IRTE

Vehicle Rollover

IRTE

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

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

IRTE's technical committee produces regular industry guidance on key topics. See page 16 for IRTE's range of guidance 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.

soe
Society of Operations Engineers

IRTE is one of four professional sectors within the professional engineering institution the Society of Operations Engineers. The Society supports and encourages its 16,000 members throughout their careers and is committed to their ongoing growth and professional development. It is licensed by the Engineering Council for registration at EngTech, IEng and CEng levels and by the Society for the Environment at CEnv level. It has recently been granted a licence at REnvP level.

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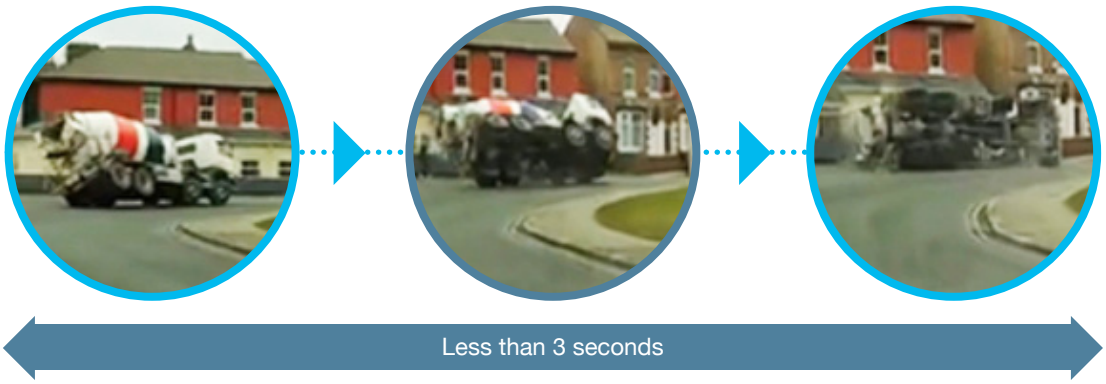
TJ Transport is the bulk haulage arm of TJ, serving the construction, building materials and waste industries with external transport solutions for their products and waste. Over 20 years of working closely with these industries has established TJ Transport as the leading bulk haulage provider in the Southern Region. For more information visit **www.tj-waste.co.uk/tj-transport-company**

Preface

There are several thousand Large Goods Vehicle (LGV) and Public Service Vehicle (PSV) road traffic accidents reported in the UK every year. Studies indicate that around 5% of these involve a vehicle rollover. Although the proportion of rollover incidents is low, the outcomes are profound. The mass and forces involved can result in significant impacts on people, property and accompanying vehicle and asset damage. The combined costs, injury, damage, recovery, consequential loss and reputational damage, places the issue into a category demanding preventive action.

Additionally there are significant detrimental effects on other road users with delays and associated expense as well as clean-up and road repair costs.



Vehicles with a particularly high centre of gravity, for example concrete mixers, and those with reduced rigidity such as articulated vehicles are more susceptible in certain conditions to rollover because of their design configuration, shape and load position.

Rollovers typically occur during cornering, rapid lane or road position changes, and low or adverse road surface grip conditions. This is 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 increase, resulting in a rollover.

'Rollover threshold' is the term for a truck's ability to resist rollover. The value is derived from the lowest point of centrifugal acceleration, which causes the truck to tip over when travelling consistently along a curved path. A vehicle's rollover threshold is directly affected by the way in which the vehicle is set-up (loads, tyre pressure, suspension etc.).

Driver behaviour and error are the main cause of rollovers, often due to speed, distraction, fatigue, load condition, interpretation of road layout, weather and mechanical condition. It is therefore key that drivers are supported and educated in the risks. They must be trained and actively managed to reduce and eliminate rollover events.

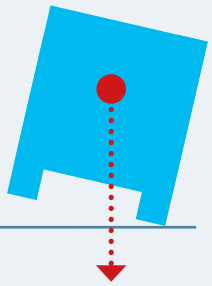
Contents

Why do rollovers occur?

