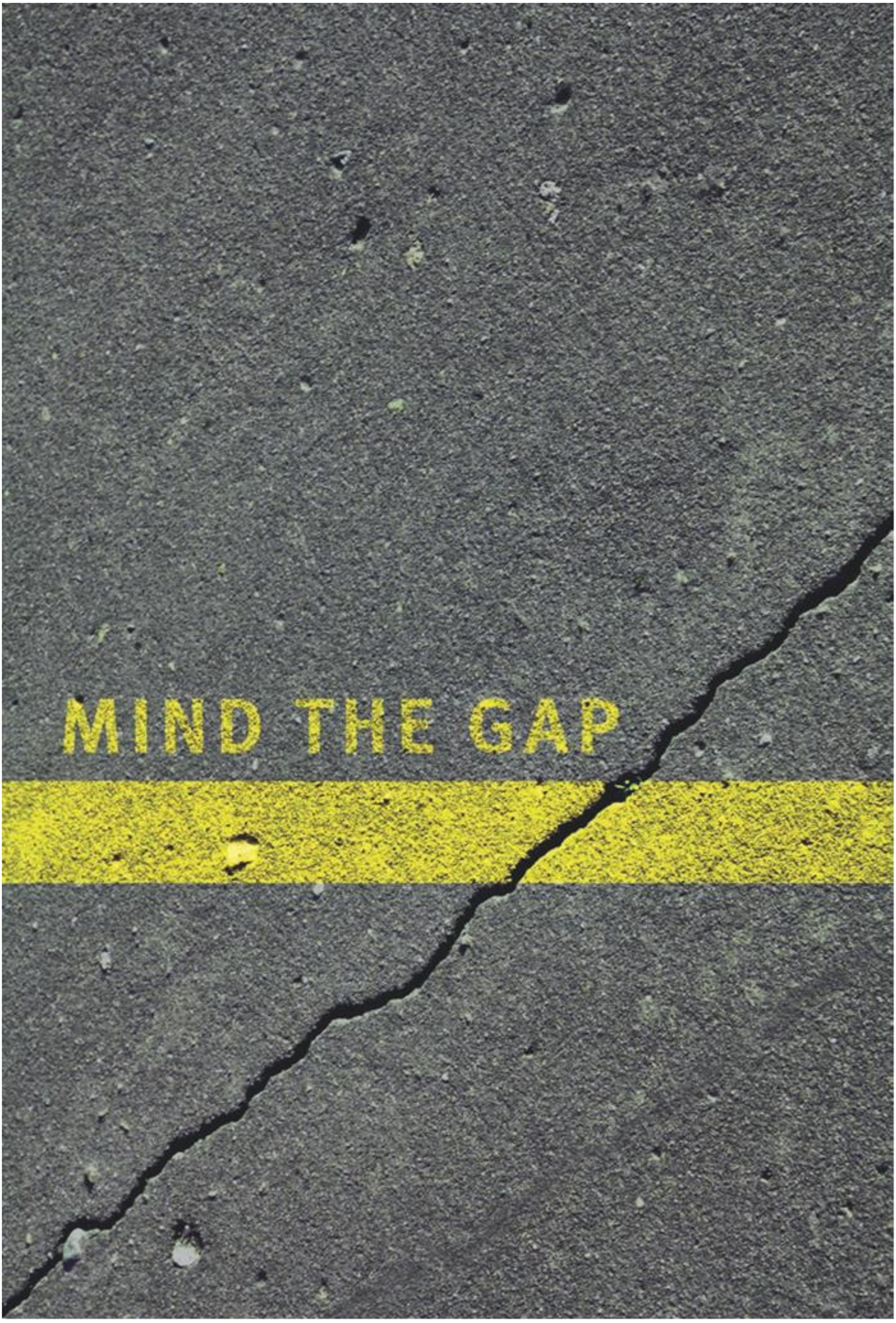
MIND THE GAP

Title of publication

Mind the Gap! Why official car fuel economy figures don't match up to reality

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Executive Summary

This report provides new evidence and understanding on why there is a growing gap between the official fuel consumption and CO_2 emissions of new passenger cars and vans and that which is achieved by the same vehicles on the road. It demonstrates that the current (NEDC) test is outdated and unrepresentative of real-world driving and current vehicles, and that lax testing procedures are allowing carmakers to manipulate the official tests to produce unrealistically low results. The report also shows that the current supervision of testing and checks on production vehicles (to ensure these are equivalent to tested vehicles) are inconsistent and inadequate, with manufacturers paying the organisations undertaking and certifying the tests. The conclusion is that the current system for measuring car and van fuel economy and CO_2 emissions is not fit for purpose and is in need to urgent updating.

Why representative, robust fuel economy and CO_2 emissions data from vehicles are essential

Providing reliable information about the fuel economy of cars helps drivers choose models with lower running costs. Having accurate tests of vehicle carbon dioxide (CO_2) emissions is essential to enable governments to levy the correct level of vehicle taxes and ensure regulations to reduce emissions from new cars are effective.

All drivers know that it is usually impossible to achieve the official manufacturer fuel efficiency figures, and for some individual models the real-world emissions are now 50% higher than the test results. The gap between official test results and typical real-world driving performance is also growing. In Germany, the gap has increased from 7% on average in 2001 to 23% in 2011 and consequently only half the anticipated improvement in fuel economy (of 1 l/ 100km) has been achieved on the road. For drivers, this is adding around €2,000 to the fuel costs of the vehicle over its lifetime. Data from Germany is supported by other studies from the Netherlands and Switzerland. The growing gap is leading drivers to become increasingly distrustful of official data on fuel economy, making them less likely to consider buying a more fuel efficient vehicle.

Three reasons why the gap is growing

There is no evidence that the growing gap is caused by changes in the way cars are used and driven. Instead, the evidence shows three principal causes:

1. The current test is unrepresentative of real-world cars and driving. Much of the technology introduced to improve efficiency of cars is far more effective in the test than on the road. For example, technology to switch off the engine when the vehicle is stationary is very effective during the test when the vehicle is stationary for 20% of the cycle.
2. Cars are also increasingly fitted with energy-guzzling accessories like air-conditioning, navigation and media systems, heated-seats, etc. This equipment is not switched on during the test and by omitting the energy consumed, the official test results are lowered.
3. The current (NEDC) test procedures to measure CO_2 and fuel consumption are outdated and lax and contain many loopholes that carmakers are increasingly exploiting to lower the results.

How carmakers manipulate test procedures

A substantial body of evidence, including a new expert study for the European Commission, shows the many ways carmakers are able to manipulate test results. By creative interpretation of the test procedures carmakers are able to achieve multiple small improvements that lower the test results as illustrated in the Figure.

The test comes in two main parts - a road load test and a laboratory test - and the results of both can be manipulated. During the road load part of the test, the air and rolling resistance of the car is measured and the results used during the subsequent laboratory test. In the laboratory test the car is driven on a rolling road through a test cycle comprising a series of accelerations, steady state driving and decelerations. Fuel economy and CO_2 emissions are measured throughout the test. The results of the road load test are used to set the resistance of the rolling road (how difficult it is for the car wheels to turn the rollers).

- The road load test

When the road load test procedures were drafted 30 years ago, no-one expected carmakers to adjust the brakes, pump up the tyres, and tape up all the cracks around the doors and windows to reduce the air and rolling resistance. These practices are now commonplace, with testing facilities being paid to optimise the results of the tests. There is no evidence that carmakers are breaking any formal rules - but they don't need to - the current test procedures are so lax there is ample opportunity to massage the test results.

Testing undertaken by an independent laboratory has found that for older vehicles, road load results in realistic tests – e.g. using regular production vehicles - were on average 19% higher than the results obtained in official tests. For more modern vehicles the average difference was 37%, supporting other evidence that the manipulation of the road load part of the test is increasing. These differences would result in around a 12% reduction in measured fuel economy.

In the US, Hyundai-Kia were found to have not conducted the road load test fairly. Several manufacturers in Europe have been successfully challenged over unfair advertisements using official test results.

- In the laboratory

Results are also being polished up in laboratory tests by, for example, allowing the battery to discharge during the test; minimizing the weight of the car; using special lubricants that are not supplied with the production vehicle and testing in unrealistically hot temperatures. Once the results have been compiled the current procedure also inexplicably allows the CO_2 results declared by the manufacturer to be up to 4% below the measured results.

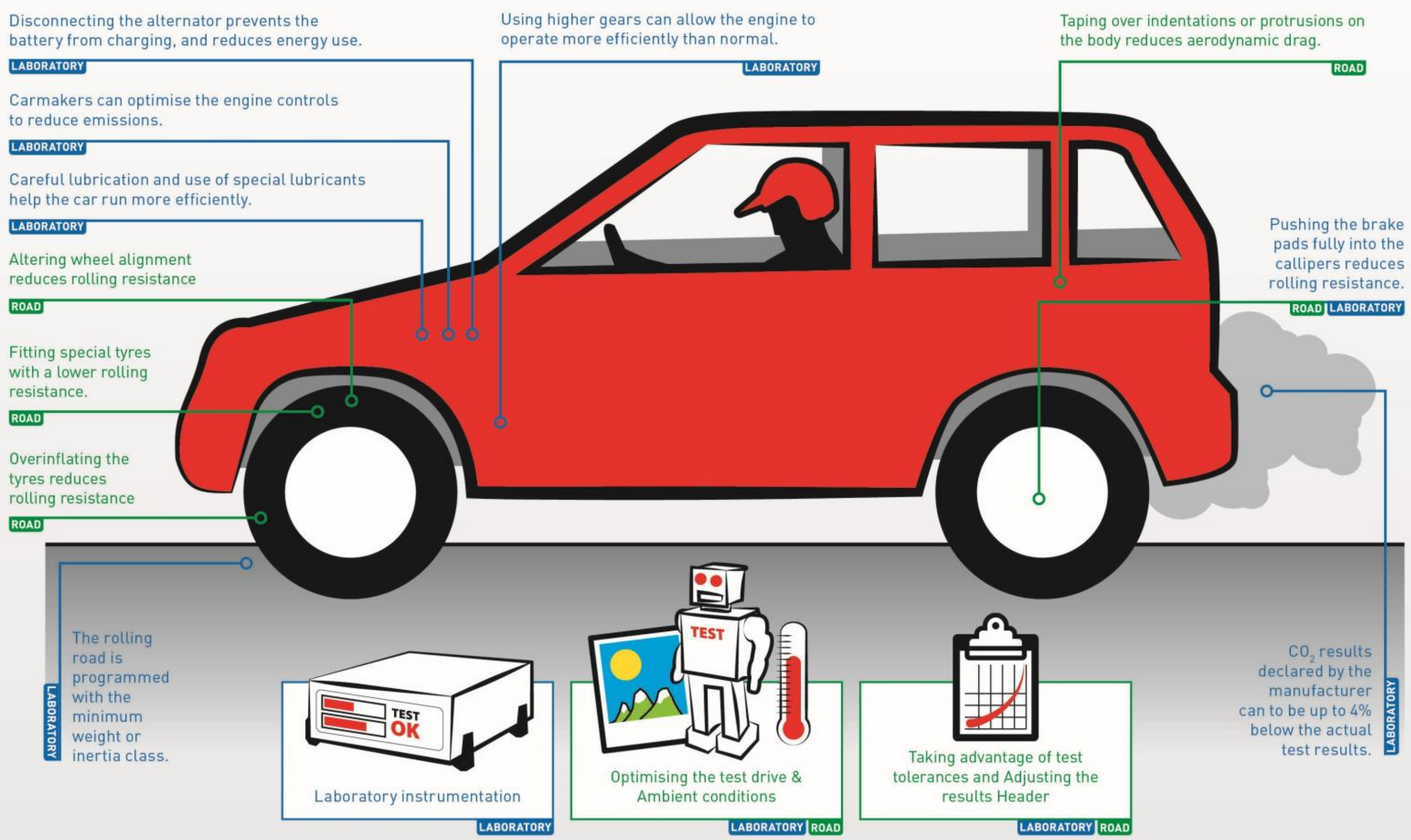
Independent laboratory tests, using the official drive cycle but with regular production vehicles and without using all the loopholes in the rules, show on average 12% higher fuel consumption and CO_2 emissions than official figures reported by the carmaker. In total, the independently executed tests lead to 19-28% (average 23%) higher CO_2 emissions and fuel consumption than the official figures reported by carmakers. About half of this is explained by differences accruing from the road load testing, the other half comes from differences in the laboratory testing. This is the same level as the average gap between official test figures and real-world fuel consumption observed in Germany.

How much are falling official CO_2 emissions the result of manipulating tests?

The extent to which manipulation of the tests has contributed to the improvement in official CO_2 figures has been estimated by consultants for the European Commission. They conclude around 30% of the net CO_2 emission reduction between 2002 and 2010 does not result from technology deployment and that “utilisation of flexibilities may account for two-fifths to one half of the net CO_2 emission reduction between 2002 and 2010.” From their detailed findings, the causes of the current gap can be estimated to be:

- About 25% due to flexibilities in the laboratory test
- 25% – 35% due to flexibilities in the road load test
- 10-20% due to omissions from the test (like air conditioning systems)
- 10-20% due to the NEDC cycle being unrepresentative
- 10-20% from unknown causes.

Common ways carmakers manipulate tests for CO_2 emissions and fuel economy



Four key steps to deliver robust fuel economy and CO_2 emission data

There are four key steps to address the current distortion of car fuel economy and CO_2 measurements in official tests and ensure the system is robust and fit for purpose:

1 New rules should be quickly introduced to close the biggest loopholes in the current (NEDC) test procedures. This should be followed by re-testing of all current production vehicles using the revised procedures to ensure official figures are a better reflection of actual CO2 and fuel economy information. Re-testing should be completed by the end of 2014 to ensure 2015 regulatory targets for new car CO_2 levels cannot be distorted by manipulating test results. In parallel, the European Commission should ensure there is much greater consistency in the way that National Type Approval Authorities and Testing Services undertake and certify official tests and checks on new production vehicles.

