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Study on heavy vehicle on-board weighing

Final report

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Executive summary

Overloading of heavy goods vehicles is a significant problem. One in three checked vehicles is overloaded, often by 10 to 20%. Overweight trucks have a negative impact on road safety, road degradation, environment and fair competition. Better enforcement is one of the European Commission's priorities and with its latest amendment to the weight and dimensions Directive 96/53/EC, the Commission also seeks to improve weight enforcement.

Technological solutions such as on-board weighing (OBW) or weigh-in-motion (WIM) are now available and allow inspectors to preselect vehicles suspected of infringements without stopping the vehicles in question. Pre-selection would increase the effectiveness of enforcement and at the same time reduce the burden of enforcement on hauliers that respect the rules.

Both OBW and WIM are practicable for screening overloaded trucks. However, a high number of WIM systems would need to be installed in many different locations to reach a high compliance check density. WIM systems cost around EUR 100'000 per site (depending on accuracy requirements).

OBW are fitted to vehicles, rather than to infrastructure, and enable the weight data to be communicated at any time from a moving vehicle to an authority carrying out roadside inspections. Equipping N2 and N3 vehicles (i.e. commercial vehicles above 3.5 t) would come at limited cost and would open immense possibilities: Not only could compliance checks be performed at any place and time, but already the carrier's awareness that the vehicle is overloaded and checks can be performed constantly everywhere would have an influence in reaching Europe's goal of better maintained roads, fair competition and improved road safety.

The accuracy levels attained by current OBW systems are best suited for pre-selection where accuracy levels around $\pm 10\%$ and better are required. Direct enforcement, where accuracy levels need to be much better, would currently only be possible at prohibitively high cost.

In order to implement a mandatory on-board weighing solution for screening the following requirements have to be met:

- Low cost equipment
- Sufficient accuracy level
- Calibrated and certified equipment
- Standardised communication interface

Currently OBW systems cost below EUR 1'000 per truck (on top of average new truck price of EUR 95.000) and they are available for all vehicle types. In case such systems would become mandatory and would be fitted in-line during production for all models, hardware costs may even come down to around EUR 500.

The certification regime and the re-calibration cycles are equal to procedures in place for the Digital Tachograph. However, practical procedures must be further developed in order to reduce the workload and thus the costs of the (re)calibration process. The communication to road-side enforcers shall be through the short-range radio interface defined by the existing CEN DSRC standards.

In conclusion, the conditions for OBW to be effective, affordable and reliable are fulfilled. On-board weighing systems are a very effective tool to prevent overloading and could be fitted to all N2, N3 vehicles at limited cost. It is therefore recommended that the EU makes this mandatory for all new heavy goods vehicles after a suitable transition period.

1 Introduction

1.1 Background

Overloading is a big problem in the trucking sector. A relatively large number of infringements is related to weights of heavy goods vehicles¹. On average, one in three vehicles checked is overloaded². These excess loads often exceed the maximum authorized weight by 10 or even 20%. Overweight vehicles lead to all sorts of negative issues, e.g. related to road safety, driver's safety, road degradation, environment and competition.

There is some discussion about making on-board weighing (OBW) systems mandatory for new trucks³. An impact assessment by the European Commission concluded that this would involve high costs (EUR 4'000 to 12'000 per vehicle) and thus the European Commission dismisses the idea for now⁴. However, information from other sources suggests this cost range is unrealistically high.

Transport & Environment⁵ would like to have better founded cost estimates as well as a solid analysis of what is technically feasible. Besides functional aspects for on-board weighing solutions also their economic viability is of importance. The contract for a study on heavy vehicle on-board weighing has been awarded to Rapp Trans.

1.2 Methodology

Rapp Trans focused on best practice and lessons learnt of European, American and Australian initiatives and experiences. Furthermore background information about European in-vehicle systems deployment (e.g. Digital Tachograph) and current standardisation processes in ISO and CEN is used. Information is collected by desk research and through contacts with important stakeholders, such as sensor suppliers and vehicle manufacturers. Where allowed by the stakeholders, concrete references are included in the text.

In summary, Rapp Trans provided support with the following tasks given by Transport & Environment, focusing on the feasibility of a mandatory on-board weighing solution:

No	Task
1	Analyse the technical aspects of on-board weight sensors
2	Estimate the costs of mandating such sensors on all new trucks (after an appropriate transition period)
3	Find a reasonable solution that provides an optimal balance between accuracy, reliability, practicality and cost
4	Estimate when it would be feasible to mandate on-board weighing sensors: how much lead time is needed as well as the vehicle categories to be covered

Table 1: Topics to be covered by the report

¹ SWD(2013) 108: COMMISSION STAFF WORKING DOCUMENT - IMPACT ASSESSMENT

² COM(2013) 195: Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 96/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic

³ See e.g. the position paper of the ETF Road Transport Section of 8 October 2013 on the revision of Directive 96/53/EC

⁴ Based on SWD(2013) 108 assuming the average price for systems in the USA and in Australia (load cell). Source: International Society on Weigh-In-Motion (ISWIM)

⁵ Together with its partners ETF, Région Wallonne and Belgian Federal State

2 Requirements on weight compliance

Different stakeholders have **different perspectives** and hence **different requirements** towards weight compliance, e.g.:

- **Public authorities** must consider how to improve the overall goals they want to achieve, e.g. reduced maintenance costs for road infrastructure, reduced environmental impact from road transport, improved road safety, more efficient use of the road transport system.
- **Transport companies** want to move goods in an efficient way, without being burdened by administration, paper work and frequent stops for compliance checks by authorities. In general, transport companies are also interested in fair competition, which includes that regulatory requirements are enforced and prosecuted equally for all market actors.
- **Vehicle manufacturers** and **suppliers** of (on-board) weighing systems want to make money by providing their customers with highly functional, productivity enhancing and distinctive products.
- **Professional drivers** want to conduct their profession under safe and comfort conditions in their cabin and on the road.

The following sections analyses the potential benefits of on-board weighing and the requirements of the stakeholders concerned, the current procedures of weight controls and conceivable improvements to the current situation through the use of mandatory on-board weighing solutions.

2.1 Stakeholder requirements

European Commission

Heavy goods vehicles transporting goods in Europe, buses and coaches, must comply with certain **rules on weights and dimensions** for road safety reasons and to avoid damages to roads, bridges and tunnels. Directive 96/53/EC⁶ sets maximum common measures, ensuring that Member States cannot restrict the circulation of vehicles which comply with these limits from performing international transport operations within their territories. To avoid that national operators benefit from undue advantages over their competitors from other Member States when performing national transport, they are bound to comply with the **standards** set for international transport.⁷

On 15th April 2013 the European Commission has published a proposal for an amendment to Directive 96/53/EC on weights and dimensions of heavy vehicles⁸.

It was deemed necessary to **amend Directive 96/53/EC** to improve the aerodynamics of vehicles and their energy efficiency, while continuing to improve road safety, and within the limits imposed by the geometry of road infrastructures.

The Commission felt that because the current Directive has no provisions on vehicle checks and the applicable penalties, many **infringements** go unpunished. The main infringement committed is **overloading** the vehicle. On average, one in three vehicles checked is overloaded. These excess loads often exceed the maximum authorized weight by 10 or even 20%. This causes premature **wear and tear** of road surfaces and increases the risk of **accidents**. It also distorts **competition** between transport companies, because the fraudsters can illegally gain undue competitive advantages.

The proposal for a Directive amending Directive 96/53/EC on vehicle weights and dimensions suggests adding new provisions to Directive 96/53/EC to enable the inspection authorities to better **detect** infringements and **harmonize** administrative penalties that apply to them.

