Tall order

Why does the UK suffer from a persistently high number of truck roll-over accidents compared with continental Europe? Few engineers are better placed to answer such questions than Gary Lock of the Frazer-Nash consultancy David Wilcox reports.

Gary Lock's warning about the risk of truck roll-over accidents becoming increasingly prevalent in the UK unless we get to grips with "the psychology and ergonomics of driving" was first published in the April 2002 issue of *Transport Engineer.* Nearly seven years on, how does this grim forecast from a Frazer-Nash Consultancy engineer look in retrospect? Time to revisit the subject at Frazer-Nash's Dorking, Surrey office, where he has been promoted to business manager. Extensive experience in investigating vehicle roll-over accidents nevertheless means his services as an expert witness in court cases continue to be in demand, about eight times a year on average, he estimates.

"There are as many roll-overs now, if not more, than there were back then," asserts Mr Lock, though freely admitting to having no hard evidence to substantiate this. Department for Transport data, based on police accident reports, are incomplete, he explains, because these reports are demanded only for accidents involving injuries. This leads to significant under-reporting, Mr Lock points out. He reckons there could be as many as three or four truck roll-overs per day in the UK.

Annual *Road Casualties in Great Britain* reports from the Department for Transport suggest that the number of overturned trucks (presumably including trucks blown over in high winds as well as those overturning for other reasons) has indeed been rising, whereas the number of reported "jack-knife" incidents has been falling steadily, doubtless as a result of the growing number of trucks and trailers fitted with anti-lock braking (ABS).

Though most trucks over 3.5-tonnes gvw on UK roads are rigids (accounting for nearly 75 per cent of the total), more than half of all reported truck roll-overs involve artics. This is no surprise to Mr Lock, who points to the two main reasons why articulated trucks are more prone to roll. First, the driver is more isolated from the truck's body and load movement. "The trailer is likely to have rolled past the point of no return before the driver knows anything about it, so he doesn't realise how close he is to the limit," he explains.

Second, because the front of the semi-trailer rests on a fifth-wheel coupling, the trailer's effective track is narrower than the width across wheel centres. This "tricycle effect" is crucial, explains Mr Lock, because the two factors of most influence on any truck's roll stability are its track and the height of its centre of gravity (c of g).

"There are plenty of secondary factors too, like roll stiffness of suspension and tyres, load shift, camber of the road and torsional rigidity of the chassis," says Mr Lock. "But effective track width and c of g height are the fundamental points." One of the things he has learnt from expert-witness duties is the need for roll-stability calculations to be simplified for courts of law. "We have computer software for dynamic modelling but I rely on hand calculations in court when working out roll-speeds," he explains. "It's important to keep it understandable. There is a very fine line between negotiating a bend successfully and a roll-over. Most drivers have no idea where that line is and how close they are to crossing it."

In the formula for calculating a vehicle's roll-over threshold on a curve of a given radius, vehicle velocity is squared. So even a small change in speed can have a significant effect. This helps explain why roll-overs are by no means always on tight bends or the result of high-speed swerves. They often occur on bends or roundabouts with which the driver is familiar. A momentary lapse of concentration or maybe a missed gear can mean a vehicle enters a roundabout a couple of miles per hour faster than usual, and over it goes.

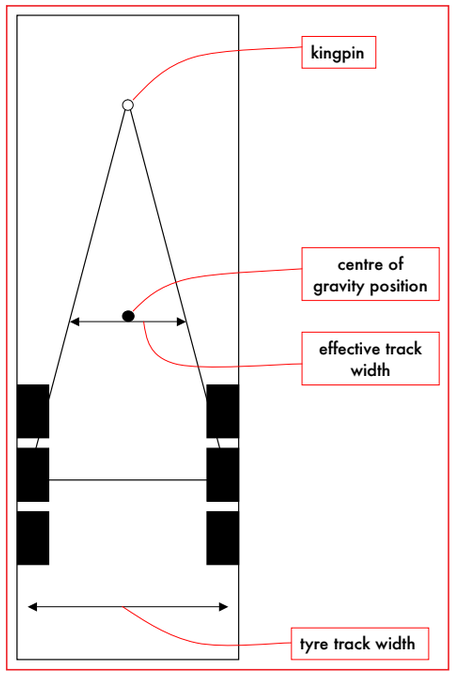
Some people tend to leap from this to the conclusion that excessive speed is the primary cause of roll-overs, and drivers therefore must always be to blame. Not Mr Lock. "I have a growing sympathy for container drivers because they pick up a container

Boxed into a corner: truck drivers are left in the dark about the centre of gravity of containerised loads.

knowing the weight, but not knowing how the load is stacked or if the load has shifted inside," he says. "So they have no idea of where the c of g is. How is that driver expected to know that he should drive defensively because of a high c-of-g cargo?"

