed.

Suspension settings

It is extremely important to have the appropriate suspension settings aligned to different situations. Incorrectly set ride height, incorrect condition and pressures for air suspension units, and failure to reset the ride height control valve after loading/unloading can all increase the likelihood of vehicle roll-over.

Tyres

A number of cases of vehicle roll-over have been attributed to under-inflated tyres. Cornering with under-inflated tyres results in the vehicle leaning more than if the tyres were correctly inflated.

Worn tyres also pose a problem. This is due to the cornering ability of the vehicle being adversely affected by the limited grip a worn tyre offers on low friction surfaces.

Roll-over prevention

There are many ways in which vehicle roll-over can be prevented; however, altering driver behaviour is key. Educating drivers to the risks of vehicle roll-over, and the ways in which they can prevent or limit the chances of it occurring will greatly help in reducing the number of accidents we see each year. As well as this, basic vehicle design, which lowers the centre of gravity, would also help in reducing roll-over.

Points to consider for reducing the chances of vehicle roll-over:

- It is very important to pay attention to the road ahead. Keep a safe distance away from vehicles and ensure you are aware of the environment around you
- Ensure you do not enter a corner at excessive speed
- It is vital the load is secured properly and loaded in the most effective way. The latter will help in lowering the vehicle's centre of gravity, vital to reducing the chances of roll-over. The former will ensure the load is not capable of moving relative to the vehicle. The DfT have produced a code of practice titled 'Safety of Loads on Vehicles' (ISBN 0-11-552547-5)
  N.B. This guide is currently in review
- It is very important to drive according to the load being carried
  N.B. Drivers of tankers and other vehicles where the load cannot be restrained, should take extra care when operating the vehicle
- Before each journey, check all tyres on the vehicle. Make sure the tread is in sufficient condition and check the tyre pressure is correct for the load and conditions
- Ensure the vehicle is always steered in a smooth manner, limiting abrupt and sudden actions as much as possible
- Driver training and effective management.

There are also a number of devices and products that actively help in preventing vehicle roll-over. Below is an outline of such devices:

- Knorr-Bremse is renowned for the development of commercial vehicle braking systems. The company has an Electronic Stability Program (ESP) for trucks and buses, which automatically brakes individual wheels and intervenes with the vehicle engine management system to stabilise the truck or bus in critical conditions.

  A separate system has also been developed by Knorr-Bremse for trailers in articulated vehicles. The TEBS G2 Trailer Electronic Brake System includes the Roll Stability (RSP) function; a system dedicated to reducing the chances of roll-over. This highly advanced system actively monitors the behaviour of the vehicle and, if instability is detected, based on lateral acceleration, vehicle speed and axle load, a "test pulse" is triggered. This test pulse, along with information obtained from systems sensors, can determine whether the vehicle is in a critical condition and roll-over is likely. If it is likely, the lateral acceleration of the trailer is reduced by a large reduction of the vehicle's speed. The brakes are applied to achieve maximum deceleration and reduce the tendency of the trailer to roll.

Roll-over prevention

Often, there is not enough time for a test pulse to be carried out, for example in a collision avoidance manoeuvre. The system is able to detect this, potentially catastrophic, roll-over danger and force an immediate RSP brake intervention.

Knorr-Bremse has also devised a system within the RSP that helps with some of the issues associated with load distribution on drawbar trailers. As the load varies on the drawbar coupling, there is a chance that the trailer may start to swing. The lateral acceleration sensor monitors this trailer swing, and should the maximum lateral acceleration exceed a preset value for a number of oscillations, individual left and right brake applications occur. The effect of that is to introduce opposite yaw moments to counter those produced by the trailer, resulting in trailer stabilisation. The system was developed mainly for the very unusual car transporter drawbar market.

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Roll Stability Program (RSP)
Control Logic