2 A new test cycle and testing procedures should be introduced in 2016. The World Light Duty Test Cycle (WLTC) is under development and is expected to be finalised in 2014, providing a modern credible alternative to the current NEDC system. This should be done in a way that ensures the new cycle is representative of typical average driving in the EU and that vehicles are tested under representative conditions, including switching on during the test all equipment such as the lights, air conditioning, etc. The new system should provide much greater transparency on how tests have been undertaken and calculations performed. A parallel system of tests on production vehicles should ensure that there is no deviation between official test results and those achieved in official (type approval) tests. The automotive industry has been pressing for, and developing the new test, but is now arguing it should not be used until 2021! This is in part because the new test cannot be manipulated to the same extent.

3 By 2020, a new system for type approval of vehicles should be introduced to ensure certifying and testing bodies are entirely independent of carmakers. This should include specific consideration of establishing an EU-wide Type Approval Authority that would then sub-contract testing services to accredited national organisations. This is needed because the current supervision of testing and checks on production vehicles (to ensure these are equivalent to tested vehicles) are inconsistent and inadequate, with manufacturers paying the organisations undertaking and certifying the tests, and Europe's many facilities and type approval authorities competing for business.

4 In order to restore consumer confidence, the car labelling directive should be reviewed on the basis of the US model that communicates the best possible estimate of real-world fuel economy.

Concluding comments

The system of regulating carmakers to ensure they achieve progressive improvements in fuel economy and CO_2 emissions of new cars is, on the whole, effective and well designed. But the existing system for measuring the performance of individual cars is not fit for purpose and needs to be updated. By doing this, drivers will achieve fuel economy similar to official data restoring trust and encouraging the shift to fuel efficient cars.

Currently carmakers are misleading their customers by promoting fuel efficiency figures that they know will not be achieved. Carmakers are also cheating policy-makers by manipulating the official tests and producing vehicles that only achieve regulatory targets during the test - not on the road where the fuel is burnt and emissions occur. An updated system will ensure vehicle taxes linked to official CO_2 data will be more effective in driving the shift to more fuel efficient models. This will support EU regulations requiring cars and vans to become more efficient and less polluting that are currently (2012/3) being considered by the European

Parliament and Council. If loopholes are not closed, the environmental and the wider economic benefits of the regulation will be much smaller than would be expected. Specifically, less jobs will be created, the increase in GDP from less oil spending will be lower and oil imports will be higher, worsening balance of payments. Greenhouse emissions will not be reduced as forecast.

The regulatory pressure to reduce new car CO_2 emissions and the significant tax breaks on cars with low CO_2 test figures are all providing an incentive for carmakers to manipulate official test results. The poor oversight of official tests is allowing this to happen. Evidence indicates the full range of test flexibilities are not yet being exploited and the manipulation of official data will continue to increase, unless policy-makers act and implement the four recommendations detailed above.

1. Introduction

The CO_2 emissions caused by a conventional car are directly related to its fuel efficiency. Cars with lower running costs therefore also produce less greenhouse gases. Having accurate information about the fuel economy and CO_2 emissions of cars is essential both to help drivers choose more fuel efficient models, and to ensure regulations designed to reduce emissions of greenhouse gases from cars and vans are effective.

This report considers why official data about car fuel efficiency and CO_2 emissions differ so widely from the experience of drivers on the road. It explains the reasons for the growing gap between official measurements and the real-world fuel efficiency achieved by drivers. Specifically the report presents a range of evidence to show the ways carmakers manipulate official tests and proposes a range of solutions to address current inadequacies in the tests, testing procedures and approval arrangements.

1.1 Measuring real-world fuel efficiency

There are a range of factors that affect the fuel efficiency of vehicles driven on the road, so the same car can deliver very different results in different conditions or with different drivers. Notable causes are that:

- Drivers drive differently
- Traffic conditions vary
- Different people use their cars in different ways
- People maintain their cars differently.

Given the wide range of factors that influence car fuel efficiency, different individual drivers will achieve widely varying fuel efficiency. The average fuel consumption of a typical driver is however substantially more (by around 25%) than the official tests suggest. Most drivers find it impossible to achieve official figures in any circumstances and are finding that the gap between official figures and their real-world experience is growing (see Section 2). The official tests systematically overestimate fuel efficiency and underestimate CO_2 emissions and Annex 1 explains why changes in driving conditions cannot account for this growing gap.

The large and growing gap between official fuel test results and average real-world driving is not caused by the way cars are used and driven, but because the official test is totally unrepresentative of typical driving and the results are being artificially lowered by manipulating testing procedures.

1.2 Official measurements of fuel efficiency

Official data about car CO_2 emissions and fuel economy are derived through laboratory testing to ensure results are repeatable. The laboratory test is a simulation that is supposed to (but doesn't currently) reflect real world traffic conditions. The vehicle is put on a 'rolling road' (chassis dynamometer) and the CO_2 emissions and fuel efficiency are measured over the test for a fixed series of accelerations, steady speed driving, and decelerations collectively known as a drive cycle. Many such drive cycles exist, intended to mimic a wide variety of driving conditions. The EU uses a test cycle originally established in the 1970s to test for emissions of pollutants such as nitrogen dioxide in urban areas. Carbon dioxide emissions and fuel consumption (calculated as a simple function of the CO_2 and other gases emitted) were subsequently added to the procedure. The NEDC test is old, outdated and was not designed to measure representative fuel efficiency and CO_2 emissions, so it is no longer an appropriate tool for current purposes. A new test is under development (the World Light Duty Test Procedure or WLTP) as part of a scheme to harmonise global testing procedures and is expected to be finalised in 2014.

A credible laboratory test must produce results comparable to the performance experienced by ‘typical’ drivers on the road and be sufficiently well described that it cannot be manipulated by carmakers to distort the results. There should also be an adequate system of approvals to ensure that the tests are conducted fairly and appropriately. This report demonstrates the current system fails on all counts. Although the inadequacies of the current NEDC drive cycle are part of the reason test values are unrealistically low compared to typical real-world driving, they do not fully explain the discrepancies, and in particular why the gap is growing.

1.3 The policy context

Whilst the issues outlined in the report are highly technical they also underpin the framework of EU and national policies designed to both improve vehicle fuel efficiency and reduce CO_2 emissions from cars and vans. The evidence, findings and recommendations are of key significance for both policymakers and motoring and consumer organisations seeking to encourage supply of genuinely more fuel efficient vehicles. The policy measures underpinned by the official fuel and CO_2 figures include:

- Regulation 443/2009 that requires carmakers to reach a sales weighted average of 130g/km of CO_2 emissions for all the new cars sold by 2015. The European Commission has recently proposed to extend this regulation to achieve 95g/km on average by 2020.
- Regulation 510/2011 that requires van manufacturers to improve fuel economy and reduce CO_2 emissions according to a similar model. The European Commission recently completed its review of the proposed 2020 target, recommending that the existing target of 147g/km be retained.
- Directive 1999/94/EC that requires Member States to ensure that information on the fuel economy and CO_2 emissions of all new passenger cars offered for sale or lease in the Community is made available to potential buyers. This is intended to help car buyers make an informed choice about fuel economy.
- National policies designed to encourage more fuel efficient vehicles including levels of circulation and purchase taxes; grants for ultralow carbon vehicles; and exemptions for road charging and access restrictions, are all based on the official EU figures for CO_2 emissions (ACEA, 2012).

The inadequate tests of CO_2 and fuel economy are resulting in policies designed to reduce CO_2 emissions from vehicles being much less effective (by approaching 25%) than they should be. They are also leading to lower revenues from vehicle taxes and cheating drivers of the fuel cost savings they expect to achieve from choosing more fuel efficient cars.

The inadequate testing regime also runs the risk that drivers will increasingly distrust the official data on fuel economy or ignore it, making them less likely to consider buying a more fuel efficient vehicle (Lane and Banks, 2010). In short, if the problems of the current testing regime are not addressed, then all of the policies listed above will be under threat, and their aims will not be realised.

1.4 This report

This report examines the evidence of and reasons for the widening gap between test and real-world fuel economy measurements and the solutions to address this:

- Section 2 summarises the substantial and growing body of evidence that shows the gap between official and real-world test results is growing and the reasons for this.
- Section 3 focuses on how the official tests are undertaken and the ways in which they are being systematically manipulated by carmakers seeking to achieve the best possible results in the tests without applying in full the new technology that would deliver real improvements on the road. This includes the results of testing undertaken for T&E to demonstrate the scale of the effects.
- Section 4 draws conclusions and outlines the policy actions that need to be taken to strengthen the type approval process, and stop the manipulation of the tests in order to produce reliable and representative official test results.

2. The gap between official tests and real world fuel efficiency

A substantial body of evidence shows that the disparity between official test results and real world fuel economy is large and growing. The strongest evidence is from technical studies and large databases of 'real world' fuel economy data. But most drivers of newer cars are already aware that the fuel efficiency stated in the sales literature, and elsewhere, bears little resemblance to that measured using dashboard instruments or by routinely checking mileage against fuel receipts.

The discrepancy between real-world fuel consumption and that from official tests has been recognised for many years. National annual fuel consumption has, in the past, typically been 5-15% greater than that calculated using official fuel consumption figures for vehicles and annual mileages driven. More recently the gap has grown on average to more than 20%, is continuing to grow, and can be considerably more for individual vehicles.

2.1 The widening gap between test results and real-world experience

The evidence of a widening gap between officially-tested fuel consumption and real-world driving experience is extensive, with the strongest evidence from two large databases of real-world fuel consumption data.

Spritmonitor

Spritmonitor is a German website that enables users to record their mileages and amounts of fuel purchased, providing an ongoing record of each vehicle's fuel economy over time. With over 300,000 vehicles and approximately 4.5 billion vehicle kilometres of distance driven within the database, it is a comprehensive record of real world fuel consumption for a wide range of vehicle models and model years. Although the data are self-reported it is possible to 'clean' them and remove outliers to produce a reliable and representative dataset of real-world fuel efficiency.

The ICCT (Mock *et* al, 2012) examined the gap between real-world and test data from 2001 to 2010 model years. The database represents around 50% of the annual car sales in Germany and is highly representative. Figure 1 illustrates the percentage by which real-world CO_2 emissions exceed test values for a range of selected models and variants over the period 2003 to 2011. It illustrates a divergence of real-world CO_2 emissions from the published test values over the past decade. In the early years of the decade a gap of more than 20% was almost unknown, whereas more recently, they become commonplace and excesses of emissions of even 50% are now found. Figure 2 illustrates how this gap is growing on average. Between 2001 and 2010 average emissions of CO_2 as reported to Spritmonitor declined by 13g/km, but the official test figures show emissions declining by 27g/km. The gap has grown from 7% on average in 2001 to 23% in 2011 and is still growing.

Half the official improvement in CO_2 emissions reported in tests has not been reflected on the road. If the gap had not widened drivers would now be consuming 0.5ℓ/100km less fuel saving on average €170 each year[1] in fuel bills.

[1] Assumes 20,000km per year and a fuel price of €1.7/ℓ

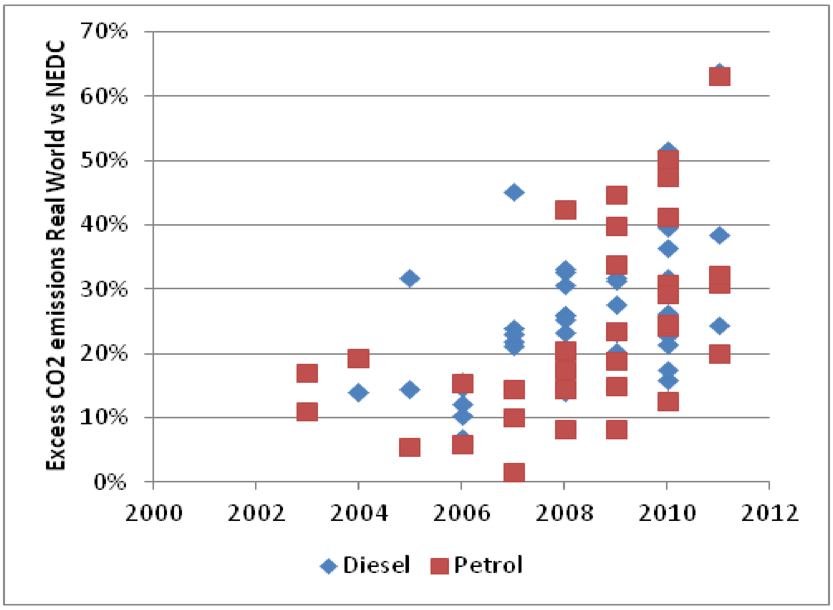


Figure 1: Comparison of real-world and test data for selected car models 2003 – 11 using Spritmonitor data

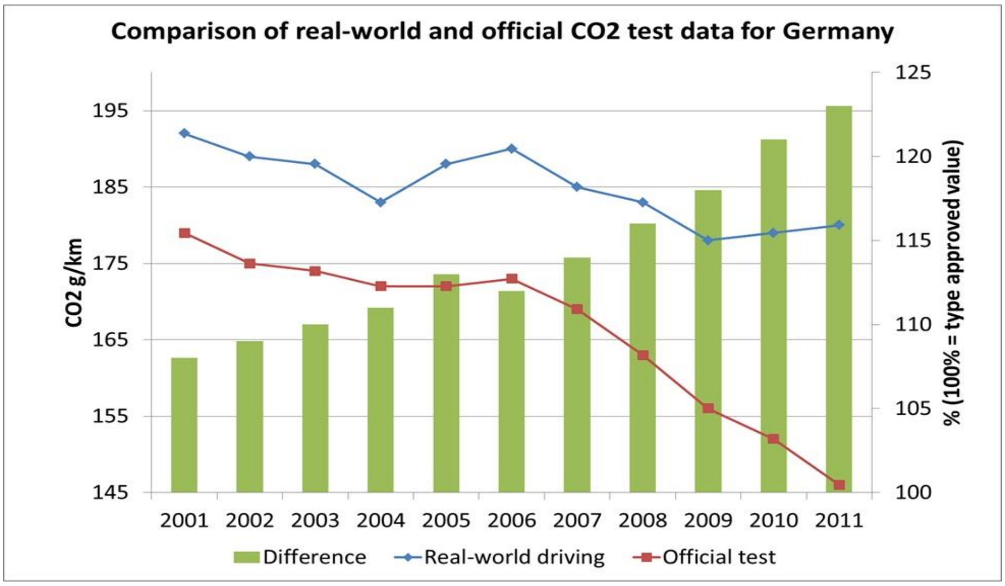


Figure 2: Comparison of average real world and official test results for Germany (derived from Mock *et al*, 2012)

The gap has grown at around 1% per year since 2002 and is continuing to grow. By 2020, the trend suggests an average car achieving 95g/km of CO_2 on paper[2] would emit 124g/km on the road.

