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Fair Measure at the Pump: Accurate In-Tank Metering

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Every day, hundreds of millions of two-wheelers, cars and commercial vehicles queue up to fill up at fuel stations; and every day, a portion of the fuel that riders and drivers pay for simply never reaches their tanks. The only volume reading that these consumers can see is the one the seller has control over. Vehicle-side instrumentation, by contrast, has never been designed to answer the very simple question of how much fuel is currently in this tank, in litres.[1] *This paper suggests this state of affairs is due for reconsideration. It documents fuel dispensing fraud from several countries, explains why conventional fuel gauges fail to provide a check on the pump, and proposes both a viable, low-cost solution for absolute on-vehicle metering and a path forward for research efforts that might lead to a metrology-grade implementation. It moves through a realistic example of the problem and its resolution, considers the engineering obstacles a working solution will face, and suggests ways to overcome them.*

Keywords: *fuel dispensing fraud, consumer protection, fuel level sensors, legal metrology.*

[1] Harsh Trivedi, 'Getting less petrol than you paid for? Here's how to handle short fuel delivery at Indian petrol pumps' *TV9* (04 November 2025) <https://www.tv9english.com/india/getting-less-petrol-than-you-paid-for-heres-how-to-handle-short-fuel-delivery-at-indian-petrol-pumps-article-10880106.html> accessed 01 September 2026

INTRODUCTION

Anyone who has ridden a motorcycle to a fuel station in a jurisdiction with mixed enforcement has had the suspicion, watching the pump's display counter, that what it is showing might not represent exactly what has been pumped into their vehicle. Is the display really starting from zero? Does the reading really reflect the amount of fuel now in the tank, or is the figure being artificially inflated by tampering from the station operator? Most riders have no convenient way to find out, because the only meter in the transaction belongs to the seller and their own vehicle, whatever fuel gauge it has, was never designed to answer this question.

This is no mere theoretical concern. Weights-and-measures departments around the world report yearly on enforcement actions taken, and several involve exactly this sort of pump manipulation. Modifying a dispenser's firmware to underdeliver by a specific percentage, bypassing the display's verification features and continuing to show the customer a falsely high reading, or subtly altering the hose to keep a certain amount of fuel inside after a fill-up are all issues that have arisen in recent years and have impacted ordinary commuters, delivery riders, taxi drivers and small transport operators, who fill their vehicles two or three times a week rather than large commercial fleets.

The fundamental asymmetry between buyer and seller in this transaction is inherent in the process: the seller owns the measuring device and is responsible for calibration, subject to government inspection, which can occur annually or less frequently, and the seller has control of the software which implements the measurement function. The buyer has no independent means of measuring the quantity of fuel involved.

A car's fuel gauge, if it is present at all, provides little more than an indication, which may show a level somewhere, but this is a smoothed-out reading that averages over several minutes so the needle does not flutter up and down with every road bump. A motorcycle's fuel gauge is often nothing more sophisticated than a float and a warning lamp, or a manual reserve switch the rider has to find and switch by hand. Both are adequate to the task of showing how much fuel is present, but neither is precise enough to detect a five or ten percent shortfall on a single fill-up, and this is the range in which many documented cases of fraud have occurred.

The proposal described in this paper is simple to state, although it may take some engineering to implement and fit the vehicles, all classes of them, not just fleet or commercial, with a sensor system capable of determining the absolute volume of fuel in the tank and displaying it to a resolution sufficient that a rider or driver can perform the arithmetic to compare it with the amount claimed by the pump. Reading the tank before and after a fill-up and comparing the two results provides independent verification that the pump has not short-changed the customer, and, if it has, the extent of the discrepancy.[2]

This paper describes why this is a problem worth solving, citing specific cases; explains in more technical terms why a vehicle's existing instrumentation is not up to the task; works through a particular example (a two-wheeler fill-up) as an ordinary rider or driver would encounter it, then extends the solution to cars and commercial vehicles; it also discusses accuracy targets and the physics that will limit them; and suggests real-world problems a working solution will encounter and possible approaches to addressing them. It sketches a research programme, and concludes with the projected benefits to consumer protection and the limitations of the proposed approach.

WHY THIS IS A REAL PROBLEM, NOT A HYPOTHETICAL ONE

It is worth being specific about exactly where this problem occurs, because 'fuel fraud exists somewhere' is not nearly as compelling as 'documented and prosecuted cases of fuel fraud have occurred in these specific places'.