Weighbridges with a lateral slope of 10 degrees could be one answer, he suggests. Computer software would provide at least an indication of the c of g location, based on the difference in wheel weights, side-to-side.

As for advances in truck technology, their impact on roll-over risk is a mixed blessing, in Mr Lock's view. As tractive units have become increasingly refined so drivers have become more and more isolated from their surroundings and loads. "The argument goes that this is good from the point of view of reducing driver fatigue, and I wouldn't disagree," says Mr Lock. "But you have to accept that there may be some downsides too. Truck roll-overs were rare in the days before power-steering, because cornering forces were felt through the steering wheel. Drivers these days have no idea of the forces being generated."



Tricycle effect: a semi-trailer's effective track is narrowed by its fifth-wheel coupling.

So is he really saying that part of the price paid for vast improvements in truck handling and braking is that the risk of roll-over has increased? Maybe drivers being lured into negotiating bends and roundabouts faster than they should by economy-driving techniques focused on keeping trucks rolling in a high gear, and avoiding braking wherever possible?

Years of having evidence cross-examined in court has taught Mr Lock to steer well clear of any such supposition and opinion. "I stick with the numbers and the facts," he says. "Once you stray away from that, you're on thin ice."

But he is prepared to venture the opinion that the UK suffers from more truck roll-overs than many other European countries, and not just because we have more roundabouts than most. An overall height limit of four metres on the continent means that most semi-trailers there sit lower, both in maximum height and deck height.

UK legislation which has allowed truck centres of gravity to rise without constraint is ill-advised, according to Mr Lock. High-cube, double-deck semi-trailers would be off-limits in his book. "The first thing I would do is bring the four-metre height rule into this country, limiting c-of-g height," he says, accepting that this flies in the face of current thinking on minimising carbon footprint by maximising load capacities. "For every benefit, there is a deficit," counters Mr Lock. "You have to work out the balance and decide where you spend the money. Banging the roll-over drum, I would like to see the four-metre limit, but I fully understand the political implications of that."

Gary Lock: "Wear and maintenance issues could be something that the DfT or HSE might like to investigate."

Nobody is holding their breath for a Department for Transport proposal on a four-metre height limit in the UK. So what practical steps can be taken by operators to lessen the risk of roll-overs when pleas for mitigation because of poor roundabout design or adverse camber will cut no ice in courts of law? Driver training and awareness, is Mr Lock's first response to this question. He reasons that if drivers are to blame for most roll-overs, they must be a big part of the solution too, and cites one company which requires drivers to watch a graphic video on the subject twice a year. This not only serves as a powerful reminder to drivers of their responsibilities but also could be used to demonstrate to a court how committed the company is to tackling the problem.

Preventing loads from moving is another basic but crucial safeguard against roll-overs, emphasises Mr Lock, pointing to a recent study by the Health and Safety Laboratory (*Transport Engineer* September 2008).

As for vehicle engineering, Mr Lock

emphasises that most attention needs to be focused on semi-trailers, not least because a trailer can be well on its way to rolling before the driver is aware of the danger. Attempting to improve the roll-stability of tractive units in the hope that this would make a useful contribution to overall artic stability would be fruitless, he argues, perhaps even counter-productive if it gave drivers a false sense of improved stability. Claims of additional artic stability resulting from wide-single drive-axle tyres on tractive units are dismissed by Mr Lock.

The engineering fix he favours above all is electronic roll stability program (RSP) systems, of the kind that have been optional, costing only around £200 in the UK, and are now integral with the latest semi-trailer electronic braking systems (EBS), such as Knorr-Bremse's TEBS G2.

An accelerometer in the EBS electronic control unit (ECU) detects trailer roll in real time, taking into account variables such as c-of-g height, speed and turn radius. Actual lateral acceleration is measured against a pre-set threshold. When this threshold is exceeded a brief test braking pulse is fired, and the response of wheels on one side compared with those on the other. If there is no difference the threshold is raised as the system "learns" the roll-over threshold of trailer and load. But if the test pulse slows the wheels on the inside of the curve (because they are off the ground or lightly loaded because of weight transfer) the RSP will automatically trigger trailer braking to reduce speed and contain the roll. It does this in about a quarter of a second. But if lateral acceleration is really severe, as in a high-speed evasive swerve, RSP skips the test-pulse stage and goes straight for the trailer brakes.

