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## Uphill battle

Pulling a heavy shopping trolley back to the car at the weekend, the difficulty of compensating for even a slight gradient in the forecourt tarmac always catches me by surprise. Although no doubt I am a 98-pound weakling compared to our nation's muscular delivery drivers, the prospect of dropping off a heavy pallet on a steep hill should scare them, too. It was just this kind of operation, tail-lifting a 1,100kg load of tiles in High Wycombe, that killed delivery driver Petru Soimu Pop in 2016 (see also pp12-13). That terribly sad accident poses lots of questions, about the management context of the delivery and of the impromptu working site. Was the driver rushing because of pressure to meet performance targets? Would he have had sufficient authority to refuse the delivery on safety grounds? Was the tail-lift big enough? Had the load been palletised securely?

Here's the easiest question of the lot: how steep was the gradient? Some basic science suggests that, assuming no friction, even a heavy load won't take much push/pull effort as long as the surface is perfectly flat. But at the other extreme, lifting a load vertically would require overcoming its entire weight. So it's logical to think that the steeper the gradient, the harder it will be to push a load. Mathematically speaking, the push force required increases in proportion to the 'sine' (a geometric function) of the angle of the so-called 'inclined plane', converted into a percentage. For example, on a 1° slope,  $\sin 1^\circ = 0.017$ , so the angle adds a force of 1.7% of the weight of the load. At 5°, that works out to be 10% of the load; at 10° the figure is 17%; and at 15°, the number is 26% (<https://is.gd/ivocow> plots these values as a curve).

HSE guidelines for push/pull are 200 Newtons (corresponding to 20kg) to start moving a load, and 100N (10kg) to continue moving it (<https://is.gd/naqule>). Greater than that, and people should try to find a way to reduce the force needed, it advises. Plugging those numbers into the formula, starting a 100kg load on a 12° slope would exceed the guideline (21kg). Starting to move a load ten times as heavy nearly exceeds the guideline on only a 1° slope (17kg). Fleets doing heavy pallet multi-drop distribution to residential addresses should consider fitting inclinometers (tilt sensors) to the truck body, and teach drivers how to use them, to help improve safety of these operations.

Will Dalrymple  
Editor