⁶ Council Directive 96/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic

⁷ Cited from http://ec.europa.eu/transport/modes/road/weights-and-dimensions_en.htm

⁸ COM(2013) 195

Among other things, Member States would be required to carry out a minimum number of vehicle checks, using either **weighing systems** built into the **road** or by means of **on-board** sensors in vehicles which communicate remotely with roadside inspectors. These measurements would allow the inspection authorities to **filter** the vehicles, so that only vehicles strongly suspected of infringement are stopped for manual inspection.

Member States shall **encourage** the equipment of vehicles and vehicle combinations with **on-board weighing devices** (total weight and axle load) to enable the weight data to be communicated at any time from a moving vehicle to an authority carrying out roadside inspections or responsible for regulating the transport of goods. This communication shall be through the interface defined by the **CEN DSRC** standards⁹.

Road owners (public/private)

Overloaded trucks increase **pavement wear** and thus contribute to premature pavement failure. It is important to understand that the rate at which a vehicle destroys a road is proportional not to its weight but **to the fourth power of its weight**. The effect of 5% overload would result in a $1.05^4 = 1.22$ or 22% increase in damage and 18% reduction in pavement life. The effect of 10% overload would result in a $1.10^4 = 1.46$ or 46% increase in damage and 32% reduction in pavement life.

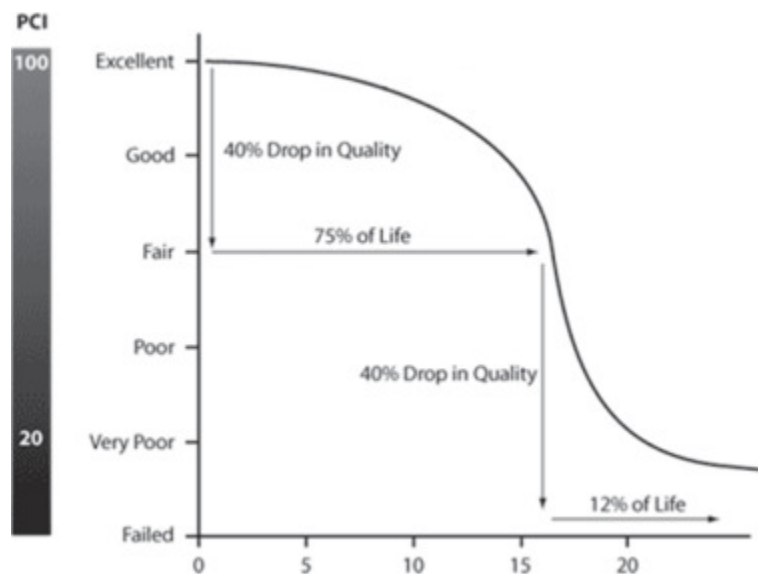


Figure 1: Pavement option curve (example); Pavement Condition Index (PCI)¹⁰

The abnormal axle load is not only stressing the pavement itself, but also the infrastructures of bridges and road structures.

The road owners' concerns are not only infrastructure driven. **Traffic safety** and **traffic flow** are getting more and more important with the increasing traffic volume in Europe. Overloaded vehicles make a negative contribution. They become under-powered which results in lower speeds on up-hill slopes as well as in increased risk of congestion, inefficient engine braking and speeding on down-hill slopes. They are also less stable because the braking efficiency is decreasing.

⁹ EN 12253, EN 12795, EN 12834, EN 13372 and ISO 14906

¹⁰ <http://www.fhwa.dot.gov/pavement/preservation/ppc0621.cfm>

Transport companies

On the one hand, transport companies (e.g. road hauliers, shippers) may **not be in favour** of further **regulatory** compliance measures. On the other hand, everyone commits to an open market economy with **free and fair competition**. Overloading leads to large distortions in freight transport competition, between road transport companies and operators. For example in France, it was estimated that a 5-axle articulated truck, operated at 20% overload all year round, generated an additional EUR 26'500 benefit per year.¹¹ Overloading also means **violation** of the taxation rules, such as vehicle registration fees, axle taxes, and toll infrastructure fees. It is therefore necessary to enforce vehicle weight and dimension regulations to minimise the number of overloaded and oversized trucks.

With respect to **intermodal transport**, overloading is not only of concern to road hauliers, but also to shippers. The amendment of Directive 96/53/EC includes Article 14 stating that for the transport of **containers**, the shipper shall give the road haulier to whom it entrusts the transport of a container a statement indicating the weight of the container moved. If this information is missing or incorrect, the shipper shall incur **liability** in the same way as the haulier if the vehicle is overloaded. Moreover, the International Maritime Organization (IMO) discussed in September 2013 a draft amendment on the **mandatory verification of gross weight of containers** prior to loading on a ship¹². If approved in 2014, the proposed measures will enter into force in July 2016. However, not all shippers fully agree with the proposed amendments (e.g. European Shippers' Council (ESC), Asian Shippers' Council (ASC), so that more discussion on this topic is to be expected¹³.

Hence, transport companies may have an interest in **proper compliance**, as long as it does not mean frequent stops by enforcers, additional administrative work nor large equipment costs. International quality transport companies, which normally do not exceed the weight limits due to the risk of losing their reputation, should therefore be in favour of better enforcement towards the ones who do not comply with the rules. This is also emphasised by ETF Road Transport Section, the European Transport Workers' Federation representing more than 2.5 million transport workers from 240 transport union and 41 European countries, who strongly supports the mandatory introduction of on-board weight sensors¹⁴.

Enforcers

Today, weight compliance **checks** are **cumbersome**. Vehicles need to be flagged down and stopped, and then guided to the closest available certified weighing scale in case of suspicion. This is very time consuming and only done when there is a clear indication of substantial overloading¹⁵. Control personnel as well as the responsible road authority would like to improve their control operations by increasing the efficiency and throughput.

A so-called **screening functionality** by introducing on-board weighing systems in combination with some short-range communication could improve the **filtering of suspicious vehicles** and support the control personnel in its daily work. A fully automated weight checking process comparable to that of speed cameras is not deemed feasible in the near future.

The **benefit to cost ratio** for such screening functionality is expected to be **excellent**, both for the vehicle owner who benefits from being left unbothered in case he shows no signs of infringement and

¹¹ HVParis2008 – ICWIM 5 – Proceedings of the International Conference on Heavy Vehicles

¹² <http://www.ecsa.eu/news-and-media/9-latest-news/70-mo-moves-to-make-container-weighing-mandatory>

¹³ <http://www.europeanshippers.eu/news/asc-rejects-imo-mandatory-verification-gross-weight-containers/#more-4606>

¹⁴ Position paper of the ETF Road Transport Section regarding the European Commission proposal for the revision of Directive 96/53/EC on maximum permissible mass and dimensions

¹⁵ Contrôle des PTAC. Les gendarmes traquent les surcharges. <http://www.vehicule-utilitaire.com/tous-les-vehicules-utilitaires/reportage/37-controle-des-ptac-les-gendarmes-traquent-les-surcharges.html>

for the road authorities who would enjoy a ten-fold increase of checking efficiency. Synergies with other applications, such as the enforcement of toll payments, do exist.

Manufacturers

Manufacturers of vehicles and suppliers of vehicle components produce what is **legally required** or asked for **by the market**. They have an interest to produce components with low maintenance costs, well-established technology and a high reliability. Manufacturers may choose to pass on the additional costs incurred by Regulation or absorb some of it themselves.

Professional drivers

Professional drivers are expected to see a benefit in on-board weighing solutions that will increase the **driver's safety** by reducing the negative impacts of overloading.

