Benjamin Drew

Would you be a CLEVER driver?

As more and more people want to get about within cities and towns, the problems of congestion and pollution are increasing. Motorcycles and bicycles take up less space and produce fewer emissions than conventional cars, but they are unsafe in an accident and don't offer much in the way of comfort or protection from bad weather. Benjamin Drew of Bath University describes an alternative solution – the CLEVER vehicle.

Key words
car safety
energy efficiency
unbalanced forces
acceleration

A CLEVER idea

The objective of the CLEVER Project was to design and develop a vehicle that could fill the gap in the market between cars and motorcycles, providing a safe and comfortable vehicle that produces less harmful emissions and takes up less room on the road than a conventional car.

CLEVER is a three-wheeled two-seater car; the passenger sits behind the driver.

CLEVER is the result of a three year long research project funded by the European Commission. The project comprised four academic institutions and five industrial partners from the UK, France, Germany and Austria who worked together to develop the vehicle. Each institution focused on a specific aspect of the work, with the goal of producing two fully functional prototypes and three crash test vehicles.

The design of CLEVER is an enclosed narrow vehicle that is three metres long and one metre wide. This gives efficient use of road and parking space, reduced fuel consumption and a reduction in harmful emissions. Table 1 compares the CLEVER car with the Mercedes Smart car which can be seen on the roads today.

	CLEVER	Smart Diesel
engine power	15 kW	30 kW
kerb weight	400 kg	800 kg
front-end area	1.0 m^2	2.2 m^2
CO_2 emissions	60 g/km	100 g/km

Table 1: Comparing CLEVER and Smart; a small front-end area reduces air resistance

Is it green?

CNG is mainly methane, CH_4. In the CLEVER engine, it burns with oxygen to produce carbon dioxide and water.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

CLEVER has an engine that runs on compressed natural gas (CNG) which produces less carbon dioxide and other harmful emissions than an equivalent petrol or diesel engine. CLEVER has two lightweight carbon-fibre tanks, each holding 6 litres, giving a range of approximately 125 miles. CNG is similar to the gas used in homes for heating and cooking, so in the future it may even be possible to fill your car up at home!

CLEVER's small size, light weight and narrow shape also mean that it is more fuel efficient, further reducing fuel consumption and harmful emissions. CLEVER's emissions are 60 grams of carbon dioxide per kilometre, which is less than half the target set by the European Union, and its fuel consumption is equivalent to 108 miles per gallon. Despite the engine being small, CLEVER's design means that it can reach 60 mph and accelerate from 0 to 40 mph in seven seconds, which is adequate for a vehicle designed specifically for cities.

Acceleration: CLEVER accelerates from 0 to 40 mph (= 17.8 m/s) in 7 s. That's an acceleration of $17.8 / 7 = 2.5$ m/s^2.

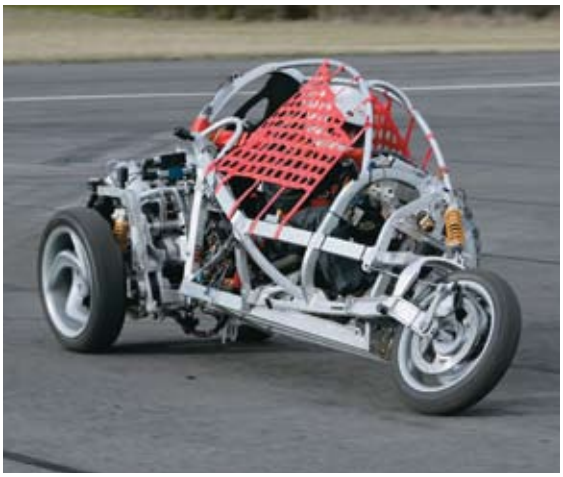
What about safety?