Nigeria: Consumer advocacy groups and the Nigerian downstream regulatory authorities have used calibrated containers to verify volume readings at pump stations, comparing the volume obtained by the customer with the volume displayed by the station. Shortfalls in the several hundred millilitres per ten litres range are frequent enough that regulatory sealing of non-compliant stations is a regular news item.[3]

Greece: Perhaps the most compelling case in recent years involved an organised operation which had modified the firmware of roughly twenty fuel dispensers, causing them to under-

[2] 'Types of fuel level sensors' (*Navixy*) <https://navixy.com/docs/expert-center/vehicle-telematics-technology/fuel-management/installation-and-initial-configuration-of-fuel-control-devices/fuel-level-sensors/types-of-fuel-level-sensors> accessed 01 September 2026

[3] 'The Litre War: Inside NMDPRA's Quiet Battle To Stop Pump Fraud' *Value Chain* (13 October 2026) <https://www.thevaluechainng.com/the-litre-war-inside-nmdpras-quiet-battle-to-stop-pump-fraud/> accessed 01 September 2026

deliver by nearly ten percent per transaction while displaying a normal reading to the customer. Investigations traced tens of millions of euros of lost product across the network before police broke seals on the dispensers and arrested those responsible.[4]

Brazil: Pumps which secretly short-change every customer by a fixed percentage have appeared repeatedly in enforcement actions taken in Brazil, sometimes associated with individual station owners and sometimes with organised networks which supplied the tampering hardware to multiple stations. Mystery shopper audits using known, calibrated containers are one of the primary means of detecting these devices, since no other independent verification of the pump reading is available to an ordinary customer. This practice is called 'Dumb Bombs'.[5]

China: Chinese authorities have prosecuted cases involving both physically altered control boards on dispensers and modified tanker truck deliveries which were under-delivered during a bulk transfer. The scale of some reported cases reaches into the tens of millions of yuan, giving an idea of the sums at stake.[6]

United States: Diesel theft rings have used so-called pulsar tampering devices which insert themselves into a flow meter's pulse network, altering the signal it sends to the display and causing it to count more slowly than it should. This has been seen in cases targeting commercial fleet customers specifically, as the fleet's overall fuel bill represents a large enough sum that stealing a few percent from each transaction is worthwhile.[7]

Similar issues have been reported in India[8], Italy, and other countries as well. None of this assumes universal dishonesty on the part of the retail fuel sector; most stations do operate

[4] Bill Giannopoulos, 'Gas Station Fraud Ring Busted: €25 Million Stolen Over 5 Years Through Tampered Pumps and Illegal Software' *Greek City Times* (22 January 2026) <https://greekcitytimes.com/2026/01/22/gas-station-fraud-ring-busted-e25-million-stolen-over-5-years-through-tampered-pumps-and-illegal-software/> accessed 01 September 2026

[5] '"Low-cost scam": understand how the gas station attempted to scam even the police' *Guia Muriae* (02 January 2024) <https://www.guiamuriae.com.br/noticias/brasil/posto-flagrado-em-golpe-bomba-baixa/> accessed 01 September 2026

[6] 'Gas station criminal risks diversify as multi-agency efforts continue to address fuel pump cheating and tax evasion' (*Hua Shui,* 30 November 2023) <https://www.huashui.com/en/frontier/detail/175.html> accessed 01 September 2026

[7] Mack Shaw, 'State investigation uncovers East Texas diesel pump tampering ring' *KLTV* (24 April 2023) <https://www.kltv.com/2023/04/24/state-investigation-uncovers-east-texas-diesel-pump-tampering-ring/> accessed 01 September 2026

[8] 'Uttar Pradesh STF raids petrol pumps, eight caught using cheating chip' *The Indian Express* (28 April 2027) <https://indianexpress.com/article/india/uttar-pradesh-stf-raids-petrol-pumps-eight-caught-using-cheating-chip-4631659/> accessed 01 September 2026

honestly, and most countries do have legal metrology requirements covering fuel dispensers, specifying tolerances, usually in the range of half a percent for larger deliveries, and requiring zeroing and tamper-evident seals on dispensers. However, tolerances only have meaning if they are enforced, and inspection regimes in the real world are usually annual or less frequent. Between inspections, a manipulated meter can operate for months, and every customer during that window pays for fuel they do not receive.

THE GAUGE DEFICIT: WHY THE VEHICLE CANNOT AUDIT THE PUMP

If the pump cannot be trusted between inspections, the obvious follow-up is to ask if the vehicle can somehow be made to serve as a verifying meter. In almost every vehicle currently in use, the honest answer is no.