2.2 Weight compliance checking today

Today, weight compliance checking is organised on a **national basis**, with different intensity and focus between European Member States¹⁶. In general, density of checks is comparably low. This is mainly because of two reasons:

- Road **police focuses on traffic safety** as a first priority and on traffic fluency as a second. For road safety, speeding and alcohol are the critical factors, less so driver fatigue. Overloading has a certain impact on road safety, but to a lesser extent than other factors, and a minor influence on traffic fluency (e.g. lower speeds on up-hill slopes). Hence police focuses on speed and alcohol checks, has an eye on the work and rest hours recorded by the Tachograph, and is active in regulating traffic. Overloading mainly causes damages to infrastructure, has anti-competitive and environmentally negative effects. Whilst these are of high interest to other stakeholders, such as the road owners, transport companies and the general public, these effects are of less concern to the police.
- Weight **compliance checking is cumbersome and efficiency is low**. A suspect vehicle needs to be flagged down and stopped, and then guided to the closest available certified weighing scale. This is very time consuming and only done when there is a clear indication of substantial overloading¹⁷. More efficiency can be obtained in an organised compliance checking campaign. Here usually a large team of police officers, often supported by other forces, typically specialised compliance forces for goods transport (such as from the BAG¹⁸ in Germany), sets up a control site. Organising such a concerted effort requires substantial preparation and binds a lot of resources.

As explained above, the **risk to be caught with an overloaded vehicle is comparatively low**, at least when driving outside areas known for weigh-in-motion installations or increased presence of enforcement personnel, such as certain mountain passes. There is very low risk to be flagged down by

¹⁶ Hellemons, Ad (2013) Developments in enforcement of heavy goods vehicles, TISPOL, Workshop Weigh-in-Motion for Enforcement, Brussels, 27 February 2013

¹⁷ See e.g. the article "Contrôle des PTAC. Les gendarmes traquent les surcharges" about the situation during one specific control in France, representative of the standard situation

¹⁸ BAG, Bundesamt für Güterverkehr (Federal Office for Goods Transport)

chance by a passing patrol, since overloading is not easily visible, except for rather extreme cases. Risk is higher to be caught in an organised campaign, but since they require substantial efforts to set up, these are rather rare. In addition, already after a few minutes of operation, organised campaigns become loose part of their effectiveness, since their location will be known and easily avoidable.

Such a campaign typically consists of a screening section, a section where suspect vehicles are flagged down and a control site with parking lot and a certified scale.

The screening can either be done in freely flowing traffic by permanent weigh-in-motion installations (WIM installations) or by directing all heavy vehicles into a side-lane or parking lot temporarily equipped with a mobile weigh bridge. A WIM installation consists of a sensor built into the road surface that allows estimating vehicle axle weight while passing¹⁹. The sensor is connected to an evaluation unit that sums up the axles weights to give the full weight of the passing vehicle. WIM sensors for freely flowing traffic require permanent installation into a specially selected and prepared road section. The section needs to be flat so that trucks do not bump up and down, there should be no acceleration or deceleration, and the road surface needs to be specially prepared. **Accuracy of WIM stations in freely flowing traffic is not sufficient for directly fining a vehicle.** It is only sufficient as a pre-selection means to flag vehicles down for closer inspection on a mobile or fixed scale.

Evidence for overloading needs to be court proof. This results in the need to put a vehicle onto some certified weighing device under closely controlled conditions. This is a process with low throughput and will only be undertaken if there is sufficient initial indication of non-compliance. Hence, an efficient means for pre-selection is essential.

The general approach is to reduce overloading by **effective controls** and **dissuasive penalties**.

Regarding effective controls, **France** has a relatively **dense WIM network**, consisting of 30 equipped sites. The main purposes of the WIM installations are the following:²⁰

- overload screening (24/24 hr) with pictures of the violators
- pre-selection upstream static/LS-WIM checks (not permanent)
- warnings and company profiling plus in-company checks
- heavy vehicle traffic monitoring

Additional purposes include:

- mean velocity check (speed limiter)
- truck traffic limitation (overtaking & Sunday/public holidays bans, etc.)
- dangerous goods and abnormal loads monitoring

Annually over 30 million of WIM measurements (HGVs) and about 900.000 checks take place in France, among them 80.000 weight controls using static/Low-Speed WIM (LS-WIM). With WIM screening 90-100% of the intercepted trucks are overloaded. The WIM accuracy lies within categories B(10) to C(15) according to the COST 323 categorisation (see Annex 2: COST 323). System costs are around EUR 85'000 per site.

Regarding dissuasive penalties, the **Netherlands** have a relatively **strict penalty regime**. The controller (usually the police) makes a police report against the offender when the permissible gross weight is exceeded by +5% or more, or the permissible axle loads by +10% or more. The amount of the fine depends on the extent to which the weight / loads are exceeded. The fines are categorised according to 7 categories. They range from 250 to 2.500 EUR. In case of recidivism, the fines may be

¹⁹ See e.g. <http://iswim.free.fr/> or <http://www.wimuser.com.au/>

²⁰ Bernard, Jakob (2013) Automatic and semi-automatic overload control using WIM – French experience and European perspectives, 8th Brazilian Congress for Highways and Concessions, 12-14 August 2013, Santos

increased with 50 to 100% and even summons may be issued. The amount of the fine for the customer is equal to the amount of the fine for the carrier; the fine is not divided between the carrier and the customer. Due to the high fines for overloading, especially transporters of manure chose to install a certified on-board weighing system (see also section 5.2).

2.3 Improved weight compliance with mandatory on-board weighing

On-board weighing could contribute to improved weight compliance in road transport in various ways. **Four basically different approaches** are conceivable:

1. In-vehicle weight display for drivers
2. Voluntary active demonstration of weight compliance
3. Mandatory on-board weighing for pre-screening
4. Mandatory on-board weighing for direct enforcement

The four approaches clearly differ in **effectiveness** and in the required equipment **accuracy** and **calibration**, but ultimately they differ in the **policy** pursued, see Annex 1.

In some cases overloading is done unintentionally e.g. when part of the load of a truck is removed which may result in overloading of an axle due to a change in the distribution of weight on the vehicle. However, often the problem of overloading is caused by **deliberate non-compliance**²¹. Therefore, **voluntary installation of in-vehicle weight displays for drivers will not improve weight compliance** compared with today and is not a recommended route to follow.

Both the Intelligent Access Program (IAP) in Australia and the PrePass system in the USA are voluntary schemes, where **vehicle operators are offered incentives to actively demonstrate compliance** (see also Annex 3). In both schemes, on-board weighing systems are installed on participating heavy vehicles and communicate the weight readings to the authorities. Companies thereby actively demonstrate their compliance to the rules and in return **receive certain benefits (e.g. allowance to operate higher capacity vehicles)**. However, considering the work and costs involved in setting up such a regime in Europe and the lack of political support for the incentives offered overseas, the improvement in compliance would **not be worth the effort**.

In contrast to a voluntary on-board weighing scheme, a **mandatory scheme** would support the desired goal to generate a substantial reduction in overweight transports.

The **requirements for the public authority to enforce the weight and dimension rules are increasing**. Mandatory on-board weighing would be a new tool that could solve many needs. The gist of the European Commission proposal expressed in **COM(2013)0195** is to better detect infringements related to overloading. The introduction of on-board weight systems that are able to communicate the weight data to the inspection authorities was first recommended only, but is now part of the latest proposed amendment to the weight and dimensions Directive ("*New N2 and N3 vehicles shall be fitted with onboard weighing devices (total weight and axle load) that enable the weight data to be communicated at any time from a moving vehicle to an authority carrying out roadside inspections or responsible for regulating the transport of goods. This communication shall be through the interface defined by the CEN DSRC standards EN 12253, EN 12795, EN 12834, EN 13372 and ISO 14906. The information shall also be accessible for the driver.*"²²).