The structure of CLEVER uses a lightweight aluminium frame with plastic body panels. The frame was developed with crash safety in mind, with specifically designed crumple zones and energy absorbing structures at the front and sides to make sure that the occupants of CLEVER would be protected in an accident. Inside, CLEVER has an airbag and seatbelts, and the interior surfaces are constructed from energy absorbing materials to reduce serious injury to occupants. Three prototypes were assembled specifically for crash testing: a frontal impact, a side impact and a 'compatibility' impact, where CLEVER crashes into the side of a car. The results of these three tests suggest that CLEVER would score 3 stars in the standard EuroNCAP tests. (Conventional cars currently on the market usually score 4 or 5 stars, so 3 stars for a first prototype is an excellent result.)

CLEVER undergoes a standard impact test in the EuroNCAP trials.

Why does CLEVER tilt?

One of the most unusual features of CLEVER is its narrow width. Being only one metre wide, two CLEVER vehicles could fit side-by-side in the space occupied by one car, which leads to reduced congestion and easier parking. The problem with narrow vehicles is that they tend to roll outwards in corners, and can topple over if cornering too quickly. When a bicycle or motorcycle goes round a corner, it tilts into the corner. An automatic tilting mechanism was designed for CLEVER to make cornering possible. This was the focus of our work at the University of Bath.



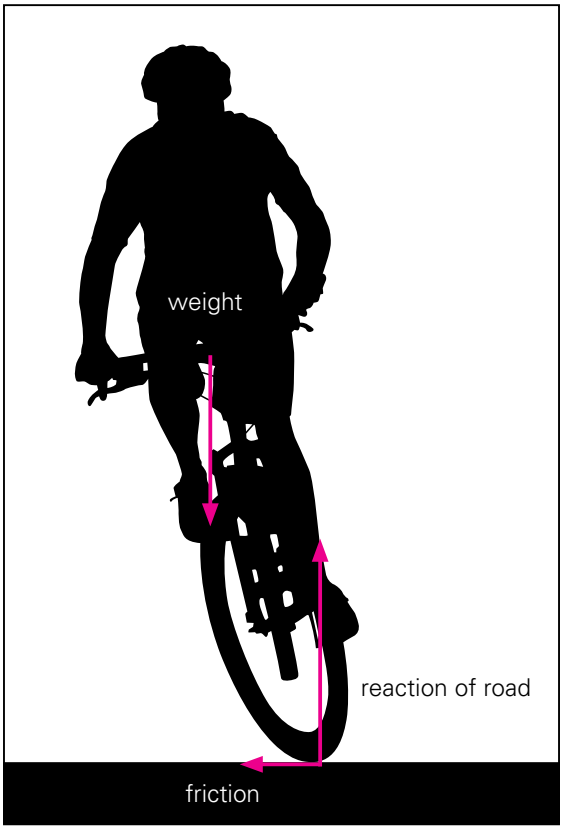
As the CLEVER vehicle corners, the front wheel and the passenger compartment tilt into the corner by up to 45°. This test vehicle also shows the aluminium frame which protects the occupants.

When a car goes round a corner it has to accelerate towards the centre of corner – this happens by the car's tyres creating a sideways force into the corner. The tighter the corner and the faster the car is moving, the greater the acceleration required. But if this acceleration is too great, the car will roll over. One way to avoid rolling over is to have a very low centre of gravity – that's why racing cars are low and wide – but this would mean that the occupants would have to sit very low down in the vehicle: getting in and out would be difficult, and the driver would have greatly reduced visibility.

To solve this problem, a mechanism was developed to tilt the body of the vehicle as it corners, up to an angle of 45°. An electronic control unit measures

the driver's inputs and the vehicle's current tilt position, and two hydraulic pistons tilt the cabin to the required angle to balance the vehicle. This shifts the centre of gravity sideways and pushes the weight on to the inside wheel, thus avoiding roll-over.

In an ordinary, non-tilting car cornering at speed, you may have felt yourself being flung sideways; in a tilting car, the occupants don't feel these side forces. The system is computer-controlled and fully automatic, so the driver doesn't have to balance the vehicle like on a motorcycle. This system not only makes CLEVER stable in corners, it also makes it good fun to drive!