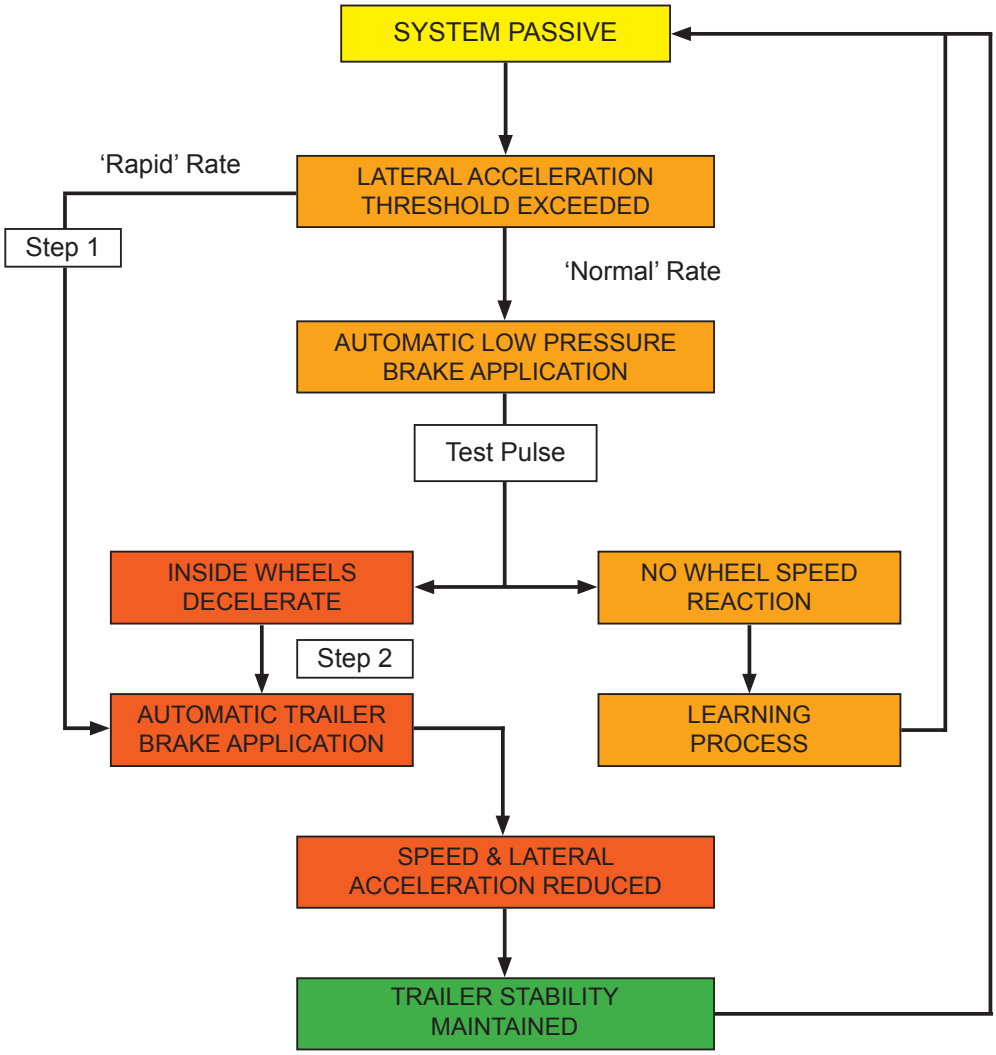


Diagram supplied by Knorr-Bremse UK

Roll-over prevention

- Wabco's ABS system incorporates their Roll Stability Control (RSC)/Roll Stability Support (RSS), which actively helps in reducing the likelihood of vehicle roll-over. The system automatically intervenes in situations where vehicle stability enters a critical area

- US truck manufacturer, Freightliner, have manufactured a device called Roll Stability Advisor. Roll Stability Advisor is a training aid designed to warn the driver when they have operated the vehicle in a way that would encourage roll-over. Messages are then communicated to the driver with increased urgency as the potential for roll-over increases. Depending on the urgency, this then triggers their RSC device, which automatically slows the vehicle

- Scania have developed a system called Driver Support, which offers the driver similar safety measures as the previous mentioned programs. The Driver Support System advises the driver and provides prompts for the best way to drive given the environment. All information is established from a series of sensors placed around the vehicle. The system is more aimed at advising drivers on the most efficient way to drive, however it undoubtedly helps in preventing vehicle roll-over.

Effect of having ESP switched on and off
Image supplied by Knorr-Bremse UK

Roll-over prevention

If using an electronic system that enables the user to download information, it is very important to do so, and analyse when and how often the stability control program was triggered.

It is extremely important for drivers to be educated to the dangers surrounding vehicle roll-over, outlining the causes and explaining prevention. Increasing awareness will no doubt reduce the number of vehicle roll-over accidents, and this guide will hopefully increase the awareness.

It should also be noted that electronic programs such as ESP, EBS, ABS, etc., act only as an assistance to the driver. The interaction of these programs suggests that an acceptable driving threshold has been exceeded.