The most common type of fuel gauge found in most cars and light vehicles uses a float connected to a resistor inside the tank; as the float rises and falls with the level of the fuel, the resistance changes, and a circuit on the dashboard of the vehicle uses this to drive a needle or a bar graph. This design is inherently inaccurate, and its accuracy is limited by the shape of the tank, which rarely takes the form of a simple box and is often curved to accommodate the transmission tunnel or spare wheel well; the vehicle's attitude as it sits on the ground; rider or driver weight shifting causes significant sloshing of the fuel, particularly in a motorcycle; and temperature: fuel expands and contracts measurably with the heat. It is deliberately damped to average over tens of seconds or minutes, so that the needle does not bounce up and down with each bump in the road. The end result is that the display is useful enough to warn a driver when he is about to run out of fuel, but not precise enough to let him know his last fill-up.[9]

Motorcycles and scooters tend to have even simpler systems; many budget and mid-range models use nothing more complex than a float and a warning lamp, or in some markets a manual reserve switch which the rider has to find and throw when the main supply runs out, providing no volumetric information at all. Taken together with the fairly common situation in which a two-wheeler is the only form of transport available to a person with limited

[9] 'How a Fuel Level Sending Unit Works' (*T P Auto Repair,* 20 November 2025) <https://tpautorepair.net/how-does-a-fuel-level-sending-unit-work/> accessed 01 September 2026

financial resources, this becomes a situation in which a person has no way to ensure they are not being regularly short-changed by several percent on every fill-up.

Trucks, buses and other heavy vehicles are somewhat better equipped to handle the task, particularly when fleet telematics systems have been fitted for purposes of fuel management and theft prevention. Capacitive and ultrasonic sensors used in these systems can achieve relative accuracy in the range of one to two percent under ideal conditions, and magneto-strictive sensors, which use a float sliding along a sensing rod to determine position via a magnetic interaction, can be more accurate still. However, these systems were designed for a different purpose: detecting bulk theft from a fleet, or providing an indication useful to fleet managers over weeks or months. They are usually not fitted to the ordinary consumer vehicles which make up the great majority of the world's vehicle fleet, and in any case were not designed to give a driver a precise indication of the volume of fuel at the time of a single retail transaction.

Temperature is an awkward factor which deserves special mention,[10] because it creates complications for a system which wishes to provide a reliable absolute volume reading. Legal metrology for fuel sales is generally applied at a standard temperature, most commonly 15°C, precisely because the volume of a given amount of fuel varies with temperature. A litre of petrol on a hot summer afternoon occupies more space than a litre of the same petrol at 15°C, even though its mass, and therefore its energy content, is the same. A vehicle side sensor which does not take temperature into account will provide a reading which appears 'wrong' compared to the pump, when in fact it reflects the true volume of the liquid in the tank. Any working system will have to compensate for this effect, and this paper discusses one approach to doing so.

WORKING THROUGH THE EXAMPLE: FROM A BIKE TO A TRUCK

It is helpful to walk through the example of precisely the kind of situation an ordinary rider would encounter, because the usefulness of the system depends critically on whether an ordinary rider, with no technical training, can use it in a few seconds at the fuel station.

[10] 'Standard Temperature Accounting: 15°or not 15°?' (*Petrol Equipment Installation and Maintenance Federation*) <https://1stdirectory.co.uk/_assets/files_comp/e2eb73db-fa69-49d9-b4dc-14c6363bc5b2.pdf> accessed 01 September 2026

Suppose a rider on a scooter has two litres of fuel remaining in the tank, indicated by a small display reading 2.00 L, and pulls up to a station to purchase more. The station attendant fills the tank, and the display indicates 2.00 L has been delivered - a fairly typical top-up for a small-tank scooter. If the transaction was fair, the rider's display should indicate approximately 4.00 L, since he added two litres to the initial two litres. If instead it indicates 4.20 L, no harm has been done; in fact, the pump may have slightly under-delivered in the rider's favour, but if the display shows 3.75 L instead of the expected 4.00 L, the rider has just discovered on the spot that he has been short-changed by roughly a quarter of a litre, or about twelve percent of the claimed delivery. That is not a rounding error; that is the sort of shortfall the recently reported Greek pump tampering case operated at.

The same calculation applies across all vehicle types: an 8.50 L reading in a car before filling, with a claimed 30.00 L delivery, should indicate approximately 38.50 L afterwards; a 145.0 L reading in a large delivery truck before filling, with a claimed 300.0 L delivery, should indicate approximately 445.0 L afterwards, the vehicle's display may not have the same resolution, however- it may only indicate to a tenth of a litre rather than a hundredth, because a tank that large does not need that level of precision. The principle is the same in every case; only the dynamic range and display resolution change.