²¹ Van Loo, H. & Henny, R. (2006) REMOVE: Requirements for enforcement of overloaded vehicles in Europe

²² COM(2013)0195 – C7 0102/2013 – 2013/0105(COD); amendment by Jörg Leichtfried

Mandatory on-board weighing for screening

Having the weight measurement **inside every truck** would enable enforcers and carriers to **read out the weight information at any time, at any location** by using a hand-held device that communicates with the truck via some short-range communication.

Such **screening functionality** would be an instrument supporting the enforcers in their daily work and improving the filtering of suspicious vehicles. As soon as an officer sees a vehicle which looks suspicious to him, he can check the weight on the fly. Possibly non-compliant vehicles can be flagged down and guided to the closest available certified weighing scale.

In order to implement a mandatory on-board weighing for screening the following **requirements** have to be met:

- Low cost equipment
- Sufficient accuracy level
- Calibrated and certified equipment
- Standardised communication interface

The issues above are further discussed in the remainder of this report. It appears that on-board weighing for screening would be very beneficial for the checking process, and hence reducing overloaded vehicles on European roads, and **should be considered mandatory**.

Mandatory on-board weighing for direct enforcement

As stated above, mandatory on-board weighing could be used for screening of suspicious vehicles based on the reading out the current weight of a truck via some short-range communication. However, a **fully automated weight checking process** would be ideal for achieving highly efficient controls of high traffic volumes.

For **legal purposes** such as direct enforcement of legal weight limits (e.g. fining on the spot), the **accuracy** of weighing solutions needs to be **very high** and depends in the respective legislation. In most European countries, the accuracy must lie within $\pm 5\%$ for 95% of vehicles checked²³. It is evident that also **on-board weighing** solutions to be used for direct enforcement of overloading in Europe need to fulfil the high accuracy requirement. Although the accuracy claimed for current on-board weighing systems is rather high, the level attained in praxis is **not (yet) deemed sufficient** for direct enforcement²⁴. In Australia weight sensors with a very high level of accuracy (also in praxis) are used to directly monitor certain vehicles. However, the very costly nature of this is compensated for by giving certain benefits (see above).

Moreover, on-board weighing solutions for direct weight enforcement purposes have **more stringent requirements** than the systems that are used nowadays by fleet owners to manage freight operations. When used for weight enforcement purposes, such systems should:

- achieve **sufficient per-truck accuracy levels** to support pre-selection and enforcement of vehicle weight limits (in future perhaps even direct enforcement)
- provide **evidence of the vehicle identification** to be used by compliance officers
- be **certified** and **tamper proof** and fulfill certain **standards** and procedures (to be developed in Europe)

²³ Jacob, B. (2010) Weigh-in-motion for road safety, enforcement and infrastructures

²⁴ Statement by major industrial players in private communication in Nov 2013

Mandatory on-board weighing for direct enforcement would enable a fully automated weight checking process, which could be regarded an ideal solution. This however, is not yet in reach due to several technical and organisational shortcomings that need to be solved first. Given the improving technology, the synergies with other approaches (i.e. Digital Tachograph, see Section 6.1) and the falling costs, this approach could become a viable option **in the long run**.

Conclusion on weight compliance

Today, the **risk to be caught with an overloaded vehicle is comparatively low**, at least when driving outside areas known for weigh-in-motion installations or increased presence of enforcement personnel. **On-board weighing** would contribute to improved weight compliance in road transport in various ways.

The problem of overloading is often caused by **deliberate non-compliance**, as a result of which **voluntary** approaches will likely **not improve** weight compliance.

On-board weighing for **screening** of suspicious vehicles would make the enforcement process much more efficient. and on-board weight sensors **should become mandatory**. Mandatory on-board weighing for **direct enforcement is currently not feasible** would enable a fully automated weight checking process, and could become an option **in the long run**.

3 On-board weighing technology

3.1 Components of an on-board weighing solution

An on-board weighing solution consists of several components that work together to form a complete operational system: the sensors, the “box” and the interconnecting internal harness (e.g. cables).

- ① The three main types of **sensors** are load cell (esp. in steel-sprung suspensions), air pressure transducer (APT) (esp. in air bag suspensions) and strain gauge.
- ② The installed sensors are connected via cables to transfer the raw data to the vehicle unit.
- ③ The “box” is the **vehicle unit**, including data processing units and communication interfaces, such as the HMI for the driver, an interface to a printer, etc.
- ④ Localization and communication modules might also be part of the box, such as GNSS, GPRS and DSRC. However, interfaces to these modules elsewhere in the vehicle might also be possible.

Following product development activity in the **interconnecting internal harness**, some current solutions are no longer hard wired but transmit data via Bluetooth or other wireless technology.

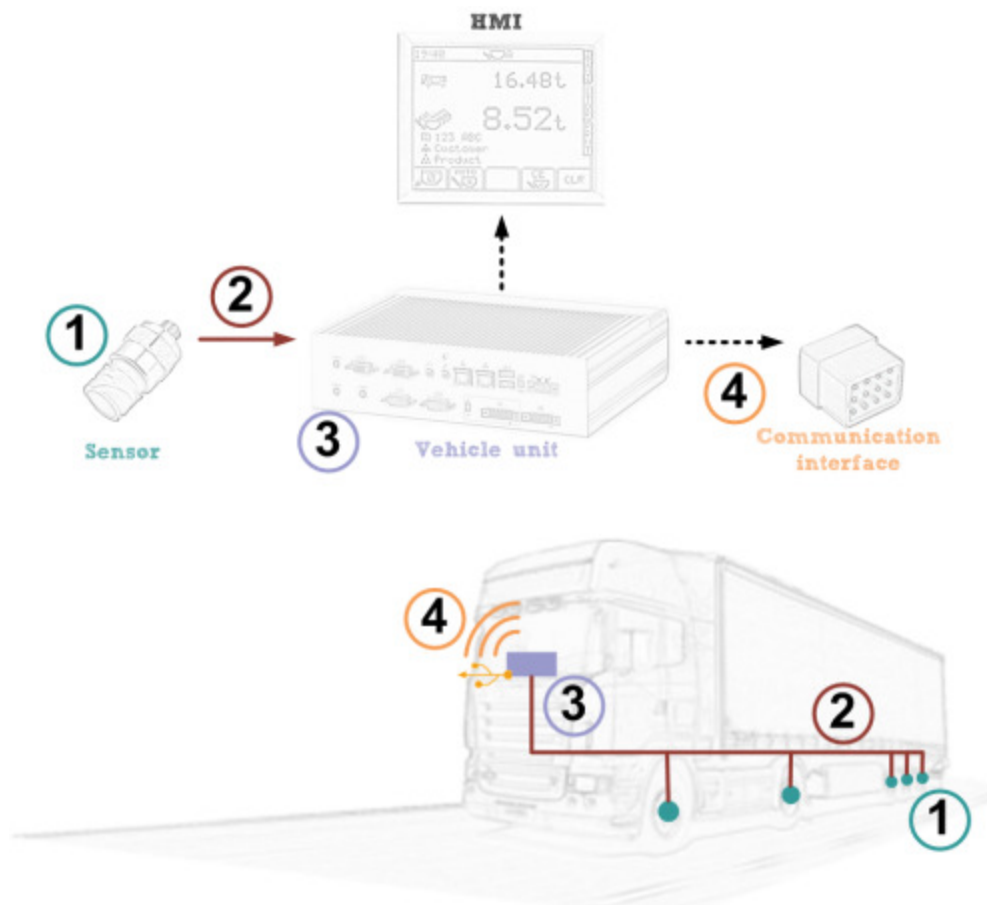


Figure 2: Basic components of an on-board weighing solution

3.2 Technical overview of sensor types

The **technology** used for on-board weighing applications is usually guided by the type of vehicle being used (e.g. type of suspension of the vehicle) and the accuracy requirement of the weighing application. The three main sensor types are load cell (esp. in steel-sprung suspensions), air pressure transducer (APT) (esp. in air bag suspensions)²⁵ and strain gauge, see also Figure 3.