Future developments

Scientists from the Cambridge University Engineering Department developed a system known as Active Roll Control. This system relies on active suspension, which automatically adjusts to the way in which the vehicle is being driven. As the vehicle corners, actuators on the outside of the curve push out, leaning the vehicle in to the curve and against centrifugal force.

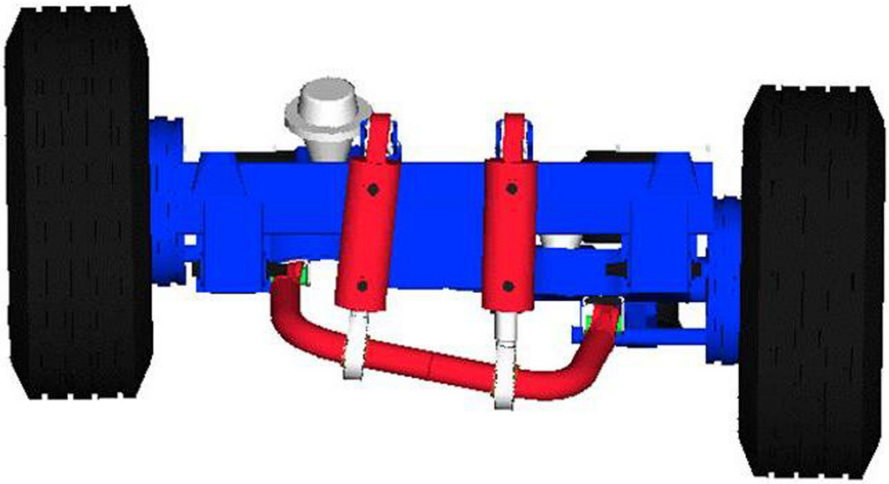


Diagram of Active Roll Control System
Diagram supplied by Cambridge University Engineering Department

This leaning action increases the vehicles Roll-over Threshold, therefore limiting the chances of vehicle roll-over.

At present, the Active Roll System is not commercially viable as a separate diesel engine is needed to power the system.

Legislation

From the 11 July 2010, it became a mandatory requirement for all new trailers over 10 tonnes gross weight to be fitted with an electronic stability control (ESC), according to the Economic Commission for Europe regulation 13 (E/ECE/TRANS/505 – Concerning the Adoption of Universal Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts). This will also be the case for trucks and buses, starting with two-axle tractive units registered from July 2011. There is currently no requirement to fit ESC systems to in-service vehicles or trailers.

Investigating a vehicle roll-over

References

McKnight, A. James and Bahouth, George T. ‘Analysis of Large Truck Roll-over Crashes', Traffic Injury Prevention, 10:5, 421 – 426

Miège, A.J.P. and Cebon, D. ‘Design and Implementation of an Active Roll Control System for Heavy Vehicles’. Cambridge University Engineering Department

Department for Transport Accident Statistics 2008

Dilich, M.A. and Goebelbecker, J.M. ‘Truck Roll-over’, Triodyne Inc. Safety Bulletin – Volume 6, No. 1

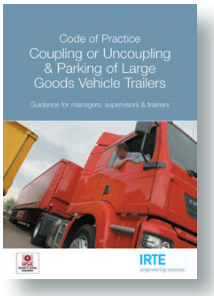
Knorr-Bremse ‘4.6, Roll Stability Program (RSP) function’, Trailer EBS TEBS G2 and G2.1 – Product Manual, 44 – 47

Wabco – Roll Stability Control/Support

Freightliner – Roll Stability Advisor

Scania – Driver Support System

IRTE publications

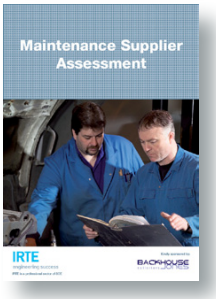


Coupling or Uncoupling and Parking of Large Goods Vehicle Trailers

The IRTE code of practice is aimed at managers, supervisors and trainers but has good advice for everyone who has responsibility for the safety of large goods vehicle and drivers.

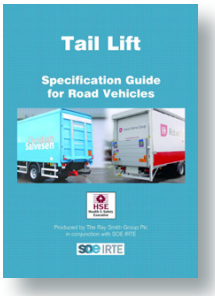
Wheel Security - A best practice guide

This guide explains the mechanisms of wheel loss and provides helpful best practice guidance to assist those specifying and maintaining commercial vehicles to reduce wheel loss incidents.