By 2020, the current trend indicates the average car will consume more than 1 l/100km more fuel on the road than the official test results. This will cost the typical motorists €340 per year.[3]

[2] The target in the proposed 2020 Regulation is for an average car to achieve 95g/km
[3] Assumes 20,000km per year and a fuel price of €1.7/ℓ

The TNO Travelcard Survey

Similar data were obtained in the Netherlands by the engineering consultancy TNO (Ligterink and Bos, 2010) that compared real-world fuel consumption obtained from corporate fuel cards (known as Travelcard) with official fuel consumption data. The sample is representative of company fleet car users, rather than private drivers, but the extensive database provides a detailed snapshot of real world fuel use over 18 months. Ligterink and Bos show (in Figure 3) that only a small proportion of drivers achieved the fuel economy that matched official test data, but on average the actual economy was around 18% worse, and in extreme cases could be more than 40% worse. Indeed, the number of drivers experiencing an adverse discrepancy of more than 40% was almost as great as the number who achieved a fuel economy as good as or better than the test results.

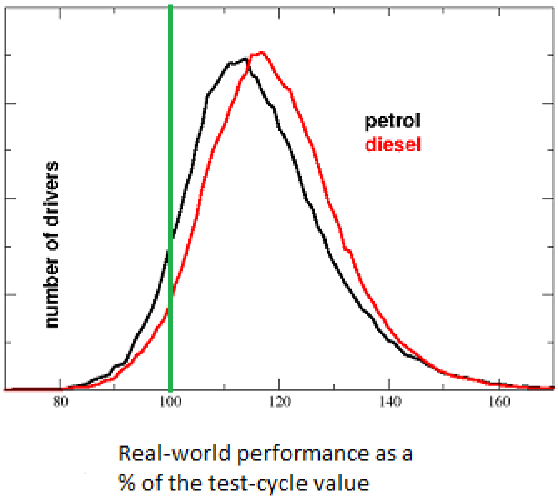


Figure 3: Distribution of test to real-world fuel economy (Ligterink and Bos, 2010)

This evidence from Germany and the Netherlands is backed up by other studies from across Europe pointing to a large and growing gap between actual and tested fuel economy. The most important of these are summarised in Annex 2 and all point to similar conclusions.

2.2 Reasons for the growing gap between test results and real-world driving

There are three main elements that are known to contribute to the gap between official fuel efficiency test results and real-world performance. These are:

1. Differences in driver behaviour and real-world road conditions
2. Deficiencies in the official test cycle that does not reflect typical driving conditions
3. Loopholes in the test procedure. These in turn fall into two areas:
    - Inaccuracies in the 'road load' test to determine the aerodynamic drag and rolling resistance of the car
    - Loopholes in the test procedure measuring the CO_2 emissions and fuel efficiency on the testbed

The variability of real-world driving conditions was outlined in Section 1.1. Average real-world driving conditions are reasonably consistent over time, and cannot therefore account for the large increasing gap between official tests and real-world data. Indeed, some evidence in Annex 1 suggests that road conditions may actually have improved in recent years.

Deficiencies in the test cycle contribute to the widening gap – but cannot account for the entire variation. Notably the test cycle hasn't changed in the last decade although the gap with real-world driving is getting wider. Part of the reason for the widening gap seems to be that manufacturers are increasingly deploying technology to improve the efficiency of cars that produce a big improvement in official tests but much smaller difference when the car is used on the road (such as stop-start technologies that switch off the engine when the vehicle is stationary). During the official NEDC test the vehicle is actually stationary for around 4 minutes or 20% of the test. Stop-start technology therefore has a considerable benefit in the test, but much less in average driving.

The current NEDC test also does not require the vehicle lights to be switched on during the test, neither must the air conditioning or heating system or other auxiliary power requirements like the radio, heated seats, etc. Steven (2005) found that on a small car with a simple air conditioning system, the difference in running the test with the AC off or on was over 37%. With a larger car and a more sophisticated system, with strong solar insolation, the difference reached 53%. Schmidt and Johannsen (2012) similarly found an increase in CO_2 of 15 or 16% with all electrical equipment turned on. These results are not representative of typical motoring, but they do illustrate that the influence of electrical equipment is important.

In practice optional equipment is fitted to vehicles because there is a demand and of course people make use of it. Whilst drivers do not run their cars with the air conditioning and other electrical equipment on all of the time, it is in use some of the time and it is clearly unreasonable and unrepresentative to entirely ignore these loads in the testing. Failing to account for this equipment in the tests makes a large difference in the results, and efforts should be made to reflect this fairly in a future test procedure.

Evidence of the causes of discrepancies between test and real-world driving are provided in detailed data from the ADAC analysed by the ICCT and described in detail in Annex 2. The analysis concludes that part of the divergence between the ADAC tests and the official NEDC tests arise from the way the official tests are being undertaken. Other reasons include: the absence of high speed motorway driving in the NEDC test; and the failure to turn on air conditioning systems in the NEDC test.

The ICCT conclude that the gap between official test and other datasets has been increasing most notably since 2007 and that "increasing discrepancy could be attributed to manufacturers increasingly exploiting existing flexibilities for road load determination, shifting strategies of automatic gear boxes, and by applying dedicated calibrations for the type-approval procedure … Reducing type-approval CO_2 emission values by exploiting existing flexibilities in the test procedures is cheaper than applying technical measures to reduce CO_2 emissions." This is explained in greater detail in Section 3.

3. Key weaknesses in EU test procedures

Section 1.2 explained that to compare the performance of different cars reliably, a repeatable laboratory test method is required since real-world driving conditions are too inconsistent. Historically it has also not been possible to measure exhaust emissions accurately from a moving vehicle, and it would also be difficult to reproduce the speeds and accelerations required in the test cycle accurately and reliably even on a test track. Instead, therefore, vehicles are tested under laboratory conditions.

To be credible, the laboratory test method must be able to produce a result that is broadly comparable to the performance experienced by typical drivers on the road. The evidence presented in Section 2 demonstrated that the current test clearly fails this requirement. There are many ways in which the current test is unrepresentative including those outlined in Section 2.2.

Some aspects of the emissions test procedure are very tightly specified and the measurement technologies used are increasingly accurate and reliable. However, a number of other aspects that can affect the test results are much less tightly specified if they are specified at all. It has long been understood that some of these amount to loopholes that could be exploited to give a more favourable CO_2 test result. Now the evidence strongly suggests that these loopholes are being exploited more vigorously and systematically in order to produce favourable test results.

This also suggests that there is insufficient independent scrutiny of the way the tests are being carried out to ensure that they are done fairly and consistently.

3.1 How vehicles are tested and approved

Laboratory tests

Vehicles are tested in a laboratory using a 'rolling road' (chassis dynamometer) with the CO_2 emissions and fuel consumption measured throughout the test for a fixed series of accelerations, steady speed driving, and decelerations collectively known as a drive cycle (Figures 4 and 5). The vehicle is driven through the test with the drive wheels turning rollers rather than the vehicle physically moving. A resistance is applied to the rollers to simulate the resistance of the vehicle when it is moving. This is because, as the vehicle is stationary, the rolling road cannot accurately reflect aerodynamic drag caused by air passing over and around the vehicle at speed.

Modern chassis dynamometers are accurate and reliable machines, as increasingly is the equipment used to sample the exhaust gases. That means that these aspects of the test have arguably improved significantly in recent years and add little if any inaccuracy to the results. However, the chassis dynamometer needs to be programmed with the weight or inertia of the vehicle in order to simulate acceleration and deceleration realistically, together with energy losses as the vehicle's tyres interact with the road surface and the machinery turns. These factors taken together make up a value known as the 'road load'. This road load value then has to be programmed into the rolling road in order to allow it to simulate a real drive over the test cycle for the vehicle in question.

Figure 4: Laboratory Vehicle Test[4]

Road load measurement

Road load is a measure of the amount of energy that is required to maintain a vehicle moving on the road at a particular speed. There are various means of calculating the road load, but the commonest and simplest is known as a coastdown test. This involves accelerating the test vehicle to speeds up to 120 km/h on a test track, shifting the drive into neutral and then timing how long the vehicle takes to coast down by every 20 km/h interval until it comes to a standstill. The deceleration gives a measure of the aerodynamic drag, rolling resistance and mechanical losses within the car. The times and distances measured are then translated into the road load value curve which is programmed into the rolling road.

While the coast down test is an integral element of the overall test procedure, and the road load figure that emerges from this test has a critical effect on the final emissions figures that are produced as public information, details of the road load results themselves remain confidential in the EU. Road load values are not publicly available because manufacturers claim that this is commercially sensitive information. Failure to publish this information makes it harder to replicate the results obtained, and makes the road load value difficult if not impossible to verify independently. In the US road load data is made publicly available and there is no reason for the information to be secret in the EU.

T&E has accumulated evidence (Section 3.4) that shows the results of the road load tests are being systematically manipulated by carmakers to ensure the results are too low. These artificially low results mean that during the laboratory tests the rollers are set with too little resistance, making it easier for the vehicle to turn the rollers and causing an under-estimation of the true fuel consumption and CO_2 emissions.

The test cycle

The official drive-cycle that is used in the EU is the New European Drive Cycle (NEDC), which was originally established in the 1970s in order to test for emissions of regulated pollutants such as nitrogen dioxide in urban areas. Carbon dioxide emissions and the fuel consumed during the test (calculated as a simple function of the CO_2 and other gases emitted) were subsequently added to the procedure. The NEDC test is now old and

[4] Image courtesy of TNO

outdated, and was not intended originally for the measurement of fuel efficiency and CO_2 emissions. That is, it is no longer an appropriate tool for the official measurements that are needed in current circumstances.

The accelerations, decelerations and braking patterns of the NEDC are shown in Figure 5. The test takes 20 minutes to complete, and the bulk of this is made up of four repetitions of the so-called Urban Drive Cycle, consisting of a series of gentle accelerations, some very short periods of steady-state driving, and decelerations back to stationary. The final part of the test is an Extra-Urban Driving Cycle, which takes the vehicle in stages up to a maximum speed of 120 km/h.

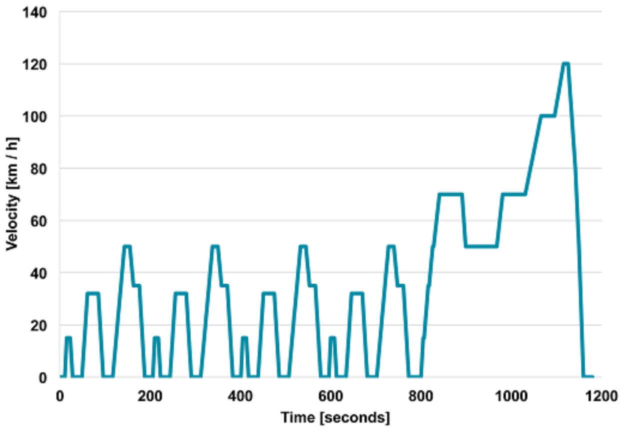


Figure 5: The NEDC drive cycle

The test is not a good representation of modern driving conditions. For example, the maximum speed attained in the urban part of the cycle is only 50 km/h, and the vehicle is allowed 26 seconds to reach this speed through gentle acceleration, whereas even a modest family car can now typically reach twice that speed in half the time. The extra-urban cycle does reflect somewhat higher speeds, but again the accelerations are nothing like those experienced in a modern car; the top speed of 120 km/h is still well below the sort of speed that is normal on some roads; and the car only holds this speed for a matter of seconds before decelerating rapidly back to a halt. The vehicle is in fact stationary for **one fifth** of the entire test duration.

A new test cycle and test procedures (the WLTP) are under development and will address many, but not all, of the current limitations. Further information on this is presented in Section 4. Zallinger and Hausberger (2009) argue that a better understanding of the full range of representative driving styles and conditions across Europe is needed. As against this, Schmidt and Johannsen (2012) show that the US (FTP) and Japanese (JC08) test cycles already include much more rapid accelerations and transient operations than the NEDC, as does the EU's own Artemis (CADC) cycle that includes motorway driving. Their analysis demonstrates that these cycles produce higher CO_2 results that are more representative of real-world driving — so an improvement on the current cycle is already shown to be possible.

The system of approving fuel efficiency measurements

In the EU, both fuel economy and CO_2 emissions are measured as part of the Whole Vehicle Type Approval process[5]. This system ensures that all vehicles sold in the EU meet minimum regulatory, technical and safety requirements. Type-approval tests are usually performed on prototype (pre-production) sample vehicles rather than actual production vehicles that are sold. Once type approval is granted for one vehicle model it can also be extended to similar models of the same manufacturer – in order to reduce the costs of obtaining type-approval for different models. For CO_2 emissions this means that a vehicle can be type approved if it is believed the emissions are no more than 4% higher than those tested on the pre-production vehicle. No actual testing of similar models is then required. The EU legislative system is designed such that once type-approval is granted it cannot be withdrawn (except for serious non-compliance cases) and must be accepted in Member States throughout the EU.

Since type approval is not usually performed on actual production vehicles, the carmaker must be able to demonstrate the performance of production vehicles is similar to the tested vehicle. This is done through demonstrating 'conformity of production', i.e. that there is consistency between the production and type approved models. Conformity of production allows some differences and tolerances between prototype and full-production vehicles.