In order to actually work, a few design choices need to be made:

Visibility at the Point of Use: The display needs to be visible at the moment of filling, not hidden in a menu three levels deep in an infotainment system. A small, dedicated display near the fuel cap or a companion application on a paired smartphone via Bluetooth are both suitable options.[11]

Settling Time: The reading needs to stabilise quickly enough that the rider or driver is not kept waiting at the fuel pump for two extra minutes while the system settles out sloshing or vibration.

[11] 'Fuel Level Sensor for Vehicle' (*Daviteq*) <https://www.iot.daviteq.com/wireless-sensors/fuel-level-sensor-for-vehicle> accessed 01 September 2026

Units and Resolution: The resolution and units need to be familiar to the end user, litres to two decimal places for small tanks, one decimal place for large tanks, rather than an arbitrary set of sensor units.[12]

None of this requires the vehicle to communicate with the pump or the station; the entire process is in the hands of the rider or driver, using only information available in the vehicle. This independence from the seller's systems is, in a sense, the whole point.

SENSOR OPTIONS AND REALISTIC ACCURACY TARGETS

Three families of sensors have matured to the point where they can be considered for this application, and none requires exotic new technology; the engineering challenge is packaging and calibration rather than invention.

- Capacitive sensors measure the change in electrical capacitance between two probes as fuel, which has a different dielectric property than air, rises or falls between them. They are inexpensive, have no moving parts, and are already widely used in aftermarket and fleet fuel-monitoring products, where they typically achieve one to two percent relative accuracy once calibrated to the shape of a particular tank.[13]
- Ultrasonic sensors measure the time taken for a sound pulse to travel from a transducer down to the surface of the fuel and reflect back, converting the time of flight to a level reading. They are non-contact, which is an advantage from a durability and fuel compatibility perspective, and can achieve similar levels of accuracy as capacitive sensors, although performance can be adversely affected by foam or turbulence on the surface of the fuel right after a fill, precisely the time at which the reading is most needed, so this needs to be specifically modelled in the verification mode algorithm.[14]
- Magneto-restrictive sensors use a float which moves along a sensing rod, with the sensor detecting the float's position via a magnetic interaction between a field in the

[12] 'Accurate Fuel Level Sensor' (*Metromatics*) <https://metromatics.com.au/product/accurate-fuel-level-sensor/> accessed 01 September 2026
[13] 'Capacitive Fuel Level Sensor: Working Principle, Calibration & Selection' (*Sino-Inst,* 25 April 2026) <https://www.drurylandetheatre.com/capacitive-fuel-level-sensor/amp/> accessed 01 September 2026
[14] 'Ultrasonic Fuel Level Sensors: Principles, Advantages and Industry Application Guide' (*Sino-Inst,* 14 May 2026) <https://www.sino-insts.com/ultrasonic-fuel-level-sensors-principles-advantages-and-industry-application-guide/> accessed 01 September 2026

> float and a current pulse sent down the road. They are the most accurate of the three options, typically used in applications where repeatability is important, but also have the greatest mechanical complexity and cost, and thus are likely to be found only on larger vehicles rather than budget scooters.[15]

A realistic accuracy target, given these technologies, is relative accuracy of about one percent or better once the system has been calibrated to a particular tank shape and the vehicle is stationary and reasonably level, which is sufficient to detect the sorts of five or ten percent shortfalls seen in the reported cases of fraud, but does not require equipment which would be prohibitively large and expensive to fit to a consumer vehicle. Resolution of 0.01 litre is achievable on small tanks; 0.1 litre is entirely adequate for larger commercial tanks given the larger volumes involved. Achieving this target requires three things: a calibration table which maps the shape of the tank; a simple cylindrical shape for a two-wheeler tank versus baffled, irregular shapes in a car tank will have widely different dynamic ranges and require different calibration; a temperature sensor to provide a correction factor back to a reference temperature; and a filtering routine which can distinguish a stable reading from one which is still settling out slosh or turbulence at the time the vehicle was stopped to fill.

ANTICIPATED OBSTACLES AND ENGINEERING SOLUTIONS

Any real paper proposing a new technology for consumer protection has to spend some time discussing the problems it will encounter in the real world rather than in an academic vacuum.

The most obvious obstacle to this particular project is the sheer volume of vehicles which would be affected by such a system. There are hundreds of millions of two-wheelers and cars in use currently; even if only a tenth of them could be fitted with the necessary hardware, that is still enough to make a noticeable difference. It is not impossible, but it is also not a trivial engineering task. Fortunately, some of the obstacles can be mitigated.