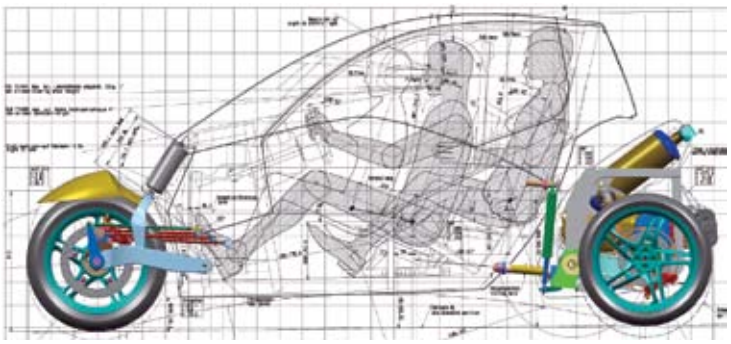


A cyclist cornering: the sideways frictional force of the ground on the tyre provides the force needed to follow a curved path.

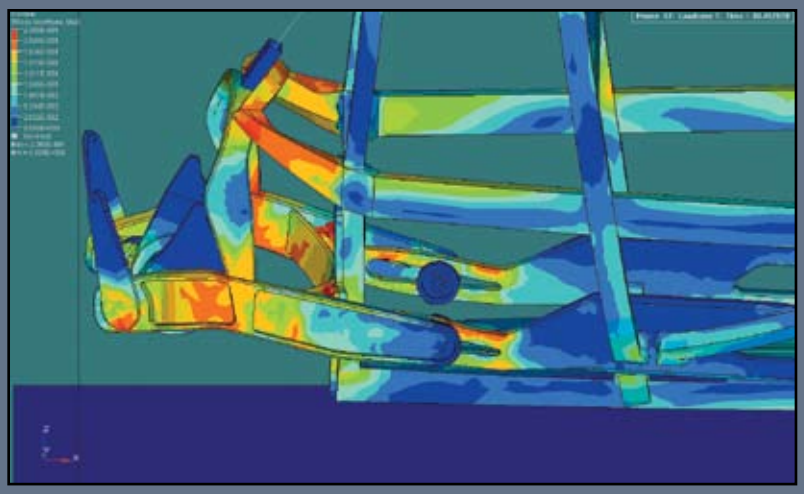
When can I buy one?

CLEVER will never go on sale in its current form, but it is envisaged that some of the technologies demonstrated on CLEVER such as the tilting system and compressed natural gas engine could be on the market in a few years time. Many car manufacturers are actively researching alternative vehicles, like CLEVER. The main reason is that the European Union will start to impose fines if a manufacturer's fleet of cars has an average carbon dioxide output above 140 grams per kilometre. For manufacturers of large premium cars like BMW or Mercedes-Benz, a vehicle like CLEVER included in their range that produces only 60 grams of carbon dioxide per kilometre will significantly reduce this fleet average, thus avoiding the fines.

Box 1 Working together



Powerful computer-aided design (CAD) software was used to design and construct a virtual CLEVER. This meant that, while different teams worked on their own individual aspects of the design, the different systems within the car (the transmission, chassis etc) could be integrated effectively. The virtual model was also used in virtual crash simulations.



Two CAD drawings of the CLEVER vehicle with the front and rear chassis parts shown in 3D.

Dr Benjamin Drew is a research officer in the Department of Mechanical Engineering at the University of Bath.

Look here!

The CLEVER Project website is at www.clever-project.net.

Watch videos of CLEVER on trial at www.summerscience.org.uk/node/43.html

You can see photos and movies of CLEVER undergoing crash tests at www.clever-project.net/gb/gb_crashtest.htm

This BBC News item about the CLEVER vehicle includes a movie showing Ben Drew test-driving the car http://news.bbc.co.uk/2/hi/technology/4930794.stm