In the EU, type approval and conformity of production must be assessed by an independent body. Each Member State appoints an Approval Authority and a Technical Service to ensure that testing complies with the requirements of the Directives and Regulations. In many countries, the same organisation performs both roles, thereby creating a potential conflict of interest. Since type approval can be undertaken anywhere within the EU (and once approval is issued it must be accepted in all Member States) there is competition between Approval Authorities and Technical Services throughout the EU for the business of type-approving vehicles and auditing to ensure the conformity of production requirement (since manufacturers will be charged for providing the type-approval services). The need to win business from vehicle manufacturers calls into question the independence of testing and approving authorities in the way they perform tests, and represents an obvious incentive for authorities to generate test results that are advantageous to the clients. This is considered further in Section 4.

3.2 10 ways carmakers manipulate laboratory test results

Whilst some aspects of laboratory tests are highly defined, others are not. Furthermore, some of the test requirements are totally unrepresentative of real-world driving. The ways in which carmakers can manipulate laboratory test results have been reviewed recently by TNO for the European Commission (Kadijk *et al*, 2012) and this has highlighted a wide range of flexibilities as illustrated in Figure 6 below.

[5] Under the 'Whole Vehicle' framework Directive 2007/46/EC

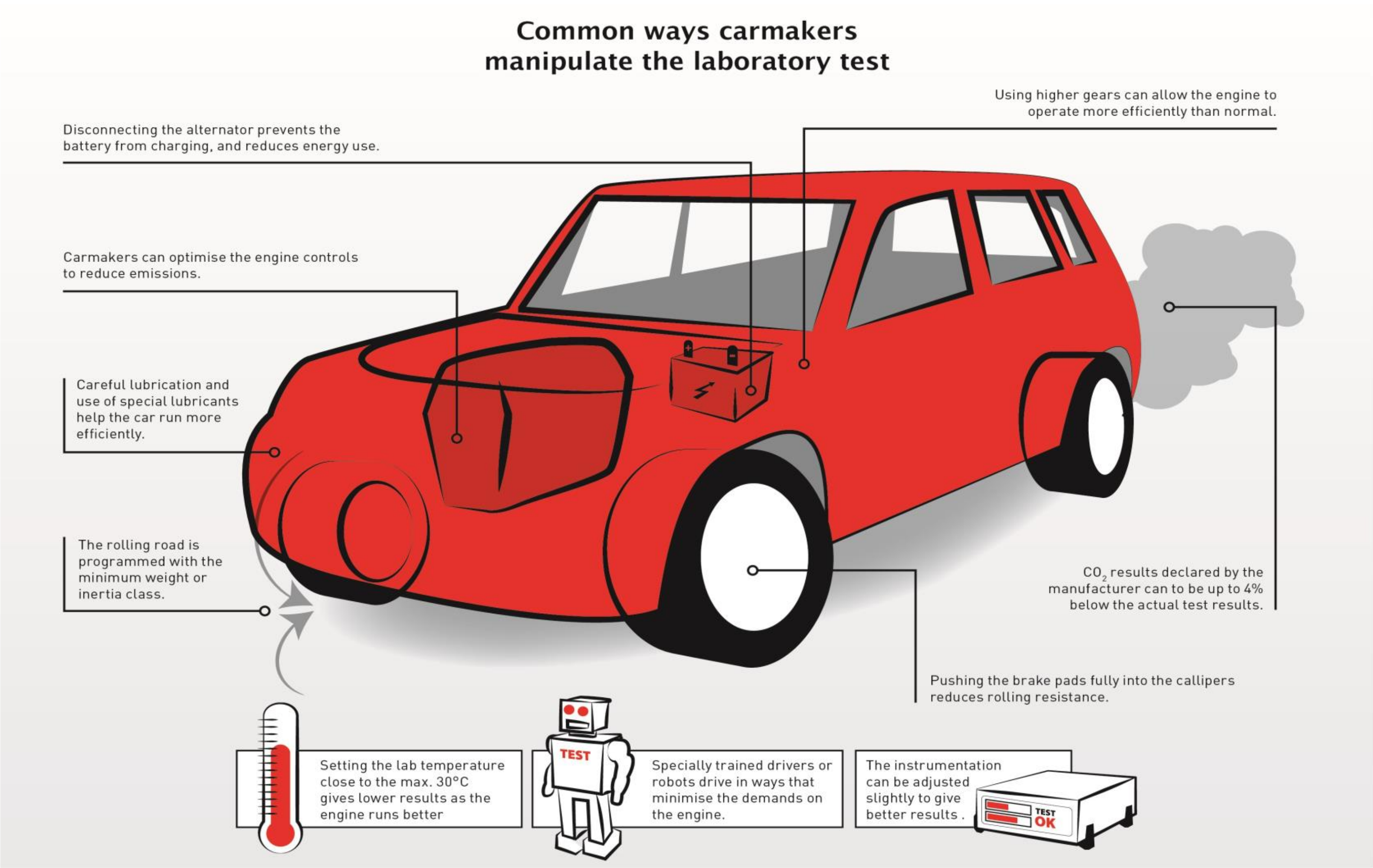


Figure 6:
Key ways in which it is known manufacturers are able to manipulate laboratory test results

Key ways in which it is known manufacturers are able to manipulate laboratory test results include:

1. **Allowing the battery to discharge during the test**
   Recharging the battery creates a significant extra load on the engine and consequently a significant increase in fuel use and carbon dioxide emissions. A fully charged battery is used during the test and does not need to be recharged during the short test. Test engineers can avoid the use of additional power to recharge the battery during the test by disconnecting the alternator or other means. The influence of the battery state-of-charge (SOC) on the CO_2 emission was part of the investigation by TÜV Nord (TÜV, 2010). They tested an extreme difference between a fully charged starter battery and an almost depleted one over the NEDC cycle. It was found that especially for small passenger cars the difference can amount to up to 30%. During real-life situations the SOC of the battery will almost never be this low, so this result is illustrative at best. However, it shows that the battery SOC has a significant influence on the overall CO_2 emissions.

   A more subtle loophole to reduce the test result is to ensure that testing commences with a fully charged battery, by using external recharging throughout the soak period (a period prior to the test when the vehicle is left standing in the laboratory so that the temperature of all its components can equalise with those of the ambient air). Compared to a partially discharged battery this can reduce the official test result by around 1% according to Kadijk *et al* (2012).

2. **'Adjusting' the brakes**
   Even when the brakes of a car are not being applied, there is usually some contact and friction between brake pads and discs. This will increase the resistance of turning the wheels and thereby increase the energy required to carry out the test, raising the CO_2 emissions and fuel consumption. By pulling back the brake callipers as far as possible the friction can be reduced or removed, thereby reducing the energy required to power the test vehicle over the test cycle. Although this makes the test more repeatable it is also entirely unrepresentative of real world conditions as this cannot practicably be done on the road.

3. **Losing weight**
   Even vehicles of the same model can vary quite a bit in weight, according to engine size, trim, optional extras and other equipment. It is nonetheless allowed to programme the rolling road with the barest minimum weight of the most basic version, with everything that can be taken off or taken out removed. Schmidt and Johannsen (2012) argue that instead of the very lightest possibility, the worst case (i.e. heaviest) variant of each model should be reflected in the test.

   A further advantage can be obtained through minimising the weight of the vehicle by utilising a loophole in the way rolling roads (chassis dynamometers) in the past used to work. Historically these were mechanical devices to which physical weights were added to increase the inertia of the rollers to the correct road load setting. Vehicles were therefore grouped into inertia classes to reflect the weights available, and the procedures were written to accommodate this. Modern chassis dynamometers do not use weights and can be programmed with the exact inertia weight of the vehicle, but the procedures still allow the historical classification. ICCT (2012) found that a test vehicle was five times more likely to be located just below an inertia class step than above it. This “conspicuous distribution” demonstrated that the carmakers were abusing the legacy of the old measurement system when the correct setting could have been programmed into the (now electronic) chassis dynamometer. Schmidt and Johannsen (2010) concluded that reduced road load setting on the dynamometer always gave rise to lower CO_2, by at least 2% and up to 11% in one case – and this was only from reflecting tolerances in the road load setting on the dynamometer. A reduction in vehicle mass of 110kg (one inertia class) can save 2 – 2.5% on the test results.

4. **Testing the car at a high temperature**
   A normal engine warms up faster and runs better at a higher temperature, thereby using less fuel and producing fewer emissions. The regulations specify that the test must be conducted at an ambient temperature of between 20 and 30°C. This range is unrepresentative of typical temperatures in the EU (where average temperatures are below 10°C). Carmakers ensure tests are undertaken at the top end of the allowable temperature range (say, 29°C). The effect of testing at a soak temperature of 29°C compared to 20°C will be to reduce the test result by around 1.5% to 2%, although Kadijk *et al* (2012) estimate that only about half of this potential has so far been utilised. Schmidt and Johannsen (2012) argue that the permissible temperature range should be greatly narrowed to perhaps 23-27°C. More representative and realistic test results could be achieved by changing the test temperature to 15°C as is now widely advocated.

5. **Oiling it up**
   The lubricant used in the engine and other moving parts are not specified as part of the test protocols, allowing carmakers to use special super-lubricants just for the purpose of the testing. These lubricants are optimised to reduce any internal friction to an absolute minimum and thereby minimise energy use and emissions. The lubricant used is usually impractical or prohibitively expensive for use in ordinary cars on the road and therefore the performance achieved is unrepresentative.

6. **Playing to the cycle**
   As the test cycle is not very demanding, carmakers can optimise their engine controls to keep emissions performance under test conditions to a minimum. Furthermore, since the cycle consists of 20% idling (which is much higher than in real life), the benefits of start/stop systems (designed to improve efficiency by stopping the engine when the car is stationary) have been exaggerated by the test. Zink and Hausner (2010) estimate that this gives a benefit of around 4-5%, much more than in typical driving.

7. **Optimising the test drive**
   The NEDC, as amended by Directive 98/69/EC, defines certain tolerances on the driving curve to allow for human error in not replicating the prescribed drive cycle (as shown in Figure 5) exactly. That is, any deviation of the test drive from the prescribed target speed curve described above must not exceed ±2 km/h or ±1.0 seconds. CO_2

emissions can be improved if specially trained drivers or robots make full use of these tolerances to further reduce the demands on the engine. Compared to a test driven exactly to the target cycle, optimisation can achieve 1% -1.5% lower CO_2 emissions.

8. **Amending the gear shift schedule**

   Gear number and change point are pre-defined in the NEDC cycle. However, some flexibilities exist which allow the use of higher gears that may reduce CO_2 emissions. For example, it may be possible to use the 2nd to 5th gears only. Higher gears may allow the engine to operate more efficiently and reduce power losses in the drivetrain. In combination an overall benefit in CO_2 of around 6% is estimated to be possible according to Kadijk *et al* (2012), depending on the vehicle. As yet however, they argue that very little of this potential has been taken up.

9. **Laboratory instrumentation**

   The legislation specifies the accuracy and tolerances for a range of instrumentation used during the test. Laboratory calibration documents are provided to the certification authority during the type approval process. It is, however, possible to utilise the tolerances available to gain a CO_2 benefit of about 2% or possibly more.

10. **Adjusting the results**

    Once the tests have been completed, the test procedures inexplicably allow the CO_2 results declared by the manufacturer to be up to 4% below the actual results from the tests. Needless to say, manufacturers often take advantage of this allowance to artificially reduce the emissions that they declare – although Kadijk *et al* (2012) estimate that only about half of the full 4% on average has so far been taken up. Hence there is still scope for further flexibilities to be deployed in the future.

3.3 10 ways carmakers manipulate the road load test

There is a considerable body of evidence that confidential road load data is also being systematically manipulated to enable the rolling road on which the vehicle is tested to have less resistance. For example, Zallinger and Hausberger (2009) found that 12% of the CO_2 reduction that they were able to achieve was accounted for by lower road load figures when they exploited some of the 'flexibilities' available in the coastdown test.

Known manipulations of the road load test are illustrated in Figure 7 and significantly extend the distance over which the vehicle will coast, and thereby reduce its road load values.

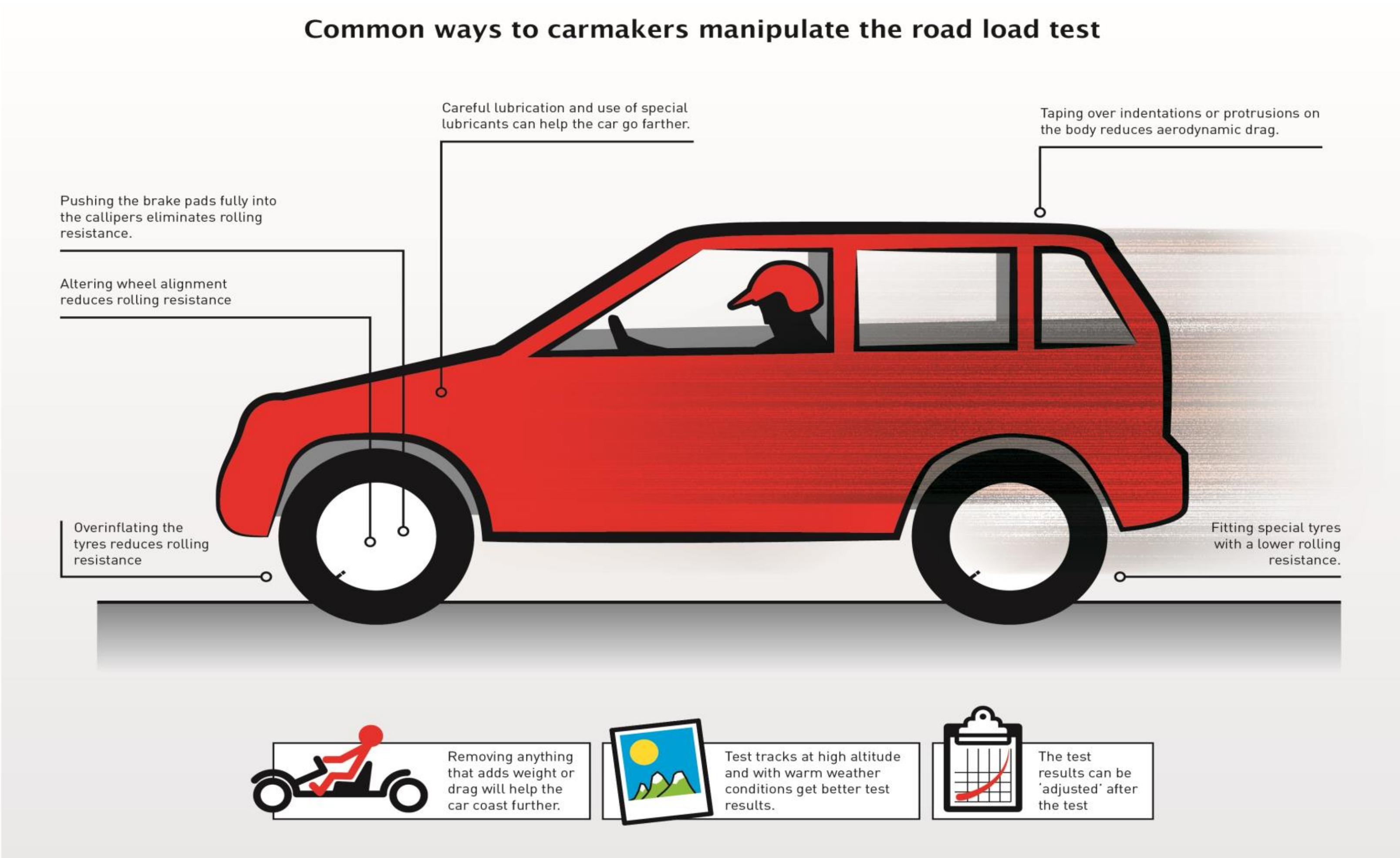


Figure 7:
Specific manipulations of the road load test

Specific manipulations of the road load test include:

1. **Removing all optional extras**
   Clearly anything that adds weight or drag to the vehicle will cause it to coast down more quickly. By removing standard and additional features (such as fitted-as-standard roof rails, additional lights, and even the nearside wing mirror) better results are obtained. Schmidt and Johannsen (2012) argue that a ‘worst case’ (i.e. heaviest and best-equipped variant of a model) should be used for the coastdown test, rather than a stripped down version.