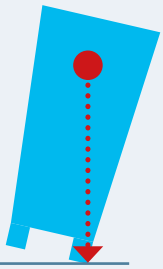
Design, structure, load and centre of gravity place LGV's more at risk of rolling over, particularly when cornering or encountering soft verges. Drivers need training in the fundamentals of the causes of rollovers. They must understand the risk and limitation of their vehicle and how speed, load, mechanical condition, distractions, road and weather conditions affect vehicle stability. Appreciating the very serious outcomes of a rollover occurring, and the importance of wearing seat belts, are crucial when encouraging driver best practice.

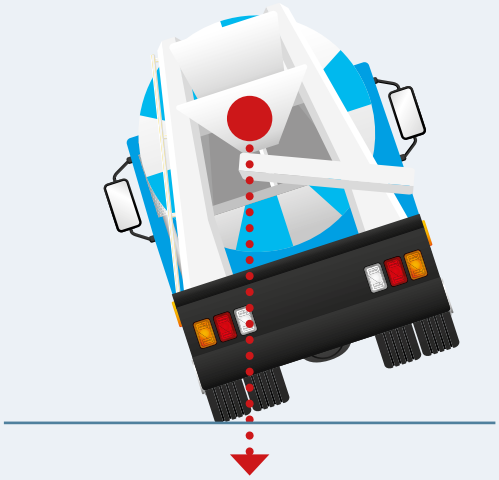
> The Physics

The taller and more top heavy an object, with a higher centre of gravity, the more likely it is to tip over



If the centre of gravity falls outside the base of the structure, it will topple over





Trucks will rollover if the centre of gravity moves outside the base of the vehicle

Risk factors affecting rollover events:

> Driver error

There are several factors that can be attributed to driver error. The most common is insufficient or ineffective training. Misjudging a corner can result in the vehicle entering too fast.

Lack of attention can also contribute to vehicle rollover. Drowsiness, distractions or simply not assessing the path ahead can result in sudden awareness of danger, leading to a rapid steering input to avoid the danger, destabilising the vehicle. There are also situations where the driver either runs the vehicle onto a soft verge or gets pulled into a rollover condition by the run-off. Impacting a kerb or a sudden load shift can also undermine stability.

> Sudden direction change

When drivers are faced with an unexpected event they can react instinctively and often take rapid evasive action. This might destabilise a vehicle and can create a rollover situation. Drivers must remain aware of the road conditions including other road users and adopt a dynamic risk assessment approach to driving. Being aware of the surroundings and the impact they can have on vehicle condition is key to providing opportunities to manage and eliminate a possible rollover.

> Excess speed

Excessive speed for the conditions. The level of speed is relatively low at roundabouts, corners and bends and is a primary cause of rollover. If approach speeds are too high the likelihood increases.

> Cornering

A high proportion of rollovers occur during cornering. Due to the higher centre of gravity, and low rollover threshold, entering a corner at excessive speeds encourages the vehicle to lean and increases the risk of a rollover.

> Oversteering

A variety of factors can lead to oversteering. As well as entering a corner at excessive speeds, or a sudden awareness of danger, it can also happen as a result of changing lanes too abruptly. Over correcting, where the driver turns too much and follows this up with corrective steering that exceeds the stability characteristics of the vehicle.

> Soft verges

If the driver accidently runs off the road onto soft or uneven ground, it is instinct to quickly turn the steering wheel to bring the truck back on the road. However this is one of the worst things to do at highway speeds – the driver needs to allow the truck to slow to a safe speed and then make a gradual, controlled return to the highway if possible.

> Jack-knifing

Jack-knifing is the folding of an articulated vehicle so that it resembles the acute angle of a folding pocket knife. The primary reasons for jack-knifing are the level of road surface grip or equipment failure. Wheels lock due to braking and poor grip from adverse driving conditions. Depending on the speed the vehicle is travelling, jack-knifing can result in vehicle rollover.

> Load

The height of the centre of gravity of the load directly affects the vehicle's centre of gravity – therefore altering the rollover threshold. This can be because the load is inadequately secured or loaded incorrectly. Certain vehicles are at greater risk; for example concrete mixer trucks with a high centre of gravity and moving load, tippers which are loaded excessively to one side and double-deck trailers particularly if a larger percentage of the load, or a heavy load, is incorrectly placed on the top deck of the trailer. Tall pallet loads with poor load security can move and alter the centre of gravity creating instability. Failure to accommodate and correct load distribution on multi-drop work can result from poor delivery planning and inadequate training.