Figure 3: Examples of sensor technologies: load cell, air pressure transducer and strain gauge sensor.

Load cell

Basic principle: converts strain to an electrical signal

When external forces are applied to a stationary object, stress and strain are the result. Stress is the object's internal resisting forces. Strain is defined as the amount of deformation per unit length of an object when a load is applied. The spring elements in a load cell (also called the beam) can respond to direct bending and shear stress. A load cell is a transducer which converts force (weight) into a measurable electrical output.

Air pressure transducer (APT)

Basic principle: converts air pressure to an electrical signal

Pressure is the ratio between force (weight) acting on a surface and the area of that surface. When an external force (pressure) is applied to an object causing a reduction in its volume, this process is called compression. This method is used to measure weight on vehicles using the vehicles air ride suspensions. The air pressure transducer converts the pressure into a measurable electrical output.

²⁵ Roughly based on: Howard Baker (2010) On Board Weighing Systems

Strain gauge sensor

Basic principle: converts electrical resistance or oscillating frequency change to an electrical signal

A strain gauge sensor is threaded on the structure to be surveyed and allows a precise and reproducible measurement of its stress changes. There are two types of technologies: In the conventional method a foil is deformed as the object is deformed, causing its electrical resistance to change. This resistance change is related to the strain. Another type of sensor is using sound or resonance frequency to measure strain or deformation. The frequency is used to calculate the suspension's physical properties (strain, load, deflection) through a specific algorithm. The response is then digitized.

Comparison

Each sensor has its pros and cons. On-board weighing solutions may consist of a combined use of sensors. Table 2 presents the most important features of the three sensor types.

	Load cell	APT	Strain gauge
<i>Accuracy</i> ²⁶	++ (better than 1%)	+ (between 3-5%)	+ (between 1-2%)
<i>Reliability (calibratable)</i>	+	-	+
<i>Ease of installation</i>	-	+	+
<i>Durability</i>	+	-	+
<i>Costs</i>	- (starting at EUR 8'000)	+ (starting at EUR 600)	+ (starting at EUR 1'200)

Table 2: Rough comparison between sensor types

Load cell based systems are more **accurate** than APT based systems. The reason is that an air bag suspension can take more than a minute to stabilize after stopping from a movement, so a mass reading taken while the air in the suspension is still fluctuating may not capture the true load. Also the accuracy of **APT** based systems can be influenced by temperature variations of the air within the air bags caused by operation of the suspension unit itself.

However, APT based systems are **less costly** and more appropriate for after-market installation. While APTs are relatively easy to fit via tapping off the vehicle's airline to the suspension, load cells are an integral part of the vehicle. So fitment of an APT on an individual axle may take less than an hour, but fitment of load cells on that axle should ideally be undertaken at the point of assembly of the trailer/axle. An aftermarket fitment of load cells for an individual axle group may take a couple of days.

New **strain gauge** sensors based on oscillating wire are known for better long term **reliability**, compared to the APT, which has to be recalibrated every year.

²⁶ Under the assumption of a maximum possible calibration. In praxis accuracy may be lower.

3.3 Technical overview of on-board weighing systems

Static and dynamic systems

Static on-board weighing systems have been used in the trucking industry for many years. They weigh the vehicle when it is stationary, e.g. at parking lots. The main objective is to optimise truck fleet management and routing with respect to their capacity and load limits.

The technology has improved and currently also **dynamic** on-board weighing systems that weigh the vehicle when it is in motion are available on the market. Such systems include, for example, components that can control and **balance the loads** per drive axle while driving. This may result in longer tires life, smooth riding and roll stability, and better braking capabilities.

In a static system the weight value is measured at one specific moment, when the vehicle is stationary. In a dynamic system the weight values are monitored continuously with a certain sampling frequency and the "real" weight value is based on complex algorithms. In principle, a dynamic system could be build out of any sensor type.

Commercial systems

Current on-board weighing systems can do **much more** than just provide individual axle group data and gross vehicle load. Wireless handheld displays, on-board printers, data loggers and weight data transmission are a few of the features now available. For example, a **mobile connection** (e.g. GPRS, UMTS) enables sending the load information to a central system (e.g. operated by vehicle owners or control authorities). A **GNSS** signal could add **location information** meeting the needs of hauliers, fleet managers, road managers and control authorities. As an alternative to GNSS, the mobile connection could also provide location information via cell location information.

There are several **suppliers** of commercial on-board weighing systems operating on the market, e.g. Cleral, Trans-Data, LoadMan, Pacific Scales, Kimax, Smeyers, Air-Weigh, Accuweigh.

For example, Cleral offers Sentinel, a wireless on-board axle weight monitoring system with a **handheld monitor** that displays all weights simultaneously and in real time (see Figure 4, left). Another example is the LoadMan LM200 Weight Display provided by LoadMan (see Figure 4, right). It is a powerful, compact multifunction device, designed specifically for on-board weighing applications with, among others, **GPS location capability** and **wireless communication** to back office management (e.g. DT, CDMA, GSM).



Figure 4: Examples of OBW systems available on the market: Sentinel by Cleral (left) and LoadMan (right)

Some on-board weighing systems are only available on certain **articulated vehicles**, such as the **Volvo OBW system**. This system combines an active hydraulic suspension system equipped with pressure sensors on the cylinders, with a dedicated electronic system to manage the suspension in real time²⁷. The system is only available on certain articulated haulers. The load weighing software is fully integrated into the vehicle's existing electronic system. In combination with Volvo's CareTrack telematics system, an operation manager or fleet owner can **monitor the equipment's load data** remotely, receiving insight into the machine's productivity. The information gathered is displayed both on the operator's display, as well as to the driver of the loader vehicle via an externally mounted **indicator light** (see Figure 5).



Figure 5: In-vehicle display of the Volvo OBW system

Conclusion on on-board weighing technology

An on-board weighing solution consists of several **components**: the sensors, the "box" (vehicle unit, HMI) and the interconnecting internal harness (e.g. cables).

The **technology** used for on-board weighing applications is usually guided by the type of vehicle being used (e.g. type of suspension of the vehicle) and the accuracy requirement of the weighing application. The **three main sensor types** are load cell (esp. in steel-sprung suspensions), air pressure transducer (APT) (esp. in air bag suspensions) and strain gauge.

There are many **suppliers** of commercial on-board weighing systems. Current systems can do **much more** than just provide individual axle group data and gross vehicle load (e.g. wireless handheld displays, on-board printers, data loggers and weight data transmission).

²⁷ <http://www.oemoffhighway.com/article/10628174/ready-set-load>

4 Accuracy of weighing devices

4.1 Accuracy measurement

The **accuracy** of a measurement can be defined as the closeness or agreement between a measured value and a (true) value accepted as a reference value²⁸.