2. **Overinflating the tyres**
   Anyone who rides a bicycle will know that it goes farther and faster when the tyres have been pumped up hard. The same applies to cars, so a test vehicle will roll much farther when the tyres are pumped up as hard as possible. This practice is not specifically excluded in the test procedure, in spite of the fact that it would be dangerous to drive a car in this condition on a real road. Steven (2005) and Zallinger and Hausberger (2009) all argue that manufacturer standard tyres and approved pressures should be mandated for the coastdown test, whereas currently only the tyre width is specified.

3. **Optimising the wheels and tyres to minimise rolling resistance**
   Since a final choice of tyres and wheels has often not been made at the time of the type approval, it is easy to perform the test using tyres with a lower rolling resistance than those that will typically be fitted to production versions of the same vehicle. For example, optimising wheel and tyre specification to increase rolling radius by 5% will change the test result by about 2%.To overcome this difficulty, Smeds and Riemersma (2011) propose that manufacturers could be required only to fit tyres on production vehicles that have the same or lower rolling resistance as the tyres used on the coastdown tests. They also point out that the allowable tread depth on test tyres is less than the average found on the roads, and that this should be amended accordingly.

4. **Realigning the wheels and adjusting the brakes**
   Smeds and Riemersma (2011) note that wheel alignment is an important determinant of a vehicle´s ability to coast, but the setting on a production car is a trade-off between good handling and road-holding against the ability to coast. In mass production vehicles the alignment is adjusted quite tightly to the specifications, but if the manufacturer actually specifies a much wider tolerance band in its formal specifications, this opens the way for the wheel alignment to be altered to a setting giving better coastdown results. Reducing overall rolling resistance by 20% in this way would reduce the official test result by around 3%.

   As on the chassis dynamometer, pushing the brake pads back fully into the callipers can eliminate quite a lot of rolling resistance and help the car to roll farther, although it would of course be impractical to do this on the open road as the benefit is lost as soon as the brakes are next applied.

5. **Improving the aerodynamics**
   Another practice that is questionable, but apparently not illegal, is to 'improve' the aerodynamics of the test vehicle and thereby reduce the effect of aerodynamic drag in slowing it down. This is reportedly done by carefully taping over every indentation or protrusion in the vehicle body, and in particular sealing the radiator grille and the cracks around all the doors and windows and the seams between other body panels and parts (Smeds and Riemersma, 2011). Cars could not practically be used in this state and the practice is therefore entirely unrepresentative of real-world driving conditions.

6. **Improving the lubrication**
   Even during coastdown, the wheels and parts of the transmission continue to rotate and this adds to the road load. As on the chassis dyno, this can be reduced by careful lubrication and special lubricants.

7. **Extending the running-in period**
   How far the vehicle has been driven by the time it is tested will influence the results of the coastdown test because a well run-in vehicle will coast farther. The regulation states "The vehicle shall be in normal running order and adjustment after having been run-in for at least 3,000 km. The tyres shall be run-in at the same time as the vehicle ... ". However, there is flexibility in this running-in period in order to achieve the minimum possible friction losses in the engine and vehicle. Some manufacturers may choose to run the test vehicle in over a much longer distance for example. The benefit will vary but Kadijk *et al* (2012) estimate that reductions in the official CO_2 measurement of 5% are possible, of which very little has been exploited to date.

8. **Use a sloping test track with a smooth surface**
   Clearly a dead flat and dead level test track is the only fair basis on which to conduct a coastdown test. However, procedures only specify that any slope on the track must not exceed 1.5%. Test tracks are often designed with precisely this degree of slope, although it is possible using modern methods to create a test surface that is much more level than this. The test must be completed in twice in opposite directions, but Zallinger and Hausberger (2009) point out that the simple averaging method that is used to combine the two results is technically incorrect and still favours results obtained on a sloping track.

   TNO (2012b) in their recent work revisiting road load results remark on the question of slope that "The procedure does prescribe that the test is carried out in two opposite directions to cancel out any wind effects, but does not contain an obligation to run the test in two directions on the same piece of road or on roads with opposite slopes". If this is correct and is indeed being exploited as a loophole, then it plainly makes a mockery of the idea of a fair and objective test. They go on to state that " The effects of performing the coast down test on a sloped test track would be sufficient to explain the major difference found between type approval road loads and the current experiments."

   Zallinger and Hausberger (2009) also suggest that test track surfaces may be optimised to improve road load values, as a smoother surface reduces the rolling resistance of the vehicle relative to what it would be on a normal road surface. Indeed, the proprietors of one commonly-used test track (Applus IDIADA, 2012) proudly proclaim that they have achieved improved emissions and fuel economy figures of between *3.1 and 4.7%* since they resurfaced their track in January 2009.

The rules do not currently specify the quality of the test track surface in any detail, but it would be both possible and reasonable to require a test surface more representative of normal road conditions.

9. **Ambient conditions**
Test tracks at high altitude with very warm weather conditions produce better coastdown results because current correction factors do not fully account for the reduced air resistance that results. The majority of coastdown tests in Europe are conducted at the Idiada test facility in Spain that benefits from this type of conditions.

10. **Taking advantage of test tolerances**
The test procedure allows for certain 'tolerances' (Schmidt and Johannsen, 2010) to be applied such that the road load values programmed into the rolling road can be up to 5% lower in the upper speed range (120 km/h to 40 km/h) and 10% lower in the lower speed range (20 km/h) than those obtained on the coastdown test. These allowances could be reduced or removed entirely and would increase the measured CO_2 by about 1%.

As with the laboratory instrumentation, there are other permitted tolerances in the road load measurements that can be exploited to reduce the CO_2 emissions. Exploiting these allowances could lower the official CO_2 results further. In general, a 1% change in the total coast down time will affect the CO_2 measured by about 0.25%. Kadijk et al (2012) estimate that the use of flexibilities in the coastdown procedure currently accounts for approximately 5.5% reduction in the stated CO_2 emissions values on average, and that this could increase further in the future.

3.4 Results of road load testing

The Dutch Ministry of Infrastructure and the Environment and the European Climate Foundation contracted TNO (2012b) to investigate the extent to which manipulating the road load test would affect official test results. The road load curves of six modern passenger car models (Euro 5/Euro 6) and two older variants (Euro 4) of the same models were measured using a realistic preparation of the vehicle and the results compared to the road load settings used for the type approval (TA) as obtained from the certification agency. The results of the tests are summarized in Figure 8 expressed as a Road Load Ratio (RLR) that illustrates the difference between the official road load results and those experienced through TNO's more realistic tests.

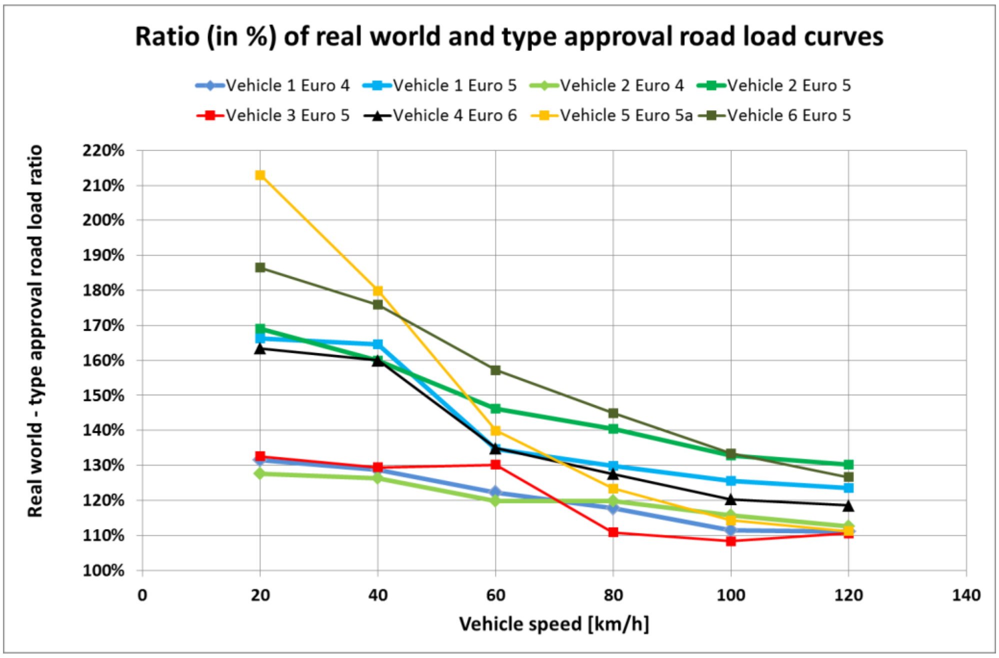


Figure 8: Ratio of type approval and real world road load test results of all tested vehicles (TNO, 2012b)

The realistically-measured road loads were found to be substantially higher than the official road loads used in the type approval. In particular at low speeds the road load differences were up to 70%. The weighted realistic road load settings of the two older (Euro 4) vehicles were on average 19% higher than the settings of the type approval road load curves. The weighted real world road load settings of the more recent (Euro 5 and Euro 6) vehicles were on average 37% higher than the settings of the official road load curves. This suggests that in recent years the test has been increasingly manipulated and is likely to contribute to the widening gap between test and real-world results.

TNO also conducted tests to assess the impact of different road load curves on the measured fuel consumption and CO_2 emissions from the subsequent laboratory tests. Chassis dynamometer tests using the NEDC test cycle were carried out both with official road loads and with the realistic road loads derived from the new coastdown tests. Figure 9 shows the results of the TNO laboratory test using the road load settings from the official test (blue diamonds); and TNO test results using the new and more realistic road load settings (red squares). On average, without manipulating the laboratory tests, the CO_2 results were 12% higher than the type approval (TA) values (with a range of 8% – 14%). Manipulating both the road load test or the laboratory tests the average CO_2 emissions were 23% higher than the TA values (with a range of 19% - 28%). The results indicate that the manipulation of the official tests is lowering the official test results by around 11.5% each in both the laboratory tests and the road load tests.

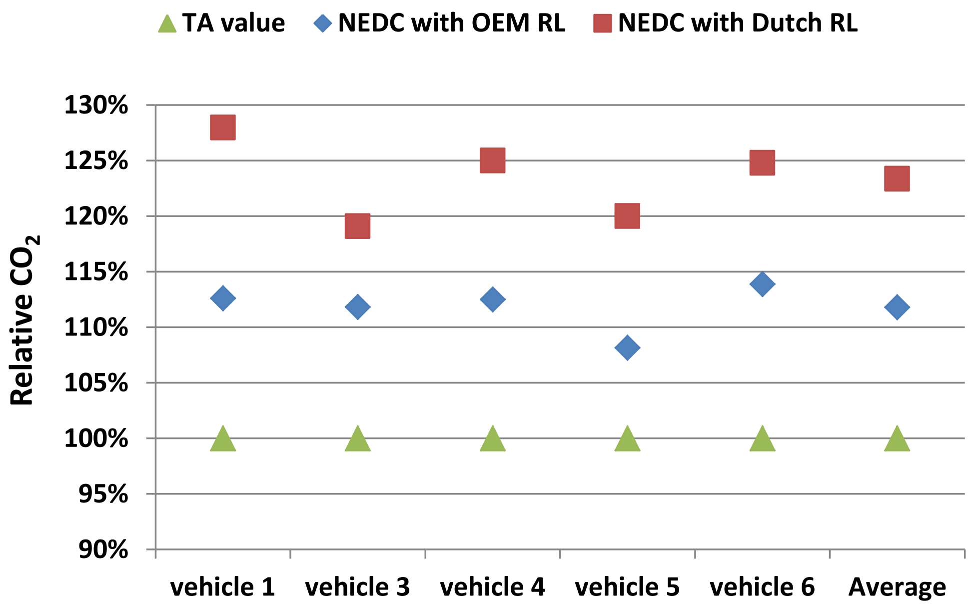


Figure 9: Summary NEDC CO_2 emissions of Euro 5 and 6 vehicles with different road load settings
(TNO, 2012b)

Other studies show similar results. For example, TU Graz have undertaken similar testing to that described above (Zallinger and Hausberger, 2009). They recreated the road load values for a small selection of vehicles using what they regarded as 'normal' settings in the test. They then replicated the drive cycle test using their own road load values and compared the results to the official type approval values. They found that "A comparison of the results from the NEDC tests run in this study with the type approval data shows that the driving resistance values gained from the real world coast down tests are on average approx. 17% higher than the values applied in type approval." The results ranged from +9% to +24%. The authors concluded that the type approval tests must certainly be using the optimum combination of tyre and road surface, as well as high tyre pressures and optimum ambient conditions, in order to achieve the road load results obtained.