> Road design and conditions

Road design and conditions can also contribute significantly to vehicle rollovers. Roundabouts, adverse cambers, on and off slips, dual carriageway contra-flow lane changes, bends and multiple bends, soft or damaged verges on narrow roads create conditions that can contribute to rollover. These conditions are often not conducive to a stable LGV. Road designs do not always have LGVs in mind and are not always effectively sign posted.

Off road conditions vary from ideal paved surfaces right through to those that are unable to support the weight of large vehicles. Rain or surface water can destabilise these access paths or roads and drivers must remain vigilant to the conditions.

> Adverse weather

The most obvious weather associated with vehicle rollover is strong wind. The probability of a vehicle rolling over in windy conditions is increased where there is a high centre of gravity.

Other weather conditions affecting the road surface (snow, rain, ice) contribute to vehicle rollovers. If the contact between the tyre and road surface is inhibited, skid conditions may result. Some high-sided vehicles and trailers, especially when not carrying a full load, are more susceptible to rollover.

> Mechanical condition

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 all increase the likelihood of vehicle rollover.

Tyres may also be a factor; several cases of vehicle rollover have been traced back to under-inflated tyres. Cornering with under-inflated tyres results in the vehicle leaning more. Worn tyres also pose a problem. The cornering ability of a vehicle can be affected by the limited grip a worn tyre offers especially on low friction surfaces.

Brakes can contribute to rollover risk; for a driver to have maximum control over a vehicle, it is important that the braking system is in correct working order. Anti-lock braking systems (ABS), electronic braking systems (EBS) and electronic stability programs (ESP) all help in preventing vehicle rollover, as they can automatically adjust the braking pattern for each wheel, giving the driver greater control.

It should be noted that 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 rollover.

Rollover prevention

There are many ways in which vehicle rollover can be prevented: however, the most important is improving driver behaviour. Competent and proficient operators recognise their responsibility and statutory obligation to ensure drivers are adequately trained. Educating drivers about the risk of vehicle rollover, and the ways in which they can prevent or limit the chances of it happening will help reduce the number of accidents each year.

Vehicle design is another key part of the solution; developing and specifying equipment with the aim of lowering the centre of gravity, would help to reduce incidents.

Vehicle maintenance forms an integral part of preventing vehicle rollovers. The roadworthiness of vehicles depends on them being mechanically sound and fit for purpose. Regular inspections, both daily pre-use checks and scheduled periodic maintenance inspections are essential. They differ in scope and depth but each type provides a means to verify the mechanical condition of the vehicle.

> Daily pre-use vehicle checks

Drivers must be trained and competent in good visual inspection of the vehicle. Visual checks are required before use of many vehicle elements but from a rollover prevention point of view they must include:

- steering
- suspension
- body and load security
- brakes
- tyres
- wheels and fixings

Varying weather conditions in winter, particularly ice forming on the top of vehicles can increase instability. Drivers have an obligation to report concerns and operators must ensure compliance with effective reporting and rectification processes.

> Periodic maintenance inspections

A structured and scheduled maintenance plan must be established for every vehicle. Periodic maintenance inspections (PMIs) are vital and are a statutory obligation. Operators, along with their transport managers, maintenance providers (workshop technicians) and drivers are responsible for checking and providing systems that ensure road worthiness.

Facilities for conducting periodic inspections must be appropriate and provide access to inspect the underside of the vehicle. The IRTE Workshop Accreditation scheme provides an assurance that inspection maintenance and repair facilities are adequate and fit for purpose. Correct tools and equipment to maintain and repair vehicles where necessary, are vitally important in producing a roadworthy vehicle and the IRTE Workshop Accreditation scheme can provide assurance in this respect.

Vehicle repair and maintenance technicians must be trained, familiar and competent with inspection processes, reporting and repair practices. All irtec technicians are extensively trained, competent and committed to ongoing professional development. They are independently and periodically

assessed to ensure their skills remain valid and appropriate.