Regarding weighing, all kinds of measurement are affected by more or less **weighing errors**²⁹. In general, the scales or sensors must be **tested on a regular basis** in order to ensure an operation within the error limits.

External errors are produced by unfavourable characteristics of the vehicle and weighing site. Overall, best accuracy is attained when the following causes for external errors are taken care of³⁰:

- Gradient of the weighing site: Almost no influence on the gross weight, but influence on the axle weight if the slope is in the driving direction.
- Vehicle suspension: The compression of the suspension results in higher axle load. Remedy: Levelling mats or flush installation.
- Friction in the suspension: Small influence if the vehicle is in good technical condition.
- Brake reaction forces: Braking causes load shift. Remedy: no braking while weighing.
- Vehicle oscillation (weigh-in-motion only): The axle load changes depending on the actual amplitude of the oscillation.
- Site unevenness

So for accurate weights, at least the vehicle must be parked on a level surface with the engine running, wheels straight, and the brakes released.

Accuracy may be increased by using **more sensors**. For example, an individual axle group might be fitted with either a single APT or two APTs. For load cells a minimum of two but more commonly four load cells are used to accurately measure all the deflection axes of the respective axle group³¹.

In any case, the accuracy of OBW data **depends greatly on the calibration procedure** of the OBW solution. Properly calibrated and used, all three sensor types can achieve a rather high accuracy (better than 5%), with load cells being the most accurate.

4.2 Accuracy classes

The accuracy achieved during the conditions of **real use** of OBW solutions (e.g. mileage driven, weather conditions (temperature, humidity), pavement condition) will **decrease** compared to the accuracy achieved during (initial) calibration. To this end, the statistical concept of accuracy class has been defined.

Accuracy class is defined by the International Organization of Legal Metrology³² (OIML) as class designation of a weight or weight set which meets certain metrological requirements intended to

²⁸ COST 323, Weigh-in-Motion of Road Vehicles, Final Report (1993-1998)

²⁹ Scheuter, F. (2009) Technical Aspects of Weighing Road Vehicles, BSEC Conference, Geneva, 18 June 2009

³⁰ Scheuter, F. (2009) Technical Aspects of Weighing Road Vehicles, BSEC Conference, Geneva, 18 June 2009

³¹ On-Board Mass Monitoring Test Report (Final), May 2009, Transport Certification Australia

³² The International Organization of Legal Metrology (OIML) is an intergovernmental organization to promote the global harmonization of the legal metrology procedures that underpin and facilitate international trade in measuring devices and in products that rely on the measuring devices

maintain the mass values within specified limits³³. In other words, the accuracy class of a measuring device (e.g. an OBW solution) defines a class of weighing devices that are subject to the same conditions of accuracy. For example, in the Metrological Regulation for Load Cells (OIML R60) load cells are ranked according to their overall performance capabilities into four accuracy classes A to D.

Analogue to the OIML accuracy classes, six accuracy classes for **weigh-in-motion (WIM) systems** have been defined in **COST 323**³⁴, see also Annex 2. The accuracy of a WIM system is defined in a **statistical way** by a confidence interval of the relative error of a unit (e.g. an axle group) defined by $(Wd - Ws)/Ws$, where Wd is the impact force or dynamic load measured by the WIM system and Ws is the corresponding static load/weight (or any specified reference value) of the same unit³⁵. Such a confidence interval centred on the static load/weight is noted $[-\delta, +\delta]$, where δ is the tolerance for a confidence level n (e.g. 90 or 95%).

COST 323 defines WIM systems by **six classes** based on their **level of accuracy**, see also Annex 2. Examples of these classes include (note that the numbers in brackets indicate the confidence interval width):

- Class A(5): Legal purposes such as enforcement of legal weight limits.
- Class B+(7): Enforcement of legal weight limits in particular cases, if the Class A requirements may not be satisfied, and with a special agreement of the legal authorities; efficient pre-selection of overloaded axles or vehicles.
- Class B(10): Accurate knowledge of weights by axle groups, and gross weights, for: infrastructure (pavement and bridge) design, maintenance or evaluation, such as aggressiveness evaluation, fatigue damage and lifetime calculations, pre-selection of overloaded axles or vehicles, vehicle identification based on the loads.

Hence, for legal purposes a confidence interval δ up to 5 to 10% is indicated (corresponding to class A(5) or B+(7)); for pre-selection for enforcement a confidence interval δ up to 10 to 15-20% (corresponding to class B(10) or C(15)).

4.3 On-board weighing for enforcement purposes

On-board weighing solutions could be used for enforcement purposes **if the legislation allows** the use of OBW for these purposes. Currently static weighing and LS-WIM systems (see below) are generally allowed for legal purposes in Europe (e.g. direct enforcement).

WIM systems fall into **two broad groups** with regards to the "motion" in their weighing³⁶:

- Low-speed WIM (LS-WIM) systems with an operating speed generally in the range of 5 to 15 km/h. The accuracy of LS-WIM systems can be 3 to 5% (i.e. class A(5) according to COST 323).
- High-speed WIM (HS-WIM) systems with an operating speed generally more than 15 km/h. The accuracy of HS-WIM systems varies from 10 to 25% for approximately 95% of the gross weight (i.e. classes B(10) to D(25) according to COST 323).

³³ International Recommendation OIML R111-1, Edition 2004 (E)

³⁴ COST 323 is supported by the European Commission with the aims to promote the development and implementation of weigh-in-motion techniques and their applications, and to facilitate an exchange of experiences between different European countries

³⁵ COST 323 Weigh-in-Motion of Road Vehicles, Final Report, Appendix 1 European WIM Specification, Paris, 2002

³⁶ Jacob, B. (2010) Weigh-in-motion for road safety, enforcement and infrastructures

Errors in HS-WIM systems result from the **difference** between the static wheel or axle loads and the impact forces applied to the pavement – and thus to the road sensors – while the vehicle is in motion. To cope with this dynamic effect, **new WIM concepts** are being developed, e.g.:

- Multiple sensor (MS-) WIM
- Bridge (B-) WIM
- Video (VID-) WIM and Automatic Vehicle Identification (AVI)

LS-WIM has been **legally implemented** for enforcement in the UK since 1978, as well as in parts of the USA, Canada and Australia. In the late 1990s and early 2000s, several European countries (e.g. Germany, France, Belgium) and Japan authorised LS-WIM for enforcement. **HS-WIM** is generally used for **screening** overloaded trucks prior to a control area equipped with static weighing or LS-WIM devices. In very few countries, such as Taiwan, HS-WIM is used for direct enforcement with tolerances of up to 30%³⁷. In the Czech Republic, HS-WIM was tested in 2011 by the Czech Metrology Institute and type approved according to Czech law in 2012³⁸. Maximum errors include 11% for axle (groups) loads and 5% for total vehicle mass.

In general, it is a great **challenge** to use WIM technologies for **automated (direct) enforcement** in the traffic flow, as is the case for speed enforcement. In most countries, the requirements are to get WIM systems in accuracy **class A(5)** for more than 95% of the vehicles, and even closer to 99%. In most European countries, the accuracy levels attained by current HS-WIM systems are deemed not sufficient for direct enforcement.

Similar to WIM systems, **on-board weighing** solutions for **enforcement purposes** need to attain a certain level of accuracy. It is evident that OBW systems to be used for weight enforcement purposes have **more stringent requirements** than the systems that are used nowadays by fleet owners to manage freight operations. When used for weight enforcement purposes, such systems should:

- achieve **sufficient per-truck accuracy levels** to support pre-selection and enforcement of vehicle weight limits (in future perhaps even direct enforcement)
- provide **evidence of the vehicle identification** to be used by compliance officers
- be **certified** and **tamper proof** and fulfil certain **standards** and procedures (to be developed in Europe)

Above all, **legislation** is needed to allow the use of on-board weighing for enforcement purposes.