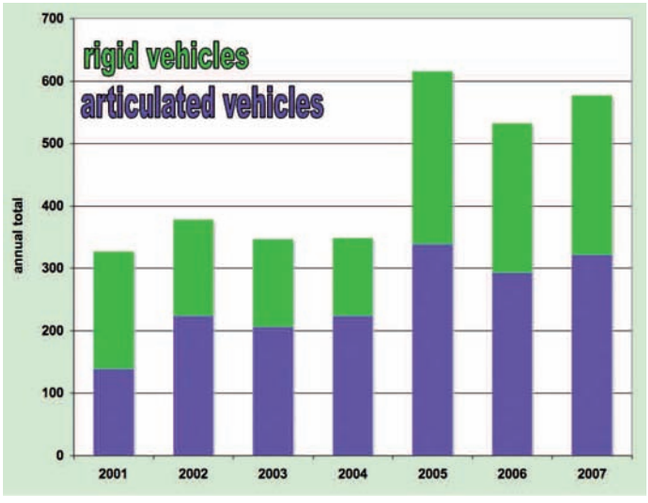
High society: the UK's high-capacity double-deckers are incompatible with the continental four-metre height limit. Trailer technology such as roll-stability programmes (RSP) is lessening the risk of roll-over for all trailers.

Though most new trailers supplied over the past six years or so are RSP-equipped, the long service life of trailers still means that most in use on UK roads do not have RSP. So drivers are forced to play a kind of Russian roulette every time they hitch up to a fresh trailer, unaware of whether it has RSP. Retrofitting the system costs £1,000-£1,500 per trailer, according to Knorr-Bremse: costly enough to deter most operators, unless and until the full cost of a roll-over accident is taken into account.

Amendments made last July to the ECE (Economic Commission for Europe) regulation 13 on braking systems means that RSP is set to become mandatory on trailers. From 11 July 2010 newly type-approved trailers over 10 tonnes gross weight will be required to have RSP. For new registrations the deadline is 11 July 2011. Mandatory fitment of electronic stability control (ESC) on trucks and buses is being phased in too, starting with two-axle tractive units registered from July 2011. There is no requirement to retrofit ESC/RSP to in-service vehicles or trailers.

"Trailer roll-control systems will prevent a significant percentage of roll-overs," says Mr Lock, acknowledging that they dispel most of his qualms about double-deck trailers. But smart operators will not leave it at that. He urges them to take advantage of the download function built into RSP systems, so they can see how often and when the system was triggered. This log of near-misses should be interpreted and fed back to drivers to raise awareness and assess training needs, he advises. It would also stand a company in good stead in defending itself in the case of a prosecution following a roll-over. Some companies even take a feed from trailer roll prevention systems to vehicle satellite-tracking systems so that high-risk locations can be pinpointed. This enable operators to build databases of tighter-than-usual motorway exit slip roads and roundabouts with adverse cambers or sharp approach/exit angles.

Turning to engineering details affecting an artic's propensity to roll, Mr Lock homes in on the fifth-wheel coupling. "The slop between the kingpin and the coupling already gives two or three degrees of roll," he says. "Roll at the coupling is particularly critical at high articulation angles, when the pitch movement built into the fifth-wheel becomes roll." He is impressed by Carl Henderson's novel turntable articulation system (*Transport Engineer* August 2008) which not only extends effective track width by means of wings from the fifth-wheel clamped to the trailer's main rails but also eliminates free play between the kingpin flange and coupling, making the driver more aware of what is happening behind him.



Overturning statistics: from the DfT's annual Road Casualties in Great Britain reports.

Mr Henderson is about to embark on another round of testing, attempting to prove that he can, as promised, improve an artic's roll threshold by 20-30 per cent.

Mr Lock sees scope for research into the impact of coupling and kingpin wear on roll stability. "Wear and maintenance issues could be something that the DfT or Health and Safety Executive might like to investigate," he suggests.

The move from steel to air suspension on trailers has vastly improved roll resistance, points out Mr Lock. The stiffer the trailer suspension and the torsionally stiffer its chassis, the better its roll stability, he says. That seems to amount to endorsement of trailer suspension with rigid fabricated trailing arms instead of more flexible, spring arms. But it would be wrong to attribute big differences to air suspension design (or damper performance), according to Mr Lock. "The suspension stiffness used for roll calculations might make half to one mile per hour difference, if that, in the accuracy of the roll-over speed prediction," he says. "When you compare it with the other variables involved it is not massively significant. Like the other secondary factors, it is all second order compared to electronic stability." It is not everyday that your hear a mechanical engineer coming out so strongly in support of an electronic engineer's solution to a persistent problem. ❑