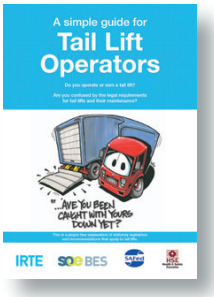
Maintenance Supplier Assessment

The IRTE's maintenance supplier assessment guide is aimed at those who contract out the maintenance of their fleet. It advises on best practice procedures to ensure the maintenance facilities of workshops used are adequate for the type and number of vehicles undergoing work.



Tail Lift - Specification Guide for Road Vehicles

Guidance for manufacturers, specifiers, installers, suppliers and users of tail lifts as to the safety issues associated with tail lift installations.



A simple guide for Tail Lift Operators

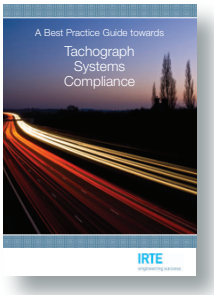
This guide provides some basic information and highlights the user's legal responsibilities in the use, maintenance and examination of tail lifts.

Improving Fuel Efficiency

This guide can be used to prepare the groundwork needed for a proper evaluation before purchase and/or fitment of an intervention can take place.

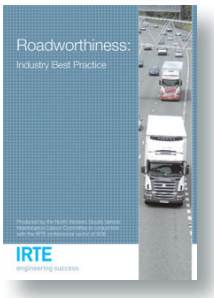
To order any of these publications, visit www.soe.org.uk to download a copy or contact the Technical Services Department on technical@soe.org.uk or 020 7630 1111.

IRTE publications



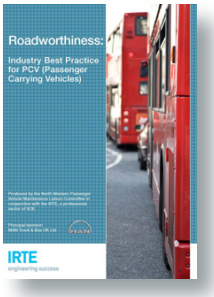
Tachograph Systems Compliance

In this indispensable guide, Senior Tachograph Consultant, Gordon J F Humphreys, explains what firms need to do to protect their Operator's Licence.



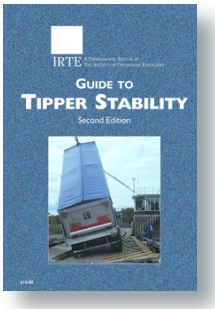
Roadworthiness Guide

This guide is intended to assist vehicle operators and managers, regardless of fleet size to improve their vehicle maintenance controls and standards.



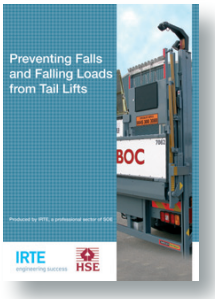
Roadworthiness: Industry Best Practice for PCV (Passenger Carrying Vehicles)

Produced with leading industry bodies, this guide gives advice on best practice so all passenger carrying vehicle operators can improve their vehicle maintenance controls and standards.



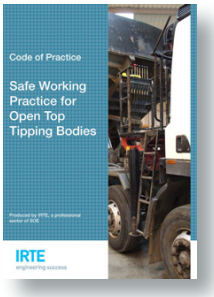
IRTE Guide to Tipper Stability

Essential guidance for those wishing to implement best practice when operating tipping vehicles or tipper trailers.



Preventing Falls and Falling Loads from Tail Lifts

Produced by the members of a Tail Lift Users Group, which included tail lift operators, manufacturers and HSE, to provide guidance for the prevention of falls and falling loads from tail lifts.



Safe Working Practice for Open Top Tipping Bodies

This Code of Practice provides guidance on the law, explains why accidents occur, and illustrates the need for procedures to ensure accidents involving tipping vehicles do not occur.

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Knorr-Bremse is the world's leading manufacturer of braking systems for commercial vehicles and has pioneered the development and production of modern braking systems for over 100 years.

As an innovative developer of advanced electronic and pneumatic systems, Knorr-Bremse has an in-depth knowledge of vehicle stability and dynamics and has supplied the European original equipment market with roll-over protection systems for truck, trailer and bus applications for over 10 years.

As well as supplying for original equipment use Knorr-Bremse UK is also able to offer the trailer based roll stability program as a retro-fit enabling older chassis to benefit from the latest technology.

To complement our PC based installation and diagnostic packages Knorr-Bremse UK has a highly professional technical team who are able to provide after sales support and tailored training programmes to meet your exact needs.

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