[15] 'How Ecotec Magnetostrictive Probes Enhance Tank Gauging Accuracy' (*Eco Tech,* 03 August 2026) <https://www.ecotecpetroleum.com/How-Ecotec-Magnetostrictive-Probes-Enhance-Tank-Gauging-Accuracy-id46095165.html> accessed 01 September 2026

Some potential solutions to the problems listed above are:

- The cost of fitting hardware to each vehicle can be mitigated if the hardware is something that can be retrofitted to existing vehicles rather than requiring an entirely new system. The more it can be reused across vehicle classes, the more economically viable it will be.
- The lack of appropriate legislation or government support for such a system can be mitigated if the system operates without requiring changes to existing law. Using only hardware already present in the vehicle and not interacting directly with the pump or the station avoids some of these issues.
- The technical challenges of implementing such a system can be mitigated if the system can be developed iteratively, starting with lower accuracy targets and gradually improving them.[16]

SKETCH OF A RESEARCH PROGRAMME

There are Two Primary Areas for Research –

System Verification: The system itself must be able to achieve the specified accuracy targets reliably. This involves determining what accuracy targets are practical, and finding ways to achieve them, possibly including improvements to sensor design, alternative sensor technologies or combinations of sensors, novel approaches to resolution and display, and so on.

Environmental Verification: The system must be able to operate reliably in the presence of interfering variables. This involves determining the effects of these variables on the sensor, and finding ways to mitigate them, possibly including novel signal processing algorithms which can extract meaningful information from sensor readings which appear noisy or otherwise unusable.[17]

[16] Alex Rowan, 'Fuel Level Sensor Integration for Fleet Fuel Monitoring' (*Fleetrabbit*, 21 September 2026) <https://fleetrabbit.com/article/fuel-level-sensor-integration-for-fleets> accessed 01 September 2026

[17] 'Acu-Trac® Product Overview' (*SSI Technologies*, 07 September 2019) <https://www.ssi-sensors.com/perch/resources/documents/acu-trac-product-overview-at-an1.pdf> accessed 01 September 2026

Expected Benefits and Honest Limits –

The core benefit is straightforward that it gives the person at the pump, for the first time, an independent number to cross-reference against the seller's number. This is a significant shift in an asymmetry that currently runs in only one direction. If enough vehicles are equipped with this capability and a sufficient number of discrepancies are reported to regulators, it should also have a deterrent effect on the kind of organised tampering; a station or a syndicate running a modified dispenser is much harder to operate without detection if a significant fraction of its customers are independently checking every fill.

Fleet operators gain an adjacent but separate benefit, an independent check not just on external filling, but internal fuel handling, where driver-level theft or misreporting is a distinct problem from pump fraud. Regulators gain a genuinely new source of distributed, real-world data, generated not by periodic official inspections but by users every day, which could help them direct scarce inspection resources to the stations most likely to be problematic. And a vehicle manufacturer that embeds this as a standard feature gains a significant consumer appeal point, 'know exactly how much fuel you have, and exactly how much you just received' is easily marketable.

It is worth honestly addressing what it does not solve. It will not stop an attendant from lying verbally about the amount before the pump has even finished, nor will it help a buyer who cannot read a display or does not think to check it. It does not replace the legal, certified pump meter as the instrument of record for the transaction, and should not be pushed as though it does. And it will do nothing at all in the case where the vehicle sensor has been tampered with by a bad-faith previous owner or installer, which is precisely what treats sensor tamper-resistance as a first-class design requirement.

CONCLUSION

Fuel is sold by volume, and right now, the only volume measurement most buyers ever see is under the sole control of the seller, a setup that has been abused, in multiple countries, at real financial scale, using methods ranging from crude mechanical fiddles to sophisticated custom firmware. Existing vehicle fuel gauges, designed for rough level indication rather than precision volumetric measurement, do nothing to close that gap, and for the riders of two-wheelers, who make up a huge share of daily fuel transactions worldwide and are

frequently the least able to absorb repeated small losses, the gap is largest. A calibrated, on-vehicle, absolute volume metering system, built from sensor technologies already in use and already proven in adjacent applications, can close it, for a scooter buying two litres exactly as much as for a truck buying two hundred. The engineering challenges are real, cost, tank shape, temperature, vehicle attitude, tamper-resistance and regulatory acceptance all require real engineering and policy work, not just an assertion that a sensor will take care of it, but none of them are a reason not to attempt it, and the potential benefit is putting a simple, independent, litres-based check in the hands of every rider and driver at the precise moment they need it, which is large enough to be worth the research programme.