Regarding the **accuracy** claimed for current OBW solutions in Europe, it may be stated that the accuracy levels attained in praxis are deemed **not sufficient for direct enforcement** of overloading, but that these accuracy levels would **allow for pre-selection** for enforcement, see also next section.

4.4 Achieving a certain accuracy

Which **accuracy level** an on-board weighing solution should attain to enable its use for enforcement purposes is first of all a **political and legal decision**.

Remember that any level of accuracy not only refers to the performance of the on-board weighing solution used (in particular the (number of) sensors), but also to the **calibration procedure and frequency**, to pavement/road quality and evenness, and vehicle behaviour.

³⁷ This may be acceptable if there are very large and frequent overloads

³⁸ Van Loo, H. & Jacob, B. (2013) Weigh-in-Motion for Enforcement in Europe, presentation for Workshop on WIM for Enforcement, 28 February 2013 (<http://iswim.free.fr>)

After installation, an on-board weighing solution must be calibrated (**initial calibration**). The assessment of the accuracy requires **testing**. In general, the more extensive the test plan (regarding time, means and thus costs), the higher the confidence in the conclusion.

Moreover, **periodical recalibration** and system behaviour checks should be performed. For WIM systems, checks at least once per year, but preferably every month are recommended. If a significant bias is found, a recalibration should be carried out.

The **purpose** of the on-board weighing solution should **guide the selection of a calibration procedure**. Different calibration methods are commonly used (e.g. static calibration, automatic self-calibration)³⁹, which depend on the sensor type, the application and requirements of the user, and the time and means available.

Generally, the following accuracy levels are expected to be feasible in combination with the respective calibration procedures:⁴⁰

- Assuming a **10% accuracy level** which allows for **pre-selection** for enforcement (i.e. according to COST 323 accuracy class B+(7) or B(10)) would mean an accuracy check or recalibration at least **every two years** (similar to the checks of the Digital Tachograph, see also section 6.2).
- Assuming a **5% accuracy level** which allows for **pre-selection** for enforcement and **direct enforcement** (i.e. according to COST 323 accuracy class A(5)) would mean an accuracy check or recalibration at least **once or twice per year**.
- Assuming a **1-2% accuracy level** which allows for **direct enforcement** would mean an accuracy check or recalibration at least **every 3-6 months**. For example, the IAPm program in Australia requires such high accuracy level. Here recalibration is performed on an "as needed" basis (where a vehicle or component fails a verification test, the device must be recalibrated) with a minimum of at least once every 6 months⁴¹.

Note, however, that the use of on-board weighing for enforcement purposes is **new in Europe**. **Further study** is needed into aspects surrounding the accuracy of on-board weighing solutions, such as calibration, tamper resistance and certification.

³⁹ COST 323 Weigh-in-Motion of Road Vehicles, Final Report, Appendix 1 European WIM Specification, Paris, 2002

⁴⁰ Based on information about reference values and experience provided by different sensor suppliers

⁴¹ Based on information provided by Peter Girgis, General Manager Operations, Project Director Electronic Work Diaries, Transport Certification Australia (TCA)

Conclusion on accuracy of weighing devices

Any **level of accuracy** not only refers to the performance of the on-board weighing solution used (in particular the (number of) sensors), but also to the **calibration procedure and frequency**, to pavement/road quality and evenness, and vehicle behavior.

Properly calibrated and used, all three sensor types can achieve a rather **high accuracy** (below 5%), with load cells being most accurate.

For example, a **10%** accuracy level allowing for **pre-selection** for enforcement (according to the COST 323 specification, similar to WIMs) is deemed feasible with a calibration procedure at least **every two years**. A **5%** accuracy level also allowing for **direct enforcement** would be feasible with a calibration procedure at least **once or twice per year**.

However, which **accuracy level** an on-board weighing solution should attain to enable its use for enforcement purposes is first of all a **political and legal decision**.

Since the use of on-board weighing for enforcement purposes is **new in Europe**, further study is needed into calibration procedures, tamper resistance, certification etc.

5 Cost estimates

5.1 Input from vehicle manufacturers

Several vehicle manufacturers were contacted by phone or e-mail with the following questions:

- Are on-board weighing sensors standard equipment or available as an option?
- On which types of trucks?⁴²
- What are the estimated costs?

DAF	<ul style="list-style-type: none"> • Option ("Axle Load Monitoring") • Vehicles with air pressure suspension • Negotiated in total price of the vehicle, perhaps a few hundred euros
SCANIA	<ul style="list-style-type: none"> • Option • Mostly bought by body builders, such as timber trucks • No idea of costs
Iveco	<ul style="list-style-type: none"> • Option ("Axle Load Indicator") • Vehicles with air pressure suspension • Ca. EUR 700
MAN	<ul style="list-style-type: none"> • Option ("digitale Achslastanzeige im Fahrerhaus") • Vehicles with air suspension axles • Costs largely depend on type of vehicle (e.g. number of axles) • Ca. EUR 600-800 for a "standard" international truck with 2 axles • This air pressure based system is not calibratable (accuracy up to +/-10%) • External on-board weighing solutions are possible as after-sales option for all types of vehicles (with air suspension axles and leaf spring axles) • Such systems are generally more expensive and better calibratable
Daimler	<ul style="list-style-type: none"> • Option ("Achslast Messeinrichtung") • Vehicles with air pressure suspension • Rough estimation: few hundred euros (e.g. based on sensor costs and perhaps replacing steel springs with air springs)
Volvo	<ul style="list-style-type: none"> • Option ("Lastanzeigesystem") • Vehicles with air pressure suspension • ±200 kg accuracy if calibrated once every year • ~ EUR 760
Mercedes	<ul style="list-style-type: none"> • Option for an air pressure system • ~ EUR 570 • in series for the Econic model • the new Actros models are standard equipped with pressure sensors that detect the air pressure in the bellows

Contact with a vehicle body manufacturer⁴³ provided us with the following feedback: the installation of on-board weighing sensors is currently not an issue of vehicle body manufacturers. The decision lies with the trailer or vehicle manufacturer or vehicle dealer.

⁴² In this context the term truck was used as the advertised combination in the catalogue (i.e. tractor and trailer/semitrailer or single truck)

⁴³ Carosseriefabriek Hartog-Est, Waardenburg, NL

In summary, most vehicle manufacturers are able to provide an on-board weighing solution based on APT sensors as an option from ca. EUR 600 onwards.

5.2 Input from sensor suppliers

Where most vehicle manufacturers nowadays offer a relatively low-cost on-board weighing solution based on APT sensors, the sensor industry is able to also offer other solutions. Especially on-board weighing solutions based on the strain gauge sensor technology seem to offer an attractive prospective.

Vlastuin

Vlastuin, a company in the Netherlands, is a high-tech, leading supplier in the metalworking chain. Vlastuin provided us with the following information regarding their on-board weighing technology. Among others, Vlastuin builds, assembles and certifies **calibrated on-board weighing systems** based on **load cell** sensors.

Nearly all **manure** transport vehicles that are delivered in the Netherlands are equipped with calibrated weighing systems, many of them provided by Vlastuin. Having an on-board weighing system is **not mandatory** for manure transport vehicles, but many transporters chose to install one out of economic reasons. There are **regular enforcement checks on the roads** and fines for overloading are high. Instead of frequently making detours to pass a calibrated weighing bridge, transporters more and more chose to install a certified on-board weighing system. Vlastuin's system has a **legal status** due to its very high accuracy (up to 100 kg is possible – category 3, up to 500 kg is allowed – category 4). For example, invoicing based on the weighing system's receipt is possible. Costs for the total system (incl. installation, certification) are **EUR 30'000**.