4. Conclusions and policy recommendations

4.1 Adding it all up

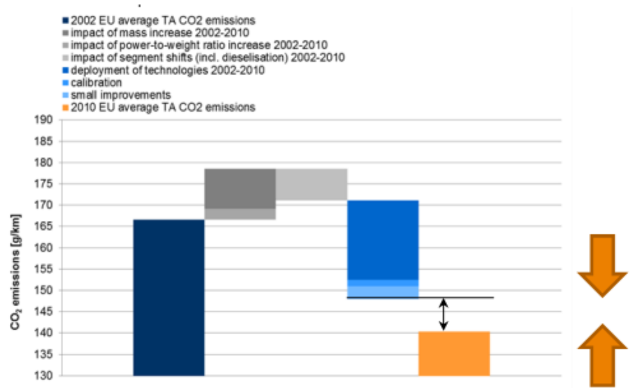
A conclusive body of evidence now demonstrates that there is a wide (approaching 25%) and crucially still growing gap between the fuel economy and CO_2 emissions measured in official vehicle tests and the fuel economy that drivers are typically able to achieve on the road. This gap exists for almost all drivers and makes and models of car. There are several contributory factors for the gap:

1 There are excessive flexibilities in the current testing procedures that allow the manipulation of test measurements, producing artificially low results
2 The test includes many requirements that are totally unrealistic such as unrepresentative test temperatures, weights and rolling resistance
3 The NEDC drive cycle is unrepresentative of real-world driving, encouraging the use of technologies that deliver lower emissions reductions on the road than during the test
4 There are important omissions from the tests (such as not reflecting the energy demands and weight of equipment such as air conditioning)
5 There are results that get 'lost in translation' through excessive tolerances in the way test results are calculated - such as the rule that enables reported emissions to be 4% lower than the test results
6 The system of overseeing tests in which national Type Approval Authorities and testing facilities compete for the business of approving vehicles and are paid by manufacturers is clearly open to abuse or inadequate oversight. The Idiada Test facility has a business focused on optimising vehicles prior to testing.
7 The failure to check or require production vehicles (bought by consumers) to achieve the fuel economy results measured in type approval tests of pre-production vehicles allows the other loopholes to be exploited with no risk of discovery

The test is unrepresentative, the procedures are too lax, and the independent oversight is inadequate

The cumulative scale of the manipulation has been estimated by consultants for the European Commission (Kadijk *et al*, 2012). They reviewed the technologies deployed on vehicles between 2002 and 2010 and identified the actual improvement in CO_2 emissions that occurred compared to how much would be expected from the technology that had been applied. Figure 10 reproduces their results from which TNO concluded, "About 70% of the net CO_2 emission reduction between 2002 and 2010 may result from technology deployment." It follows from this that 30% of the emissions reduction was therefore not from technology. This is equivalent to 8g/km of the observed net reduction in emissions (TNO, 2012a).

The report also undertakes a 'bottom up' analysis to identify whether flexibilities in the testing procedures could account for the 8g/km gap between what the technologies should (and actually did) deliver and the test results. It concludes that "Utilisation of flexibilities may account for two-fifths to one half of the net CO_2 emission reduction between 2002 and 2010."



Item	CO₂ [g/km]
2002 EU average TA CO2 emissions	166.6
impact of mass increase 2002-2010	9.5
impact of power-to-weight ratio increase 2002-2010	2.5
impact of segment shifts (incl. dieselisation) 2002-2010	-7.4
deployment of technologies 2002-2010	-18.5
calibration	-1.4
small improvements	-2.9
result sum	148.4
gap	8.1
2010 EU average TA CO2 emissions	140.4

TNO innovation for life, AEA, IHS Global Insight, Ricardo

Figure 10: Top-down deployment of the contribution of technologies to CO_2 emissions reductions **2002-10 (TNO, 2012a)**

Between 2002 and 2010 average new car CO_2 emissions fell by 27g/km under official figures, but the use of flexibilities in testing procedures accounted for around 12g/km of this improvement. (TNO, 2012a)

For Germany, TNO estimate that 12g/km of improvement between 2002 and 2010 that arises from the deployment of flexibilities almost exactly matches the 15g/km improvement in real-world emissions that has been observed by Spritmonitor (Figure 1).

Kadijk *et al* (2012) have characterised the extent to which these different elements cause the gap as follows:

- About 25% of the gap arises from flexibilities in the laboratory test.
- 25% – 35% of the gap arises from flexibilities in the coastdown test.
- 10-20% arises from unknown causes.
- 10-20% arises from omissions from the test (such as air conditioning systems).
- 10-20% arises from the NEDC cycle being unrepresentative.

Combining these estimates with emerging evidence on the overall size of the real-world 'gap', the relative contribution of the different elements is illustrated schematically in Figure 11 below.

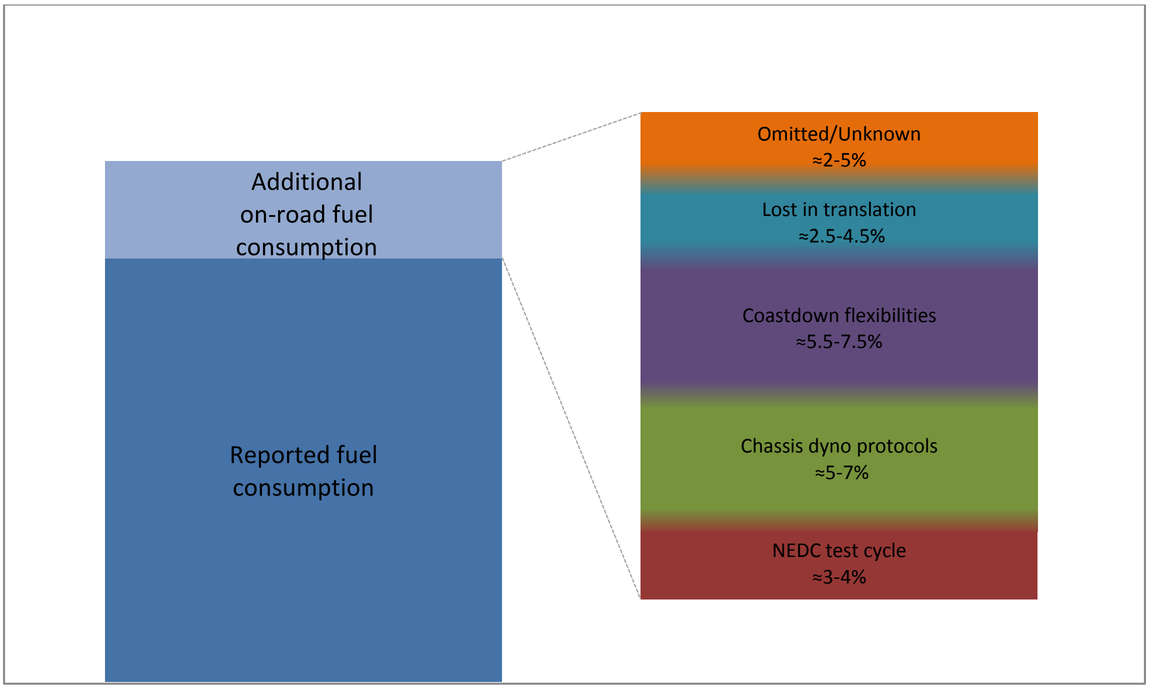


Figure 11: Schematic of causes of the gap between official test and real-world CO_2 emissions

There is no longer any question whether the growing gap between real-world figures and official tests is a problem, or whether a significant cause of this gap arises from carmakers manipulating official tests. The remaining question is how will we fix the system.

4.2 The way forward

The fuel economy gap is undermining the credibility of the official figures, and of regulatory efforts to reduce greenhouse gas emissions from transport. It is also a bad deal for motorists. The problems arise from several underlying causes and a suite of actions are therefore needed to strengthen and bring credibility to the current system of vehicle fuel efficiency testing. These are detailed below in stages:

Immediately (in 2013)

1 The European Parliament should amend Regulations 443/2009 (on the CO_2 emissions of new cars) and 510/2011 (concerning vans) to ensure that the procedures for measuring CO_2 emissions are strengthened. T&E supports amendments tabled by MEPs that would ensure a new test cycle and supporting procedures (based on the WLTP) are introduced by 2016. Furthermore, it should be mandated that a new system of checks on production vehicles (conformity of production) is introduced to ensure that new cars achieve the same fuel efficiency and CO_2 emissions as pre-production vehicles used in official Type Approval tests. Council and Commission should support these changes in final dialogue discussions.

2 The European Commission should commence work to bring forward a proposal (in 2014) updating Directive 1999/94/EC. This Directive requires Member States to ensure there is information on the fuel economy and CO_2 emissions of all new passenger cars offered for sale. This Directive is in urgent need of updating to ensure car buyers are given accurate information about the real-world emissions and fuel economy that the car will achieve and to ensure the information is provided in advertisements and is not presented in a misleading form. The US is far more advanced than the EU in this respect. For example, the fuel economy figure presented on a US new car label actually differentiates between fuel consumption in one of the cold states in the North, and in one of the warmer states in the South. The EU should learn from this and other good practice and ensure car-buyers are provided with reliable information.

In the short-term (by 2015)

3 New rules should be introduced that close the biggest loopholes in the current test procedures, especially in the coastdown test. Smokers *et* al (2012) identify a wide range of potential areas for action. Ending the rules that allow test results to be reduced by 4% is one obvious change that must be implemented. The revised procedures should require transparency in the way results have been achieved including publication of roadload data in type approval documents. These changes should be implemented quickly in order that the worst excesses in the current tests are eliminated. The current NEDC test would continue to be used for the time being to avoid delays.

4 All current production vehicles should be re-tested using the revised procedures in order to produce accurate CO_2 and fuel economy information. This will ensure that all carmakers achieve their legally binding targets for 2015 (130g/km) by fitting technology to improve the efficiency of the car – not by manipulating the test.

5 The European Commission should ensure there is much greater consistency in the way that National Type Approval Authorities and Testing Services undertake both Type Approval and Conformity of Production checks. This should include far greater independent scrutiny of the work being undertaken at a Member State level.

In the medium term (before 2017)

6. A comprehensive new test cycle (the WLTP) and procedures should be introduced. The WLTP process is expected to be completed in 2014. When introducing the WLTP in Europe it is essential that:
   - The WLTP cycle used in the EU is representative of typical average driving in the EU
   - That vehicles are tested under representative conditions – for example, at temperatures consistent with average ambient temperatures in Europe
   - The additional fuel consumption and emissions arising from using additional equipment such as lights, air conditioning and other optional equipment are fully taken into account in the test results
   - That the allowances built into the regulation are representative of the state of the art equipment used in Europe and there are no compromises that weaken the standards to accommodate global harmonisation
   - That the new system provides greater transparency concerning how tests have been undertaken and calculations performed including publication of road load values.

7. That a new system of checks on the CO_2 emissions and fuel efficiency of production cars is introduced to ensure these match Type Approval values. The system should be part of Conformity of Production checks and be consisted with the system under development to ensure air pollution emissions from vehicles in use achieve type approval values. (Weiss *et al*, 2013). This approach could also include a system of random checks of production vehicles to ensure that they fall within an agreed tolerance of the test values; and/or a feedback mechanism to ensure that realistic road load values are incorporated back into official test results (as suggested for example by Smeds and Riemersma, 2011).

In the long term (by 2020)

8. A new system for type approval of vehicles should be introduced. This should be designed to ensure that vehicles achieve in typical use performance that is no worse than during type approval tests. This new system should also ensure that National Type Approval Authorities are entirely independent of National Testing Services and that neither is compromised by the fees they earn by carmakers paying for the services undertaken. This should include specific consideration of establishing an EU-wide Type Approval Authority that would then sub-contract testing services to accredited national organisations and require uniform standards and procedures.

4.3 Final thoughts

The system of regulating carmakers to ensure they achieve progressive improvements in fuel economy and CO_2 emissions of new cars is, on the whole, effective and well designed. The issues identified in this report do not call into question the regulation but rather indicate that the system of measuring the performance of individual cars needs to be updated.

The unrepresentative test results distort the framework of vehicle taxes and regulation designed to produce a shift in favour of lower carbon and more fuel efficient cars and vans. Since most national car tax systems within the EU are based upon official CO_2 emissions the vehicles are taxed at a lower level than they should be and the fiscal incentive of choosing a more fuel efficient vehicle is reduced. Carmakers are in large part also achieving their regulatory targets for new car CO_2 emissions (currently 130g/km by 2015) because of the way they are able to manipulate the test results rather than by fully applying the new technology that is needed.

Carmakers are cheating policymakers by manipulating the tests and producing vehicles that only achieve regulatory targets during the test - not on the road where the fuel is burnt and the emissions actually occur

The manipulation of the tests is just one of a number of “flexibilities” being exploited by carmakers to achieve their regulatory targets by means other than making vehicles more efficient. For example; double and triple counting of electric vehicles through use of supercredits also weakens the regulation.The 95g regulatory target should mean 95g on average being delivered on the road and policymakers should look to close these loopholes and stop the abuses to ensure 95 means 95.

By producing artificially low fuel economy figures in tests and using technologies that work far more effectively in tests than in the real world carmakers are cheating their customers of anticipated improvements in fuel economy. Customers become disillusioned, no longer trust official figures and are more reluctant to buy more fuel efficient cars. This in turn makes it more difficult to sell these cars that manufacturers need to do to achieve their targets. Carmakers are creating a vicious circle in which the only way they can compete and achieve their targets is to cheat. Evidence from Kadijk *et al* (2012) makes it clear that there are further flexibilities that have not yet been exploited but could still be deployed in the future to further artificially drive down the official test results.