Inspection frequency is established and forms the basis for scheduled inspection and maintenance programmes. The time between inspections is determined by vehicle use, distance and type of work. The programme must be developed, documented and outcomes of both before and after vehicle conditions recorded by the operator.

There are a number of practical steps operators and drivers can take to reduce the risk of a vehicle rollover. These include basic vehicle design – is it capable of coping with the physical forces of normal operation? How will the vehicle be driven and operated? Will the mechanical condition of the vehicle along with any imposed load affect stability?

The vehicle must be fit for purpose – low centre of gravity designs help when the proposed load has a high centre of gravity, for example step frame semi trailers. Operators can improve vehicle safety through design and should consider specifying or adopting systems and equipment that go above and beyond the minimum laid down by legislation.

Vehicle rollover can be prevented by educating and improving the skills of drivers, to alter their behaviour on the road. Training and education is fundamental to drivers understanding the risks and, crucially, what they can do to minimise them.

Ensuring the mechanical condition of the vehicle is to a level where safety is not compromised is key and can be achieved with both scheduled and driver checks.

Finally, the load itself often has a considerable part to play in rollover prevention. Car transporters and double deck trailers with lower decks empty and the top deck still loaded illustrate examples of extremely high centre of gravity and heightened risk of instability. Loads with high or varying fluidity (concrete mixers), petro-chemicals or hanging foodstuffs, are all examples where additional safeguards are required in both vehicle design and operation.

> Points to consider for reducing the chances of vehicle rollover

Driver awareness is paramount and they must remain vigilant to the changing conditions – road layout, traffic density, speed. Driver distraction from in-cab technology must be considered and steps taken to remove, manage or minimise them.

Drivers must adopt cautious approaches towards vehicle direction changes, corners, roundabouts and lane changes. It may seem obvious, but when direction changes are made suddenly or rapidly and combined with a high centre of gravity the risk for rollover increases considerably. Most vehicles used on the roads today have several in-built protection systems, which operate behind the scenes carefully adjusting the vehicle, often unknown to the driver. A rollover is more likely if a driver comes to rely on them, producing a false sense of security. That is until something extraordinary occurs and the protection systems become overwhelmed and the laws of physics take over.

It is vital loads are secured properly and positioned on the vehicle in a manner which provides the lowest possible centre of gravity. The latter will help in lowering the vehicle's overall centre of gravity, crucial to reducing the chances of rollover. The former will ensure the load is not capable of moving relative to the vehicle and rendering it unstable. The DfT has produced a code of practice Load Securing:

Vehicle Operator Guidance (see References for details).

> Tyres – Tyre Pressure Monitoring

Under inflated tyres provide and produce a number of challenges in terms of vehicle performance and the impact on the environment with increased emissions and fuel consumption for example. However, key for this guide is increased instability created by excess leaning to one side. Worn or under/over inflated tyres in adverse weather conditions inhibit the steering, braking, suspension and vehicle electronic systems to correct a potential rollover condition. In service, individual Tyre Pressure Monitoring systems advise drivers and maintenance teams of low pressure and potentially imminent failure. Tyre overheating due to under inflation is a common cause of rapid deflation and possible fire. If this occurs while driving at speed or negotiating a bend or corner, the risk of a rollover increases dramatically.

> Vehicle Stability Systems

If a condition arises where a vehicle is at risk of rollover, the driver needs to acknowledge the danger rapidly and take immediate action to bring the vehicle back under control. Electronic stability programmes (ESP) constantly monitor the ride dynamics of a vehicle and intervene automatically using the engine management and brake systems if the vehicle is in danger of rollover. It is able to assess situations even

> The effect of having ESP switched on and off

more rapidly than a very experienced driver and, provided the vehicle has not exceeded the physical limits of stability, drivers can often regain and maintain control.

> Operation

ESP often comprises of two main systems a dynamic stability program (DSP) and a rollover prevention (ROP).

DSP assists drivers to keep a vehicle stable for example on wet roads, ice and snow. It takes effect in the event of low grip situations when there is a difference between the direction a driver intends to take and the actual direction of the vehicle.

ROP reduces the risk of the vehicle overturning in the event of high grip conditions on dry roads.

Vehicle manufacturers are continuously developing systems to enhance and support safe operation including rollover protection. Methods and operating systems may differ from vehicle to vehicle, as can the descriptive acronym label but, a carefully chosen system over and above the minimum legislative requirement can have a marked and positive effect on vehicle stability.

> Route planning

Proactive route planning can be an effective means to reduce rollover risk. Assessing the route for rollover risks and encouraging drivers to follow chosen routes will help. Providing instruction for speed and approach or simply avoiding areas of particularly high risk greatly assists in incident reduction.

> Telematics

Most if not all LGV and bus and coach manufacturers employ sophisticated electronic vehicle monitoring systems – telematics. On board information provides a useful insight into how vehicles are driven – fuel consumption, acceleration, deceleration, harsh braking and harsh steering to name a few. Note if vehicles are not fitted with OEM telematics, aftermarket systems are available and can be retrofitted and employed successfully in this respect.

If using a system that enables the operator to download information, it is important to analyse the data, establish trends, create change and training programmes to support and alter driver behaviour.

Modern vehicles are designed with a high degree of safety as a key requirement. The systems employed can very easily protect a driver from a potentially harmful outcome when the physics determine a rollover is imminent. If a driver regularly exceeds vehicle design limits and ‘on-board’ systems are correcting the outcome beforehand, then scrutiny of the data will show the frequency and extent of the stability control program being triggered.

It is important that vehicle data is reviewed and shared with drivers. It provides opportunities for focused training to avoid the risks and cost in terms of injury, possible fatalities and vehicle and infrastructure damage. Understanding how driver input affects the vast majority of vehicle rollover incidents, outlining the causes and explaining prevention techniques is key. Increasing awareness will undoubtedly reduce the number of rollover incidents.

Future developments

> ADAS

Advanced Driver Assistance Systems (ADAS) is truck safety technology that seeks to ensure safer vehicles are operating on roads. In most road incidents or accidents driver error, driver behaviour or impairment are contributing factors (UK Government, 2020). ADAS systems create safer vehicles and drivers and ultimately aims to remove accidents from the roads.

ADAS is an electronic system that interacts between vehicle and driver. The design aim is to assist in use of the vehicle with a wide range of technologies that either alert the driver of potential hazards and/or take temporary control of the vehicle if calculated reaction times are not prompt enough to avert an incident.

Safety and efficiency are major elements of the supply chain industry, and the vehicles and equipment it uses. The expectation is that ADAS scope will increase and should be seen as a mandatory feature as opposed to optional.

Legislation

This document outlines and illustrates key factors and shows best practice for the prevention of vehicle rollovers. Manufacturers are continuously developing new safety systems to improve and enhance their products. They work closely with legislators who ultimately produce regulations for adoption on various categories of vehicles. The legislation regarding vehicle type approval (a requirement to register a new vehicle) is too extensive to list in this document.

For further information contact relevant vehicle manufacturers and:

Department for Transport
www.gov.uk/government/organisations/department-for-transport

Vehicle Certification Agency
www.gov.uk/government/organisations/vehicle-certification-agency

Driver and Vehicle Standards Agency
www.gov.uk/government/organisations/driver-and-vehicle-standards-agency

> Current requirements:

Antilock brakes systems (ABS) allow brakes to work at their maximum without locking-up. It is a requirement for all M and N category vehicles (and their trailers) to have ABS fitted.

All **new vehicles** require electronic stability control (ESC) (also called ESP) together with a yaw sensor to predict the drivers intended movement with the vehicles actual reaction (detects when the vehicle is skidding). The system applies an appropriate level of braking to allow the vehicle to recover from, or prevent, a skid.

With additional control to individual braking modules, ABS and ESC, there are a range of other safety systems.

- Trailer roll stability (TRS) can predict the rollover threshold and slows the vehicle when cornering.
- Electronic brake distribution (EBD) systems monitors the load on the wheels and balances the braking as appropriate.
- Load-proportioning brake valve (LPBV) system is similar to EBD but is not electronic. It monitors the pressure in the air suspension (it can be retrofitted to mechanical suspension) and adjusts the air pressure for each specific axle.

REFERENCES

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2. UK Government. Statistical data set. Contributory factors for reported road accidents (RAS50). Updated 30 September 2020.

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