Carmakers are misleading their customers by promoting fuel efficiency figures that they know will not be achieved

The regulatory pressure to reduce new car CO_2 emissions, the significant tax breaks on cars with low CO_2 test figures and high oil prices have all increased the incentive for carmakers to manipulate official test results. This does not excuse, but rather explains the reasons behind the current trends. Research has shown the full range of flexibilities in the test are not yet being exploited, but probably will be unless decisive action is taken soon.

The manipulation of official data will continue unless policymakers act to change things

In the US, Hyundai-Kia have been found to have used unfair practices in the way roadload tests are conducted. They have promised to reimburse almost 1 million customers and face the possibility of civil penalties from the US Environmental Protection Agency. Several manufacturers in Europe have been successfully challenged over unfair advertisements using official test results. This study has not found clear evidence that carmakers are actually breaking any formal rules in the NEDC test – but they don't usually need to because the NEDC procedures are so lax that there is ample opportunity to manipulate the results without going so far. When the rules were drafted 30 years ago no one expected carmakers to adjust the brakes, pump the tyres up hard, and tape up all the cracks around the doors and windows for a coastdown test. But whilst the letter of the law is probably mostly followed, actions such as these clearly go against the spirit of what was intended and amount to a form of cheating.

Vehicle manufacturers argue that the current, discredited, NEDC test should continue to be used until beyond 2020 – leaving the almost-complete WLTP work 'on the shelf' for a further five years or more. This cynical suggestion is simply intended to make carmakers task of achieving the 95g/km 2020 target much easier. However, it will also reduce the considerable benefits of more fuel efficient cars - lower fuel costs, job creation and growth in addition to lower CO_2 emissions. Furthermore, if the introduction of WLTP is delayed for another eight years, by 2021 car buyers will be so disillusioned by misleading official figures they will be very reluctant to base purchase decisions on the official fuel economy data – even if it is greatly improved. The early introduction of WLTP and the other approaches to strengthening testing detailed in this report will enable the system of fuel economy and CO_2 testing to become fit for purpose realising benefits for drivers, policymakers and the environment.

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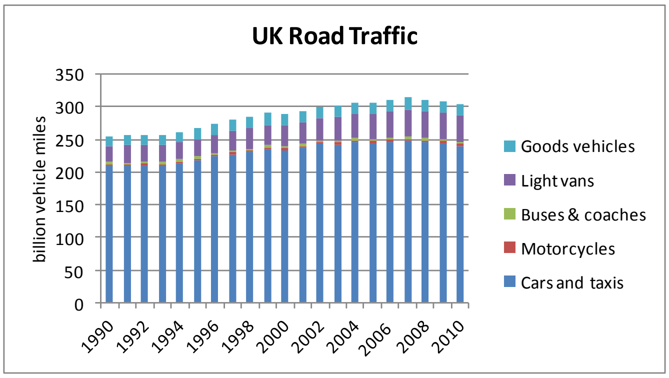
Annex 1: Note on UK traffic conditions over the past decade

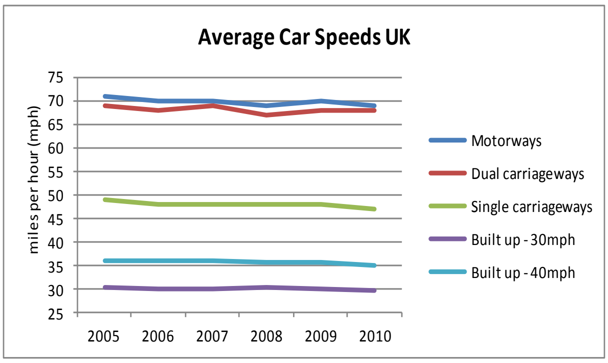
One possible explanation for the deterioration in the relationship between real-world fuel consumption and that reported under the type approval procedure would be if real-world driving conditions had deteriorated significantly over the period in question, leading to poorer fuel economy on the road and a growing divergence between test cycle and real-world conditions. This is not an implausible hypothesis, given that in Western European countries we have become accustomed to ever-increasing levels of traffic, seldom matched by an increase in road capacity, leading to growing congestion and growing adversity in real-world driving conditions with respect to fuel economy. An additional possibility is that, as the top speed and power of new cars increase over time, and as a growing share of traffic goes to motorways and other major roads, increasing incidence of very high speeds might also contribute to a deterioration in real-world fuel economy.

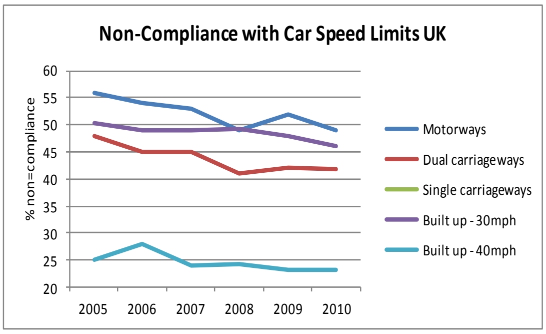
However, a brief analysis of UK traffic statistics does not in fact support either of these hypotheses — if anything, quite the opposite.



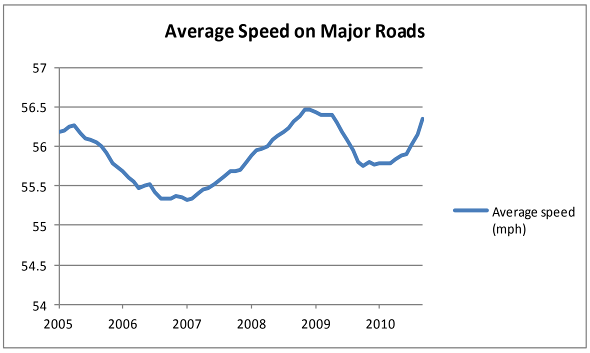
Turning first to aggregate traffic levels, it can be seen from the graph to the left that there has been a general upward trend in all classes of road traffic for much of the past two decades. However, this upward trend has been punctuated by several episodes of stagnation or even decline in the level of traffic. For example growth was negligible in the period 1990-1992, and the most significant decline began in the year 2008. This is accounted for in large part by the economic recession, and possibly also by the rising price of fuel and some other structural factors. As a result, total traffic has fallen steadily in recent years, and by 2010 had returned to the level of 2003. Thus there is no strong *prima facie* case to assume that in aggregate, pressure from increasing traffic has led to a serious deterioration in driving conditions over the past decade.

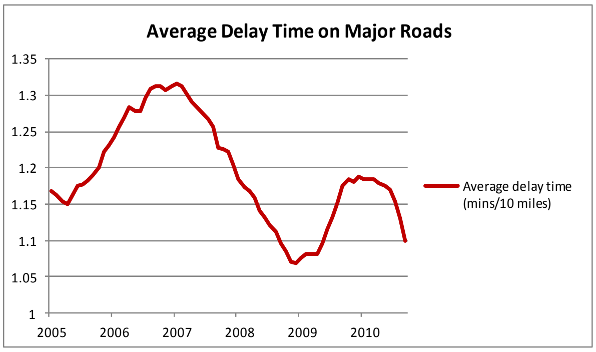
Thanks to the level of detail available in UK traffic monitoring and statistics, it is also possible to explore the actual conditions on the roads in greater detail. Turning first to average speeds on all classes of UK roads, it can be seen from the graph to the right that these have been steady or in some cases are in gradual decline. This could initially lead to the conclusion that growing congestion has led to a decline in average speeds, but these data refer specifically to average speeds in free flow traffic conditions, so road congestion is discounted and cannot be the explanation. On the contrary, the next graph illustrates that the main explanation lies in a growing level of compliance with mandatory speed limits. Taking these two pieces of evidence together we have a picture of the average speed of all UK motorists converging towards the average for each road type, and these averages remaining steady or slightly reducing. These conditions would be expected to deliver an improvement in real-world fuel consumption, not a deterioration.



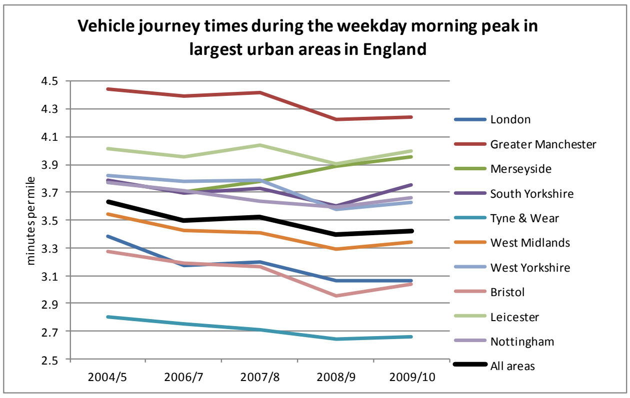


This nonetheless leaves open the possibility that increasing road congestion that is not reflected in the tables above could be an important confounding factor. However, the following two graphs illustrate that on all the major roads which carry most of the UK traffic, there is no clear trend in overall average road speed and rather little variation from year to year, suggesting that there has not been a significant shift in traffic patterns that could adversely affect real-world fuel economy. On the contrary, the second of the two graphs illustrates that the average delay time over a given distance is inversely related to the average speed as expected, and if anything exhibits a slight downward trend over time. Again, this should argue for an improvement in fuel efficiency through reduced delay time in stop-start driving conditions, not a deterioration.





The data above refer only to interurban roads, so this still leaves open the possibility that growing congestion in urban areas is having an adverse effect on fuel economy for traffic in towns. However, again the UK data do not suggest that this is the case. The figure to the left shows monitored journey times in all the largest conurbations in the UK, and, perhaps surprisingly, the trend has been markedly downwards in most cases and on average. Again, this suggests smoother journeys with fewer delays, which we would expect to improve real-world fuel economy for those driving in towns rather than the contrary.



In summary, the data available do not at all support the argument that deteriorating traffic conditions could account for the growing divergences in recent years between real-world fuel economy and that reported under type approval. On the contrary, road traffic conditions in the UK appear to have improved in recent years in all major respects, which would lead one to expect a convergence between real-world and type approval results rather than the opposite.

Of course, the discussion above relates only to one country for which good data were readily available. This cannot be regarded as conclusive, as there are obvious possibilities that conditions in the UK are not typical of those across the EU as a whole. However, preliminary evidence does suggest that the trends outlined above are also observable in a number of other major economies in western Europe.

Annex 2: Other evidence of the widening gap between test results and real-world data

In Switzerland, Schwizer and Löhrer (2008) compared real-world fuel efficiency information compiled by the Swiss Touring Club against official data provided by manufacturers for the Swiss test cycle (which is different from the NEDC). Their analysis showed that whilst published test figures suggested a steady improvement in fuel consumption over more than a decade, real world consumption was practically unchanged (Figure A2.1). The Swiss trends are not identical to those in Germany, but the database is much smaller and official test different. The overall picture is however consistent.

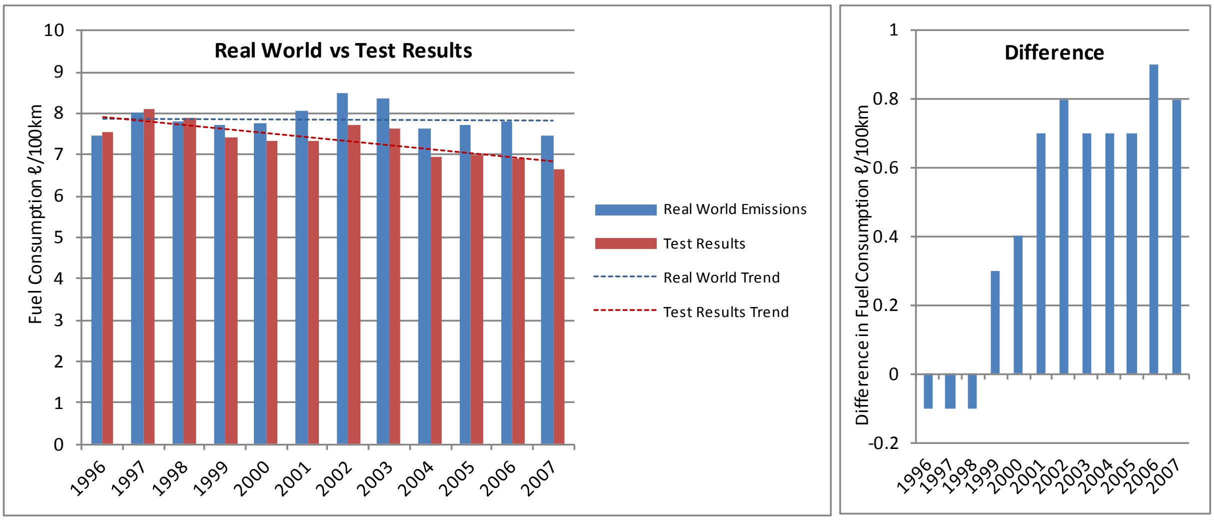


Figure A2.1: Comparison of test and real-world fuel consumption provided by the Touring Club of Switzerland

A study by Mellios *et al* (2010) surveyed and analysed a wide range of 'real world' data sources and calculated that the excess of real-world fuel consumption over type approval was 16.0% for diesels and 11.3% for petrol vehicles. Using the sample consisting only of those with 'real' fuel consumption data available (i.e. not just theoretical values), the average uplift increased to 20.0% for diesels and 14.6% for petrol-engined vehicles.

A different approach was adopted in 2009 by *What Car?* magazine that tested a range of popular car models in 'real world' driving conditions. They found that most cars across a range of classes used between 10 and 20% more fuel than the official figures suggested. *Which?* magazine also tested a range of 'green' (i.e. fuel-efficient) car models over a series of driving cycles. They found that all the cars tested emitted between 20 and 28% more CO_2 than the official tests suggested. The latter effect is to an extent predictable, as failure in the tests to account for battery recharging or use of air conditioning (as explained below) is likely to have a disproportionately large effect on a smaller or more efficient car.

Schmidt and Johannsen (2010) investigated several aspects of the testbed test procedures in detail. They point out that “The engine speed and the gear shift points have a crucial effect on fuel consumption. The driving cycle defined by the Directive includes fixed gear shift points for vehicles equipped with internal combustion engines and manual gearboxes. In contrast, the manufacturer can define gear shift points for vehicles using automatic transmissions and hybrid vehicles with gear shift indicators.” This, they conclude, biases fuel consumption test results against manual gearshift models as gear shift points are often at higher revs than is realistic or suitable for a modern car, especially a diesel. As a result, manual variants of a particular car model now routinely have higher CO_2 emissions ascribed to them than their automatic equivalents. These criticisms are not new; in 2005, Heinz Steven of TÜV Nord Mobilität was already highlighting that the NEDC measurement method is not suitable to capture the effect of new transmission designs (eg 6-speed gearboxes and advanced automatic gearboxes) that allow more fuel-efficient gearshift strategies.

Engineers at TÜV Nord Mobilität (Schmidt and Johannsen, 2010) tried to replicate the official test results for several car models using their own equipment. For most models tested they found that their own repeats of the NEDC tests always produced a higher CO_2 value than the manufacturers’ published values – in some cases by more than 20g/km.

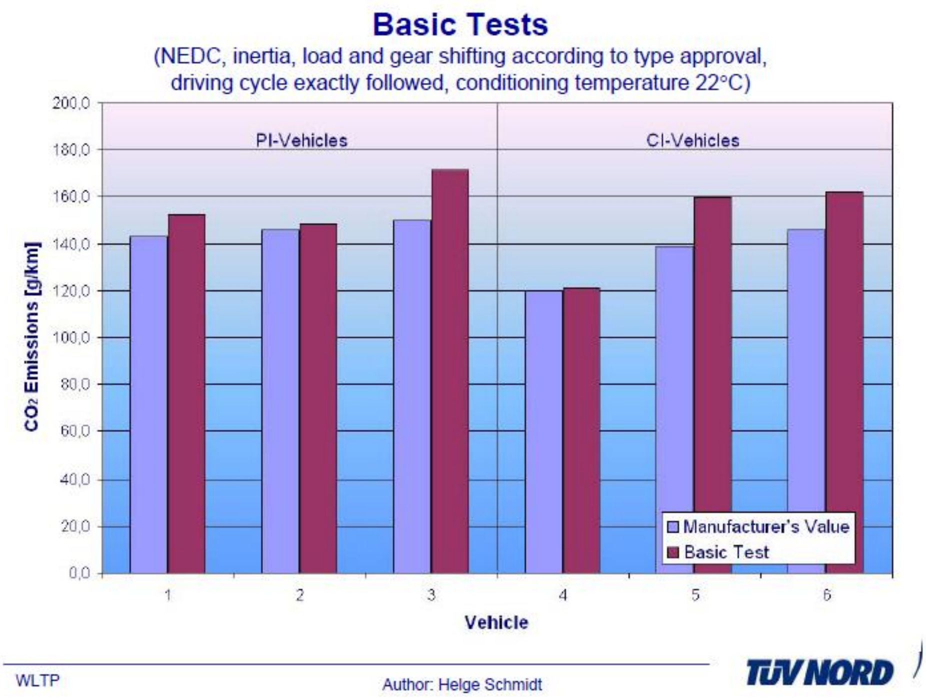
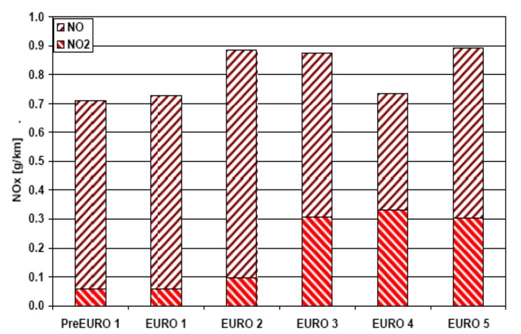


Figure A2.2: Comparison of manufacturers’ CO_2 results with Schmidt and Johannsen’s own tests

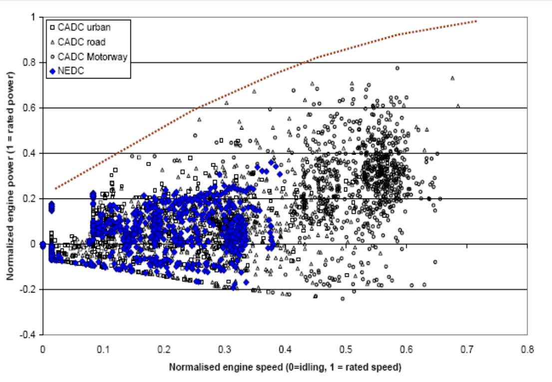
They noted that “Values remotely approximating to those declared by the manufacturers were only measured during tests with all the optimization measures permitted by the Directive” – and in one case even this did not get close. They concluded that “The results suggest that some vehicle manufacturers already take advantage of the possibilities allowed by the Directive to declare optimized values for CO_2 emissions and fuel consumption.” The discrepancy between the original test and the retest figures was significant enough in some cases for it to raise serious questions. Some dispute their findings, but if they are correct they point to the possibility of some carmakers bending the rules even further than we already know.

And another Problem with the NEDC ...

Hausberger (2010) collected historic test data on 367 vehicles and compared emissions from ‘real world’ test cycles against those of the NEDC. He highlights that, for new diesel cars, while emissions of nitrogen oxide and nitrogen dioxide appear on the NEDC test to have fallen over time in line with legislative requirements, no such improvement is visible under real world cycles – in fact, the data suggest that the problem has actually got worse, as this graph shows:



He reiterates his conclusion that we cannot expect large reductions in the real world NOx emissions from EURO 5 diesel cars if the type approval procedure remains unchanged, and predicts that the same will be true for EURO 6. This he attributes to the very limited engine load map of the NEDC compared to the Artemis cycle, as shown below.



Given the ever-increasing market share of diesel cars across Europe and the intractable problems that many municipalities are experiencing in meeting their air quality targets, this alone appears to be a compelling enough reason for early action to revise the test procedures, including the NEDC test cycle itself.

The ADAC EcoTest

As a service to its members, German motoring organisation ADAC retests all new car models coming on to the market with a test known as the EcoTest to give them a clearer idea of the real fuel economy of cars that they might buy. They use a test procedure similar to that of the EU official tests but apply slightly different test conditions to give a better representation of real world performance. For example; ADAC require air conditioning to be switched on for part of the test. ADAC also include their own highway drive cycle whereas NEDC under-represents this type of driving. Figure A2.3 summarises the results achieved for different models and variants since 2003.

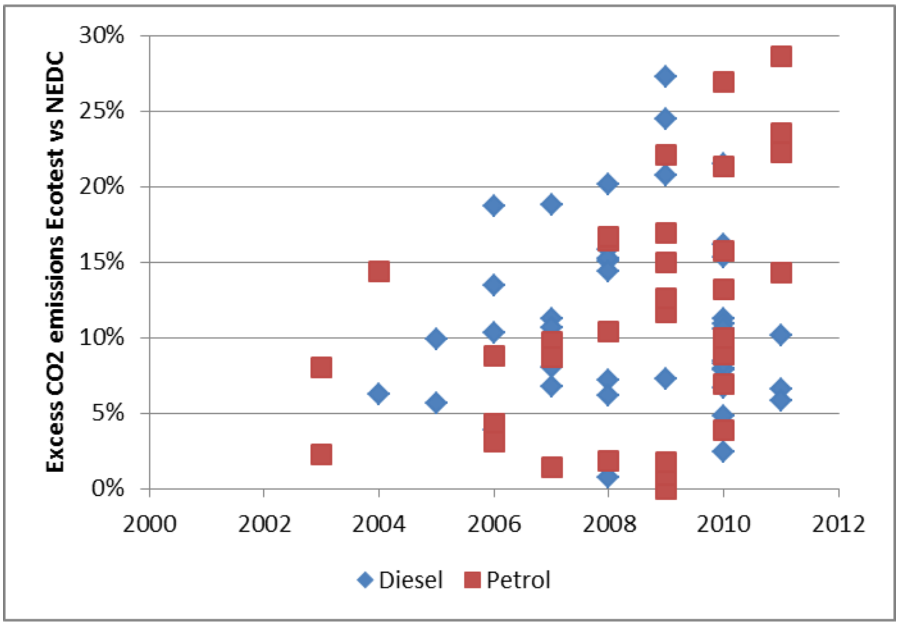


Figure A2.3: Comparison of real-world and test data for selected car models 2003 – 11[6]

The ADAC test procedure differs from the EU official test in order that the results are more representative of real-world driving, so a direct match to the official test results is not expected. However, the tests are quite similar so the relationship between the two sets of results should be quite stable and also stay more or less constant over time. Instead, Figure 4 illustrates that the gap between the ADAC test results and official test results diverges – just like the real-world data. The divergence of the ADAC data is less than identified by Spritmonitor, rising from around 10% in mid-decade to up to 30% in 2011 (Figure 1 shows a real-world divergence of up to 50%); this suggests that the divergence arises partly from changes in the way that the official tests are undertaken, and partly for other reasons. The ICCT (Mock *et al*, 2012) analysed the ADAC and Spritmonitor data to explore the reasons for the discrepancy between test results and real-world driving. The key findings are summarised in Figure A2.4.

[6] Derived using ADAC data

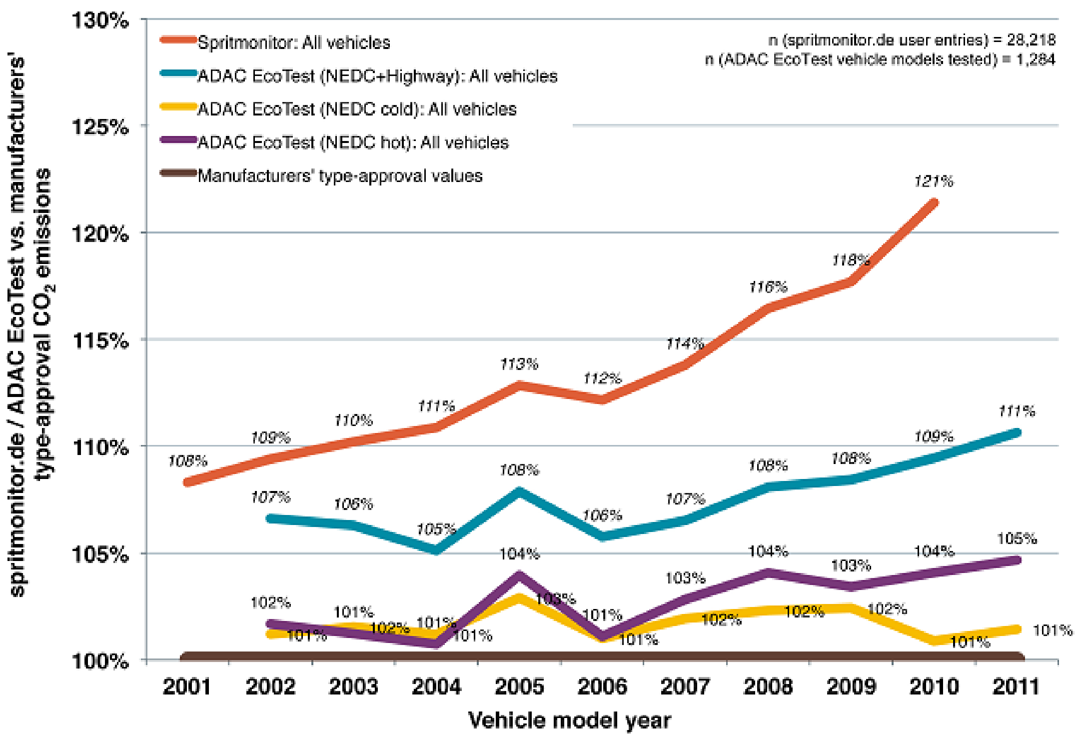


Figure A2.4: Differences in the level of CO_2 emissions from other data sources as percentage of type-approval values over time

The ADAC EcoTest consists of 3 separate tests:

- NEDC cold: duplicating the EU type approval test, but using a lower test cell temperature (22°C) and using the actual weight of the tested vehicle, instead of a usually lower test weight and discrete inertia classes
- NEDC hot: same as NEDC cold, but starting with a warm engine, and the air conditioner unit switched on (setpoint of 20°C)
- ADAC motorway: a dedicated cycle for driving on a motorway with speeds up to 130 km/h.
- The overall EcoTest result is produced by combining the result of the three separate tests. The EcoTest is more representative of real-world performance than the test-cycle but lower than the real-world Spritmonitor data that is real-world driving.

Figure A2.4 shows that the difference between type-approval CO_2values and the ADAC EcoTest (NEDC cold) is the smallest. In this case, the only differences in characteristics between the EcoTest and the official test are: a more realistic vehicle weight, a lower ambient test temperature and a more realistic starter battery state of charge in the Eco-test. There is no particular trend for a widening gap over time, suggesting few differences of approach between the two tests over the last decade.

In contrast, the difference between official EU to tests and the ADAC EcoTest (NEDC hot) is larger and there is a trend over time of a widening gap from just 1% difference in 2006 to 5% in 2010. The principal difference between the two tests is that the EcoTest has the air conditioning system switched on, illustrating the important contribution this can make to fuel consumption. The widening difference over time is likely to arise principally because an increasing number of vehicles are now equipped with air conditioning. This illustrates the growing importance of taking fuel use by air conditioning systems into account in future official tests.

The overall EcoTest result diverges much further from the official test results. The principal reason for the divergence in this case is the more representative motorway driving component of the EcoTest. The difference between the Eco-test and official tests has grown in line with that for the Hot EcoTest, but has not grown to the same extent as the Spritmonitor (real-world) data. The difference between the Spritmonitor and ADAC data in 2010 is about 12%, which largely arises from a combination of the state of charge of the battery, actual road load, realistic temperatures, driving patterns and gear-shifting strategies.

The ICCT note that the gap between official test and other datasets has been increasing most notably since 2007. ICCT conclude that the “increasing discrepancy could be attributed to manufacturers increasingly exploiting existing flexibilities for road load determination, shifting strategies of automatic gear boxes, and by applying dedicated calibrations for the type-approval procedure … Reducing type-approval CO_2 emission values by exploiting existing flexibilities in the test procedures is cheaper than applying technical measures to reduce CO_2 emissions.“ This is considered further in Section 3 of the main report.