Sense-Tech

Originally, the Kimax system from Sense-Tech was developed for vehicles with air suspension. Air pressure is measured on the right and left side of each axle and routed to the Kimax instrument to get the most accuracy weighing results under different circumstances.

On vehicles with steel spring suspension (parable springs or leave springs) e.g. on front axles, strain gauge sensors are used. Such a sensor has to be glued on the front axle in order to read the bending of the front axle (more precise—to read the strain in the front axle) caused by load of the vehicle.

Each axle has to be calibrated after installation. The calibration is carried out by weighing each axle of the vehicle on a weighing bridge – once empty and once loaded. The calibration process should be repeated every year to get an **accuracy of ±1%**. It was mentioned by the experts at Sense-Tech that the drop in accuracy over the year also depends on outside influences like rough road conditions.

The price of retrofit for a typical commercial vehicle lies around **EUR 2'000** including all sensors, cabling, vehicle unit and the information display for the driver. For larger quantities and installation during initial vehicle construction, the price could easily drop to the level of current APT solutions (around EUR 600).

Digi Sens

In regards to on-board weighing systems Digi Sens is mainly using **two solutions**. The first one is through **load cells** which are to be mounted between the main chassis of the truck or trailer and the body. This solution is mainly used for certified weighing solutions with a precision of 10 kg for the full payload. The cost of both the equipment as well as the integration is relatively high. A typical end customer price for a standard solution is of EUR 20'000.

The second solution is much more affordable, as it is done through indirect measurement, using sensors which are integrated into an existing structure, measuring the local deformation (gauge) created in this structure when being loaded. It is based on the **oscillating wire technology** and specially well suited for this type of application due to the fact that it is highly sensitive to the smallest structural deformations as well as its extremely long term stability, meaning there is no need for constant recalibration. Another big benefit of using a purely digital signal (no conversion from analogue to digital) is the robust data transmission in the harsh environment of a truck.

The equipment (sensor, electronic unit) is much less costly than the solution with load cells. The average cost for the end user tends to be of EUR 4'000 (including calibration) based on small series. This cost would automatically go down should this be done on an industrial level.

Today, this solution is used for waste and recycling vehicles, salt spreaders and road sweepers and train wagons. Another successful implementation of this solution on a large scale basis is within the elevator industry.

5.3 Cost figures from Australia

Australia recently extended their Intelligent Access Program to incorporate the use of type-approved on-board mass units (OBMU), also known as **IAP Mass (IAPm)**, consists of the axle mounted scale sensors (load cell or air pressure transducer), A/D converters, wiring and in-cabin head unit. This program runs since September 2013.

Regarding **recent** cost figures in Australia, the cost of an on-board mass system is generally **AUD 5'000** for the **prime mover** (including the in-vehicle screen display) and **AUD 1'500 per axle group**. So a semi-trailer or rigid would cost AUD 6'500 and a B-double would cost approximately AUD 9'750. Certainly the **costs are coming down** now because of good competition and regulatory applications being deployed.

Also the **test program** on commercially available on-board mass monitoring (OBM) systems in Australia is relevant for this study⁴⁴. A total of twelve OBM systems from eight suppliers were tested across five Australian States. Both APT and load cell based systems were involved in the test with indicative costs ranging from EUR 5'000 to 13'000 per vehicle.

The following information was deduced from the Test Report (2009):

There is a significant **difference in the cost** of an OBM system which is directly related to the choice of sensor, i.e., load cell or APT.

On the basis of an individual axle group fitted with an **air bag suspension system**, either a **single APT** or **two APTs** are fitted. Some OBM suppliers fit two APTs in order to monitor each end of the axle, or one APT is fitted on the main airline to the airbags on both sides of the axle.

⁴⁴ On-Board Mass Monitoring Test Report (Final), May 2009, Transport Certification Australia

For **mechanical spring suspensions**, fifth wheel (turntables), steer axles and trays on rigid trucks, load cells are required. No air pressure measurement is possible. To accurately measure all the deflection axes of an individual axle group, a **minimum of two** but **more commonly four load cells** are required per axle group.

Furthermore while APTs are relatively easy to fit and may take **less than an hour**, but fitment of load cells should ideally be undertaken at the point of assembly of the trailer/axle. An aftermarket fitment of load cells for an individual axle group may take a **couple of days**.

It follows that APT systems have a significant price differential over load cell systems. Moreover, there seems to be more product development activity in APT based systems. The increasing demand for APT systems will likely lead to future reduction in APT based OBM system costs.

The sensor accuracies are specified per axle group rather than per laden weight. When calibrated the **axle group masses must be within ±100 kg** of absolute. In addition, the total combination mass (TCM) accuracies for the whole vehicle must be within a certain tolerance for certification reasons (see table below).⁴⁵

Number of Axle Groups	Weighbridge TCM Tolerance [kg]
2	750
3	900
4	1000
5	1150
6	1250
7	1350
8	1450
9	1500
10	1600

Figure 6: Total combination mass (TCM) accuracies for certification.

Applied to Europe, the equivalent for a 40 t vehicle with for example 5 axle groups would result in an accuracy of $1'150 / 40'000 \approx 2.9\%$. The costlier load cell-based weigh systems are typically accurate to within 0.5% of the vehicle's gross vehicle weight, but in certain configurations they can cost up to AUD 17'000.

Customers appear to be price sensitive with costs as a major factor in purchasing decisions. Compared to a possible on-board weighing screening solution in Europe, the high costs mainly originate from the high accuracies required. Additional efforts for the retrofitting contribute to this as well as the fact that the larger vehicles in Australia require more sensors.⁴⁶ Another influence for relatively high costs is the small market with currently three approved OBM suppliers.

The calibration is done at tare (empty vehicle) and full and linearity across total measurement range must be demonstrated. The **recalibration** is performed on an **"as needed"** basis: If a vehicle or a

⁴⁵ Information provided by Transport Certification Australia

⁴⁶ According to Transport Certification Australia the cabin units are available for AUD 200 to 350 and air pressure transducer sensors for such high accuracies can be obtained for approximately AUD 550 per axle group. These are hardware costs only.

component fails a verification test, the system must be recalibrated, but **at least once every 6 months** as a minimum.

5.4 Cost developments

Costs for equipping heavy vehicles on a mandatory basis with on-board weighing solutions for screening will include costs for:

- Hardware, including sensors, vehicle unit, interconnecting internal harness
- Installation costs, including initial calibration
- Integration costs, including special components for secure and authenticated communication, tamper resistance, integration with other components (e.g. DSRC module of Digital Tachograph), etc.
- Recalibration costs

Hardware and installation costs

The **cost ceiling** for hardware and installation costs is comparable to the numbers given for current APT and strain gauge solutions (today in the **range between EUR 600 and 2'000**). Load cell based systems would be more accurate (if calibrated properly) but also much more expensive. But giving the higher costs such systems seem not to be the appropriate solution for providing the screening functionality, where accuracies between 5-10% are needed.

APT and strain gauge sensors can be seen as equal candidates. Moreover, **one approach does not exclude the other**. Both sensor types could be used on the same vehicle (e.g. APT sensor at the rear axle with air suspension and strain gauge sensor at the front axle with a leaf spring). Their accuracy characteristics are approximately equal. All in all it is **a question of calibrating them properly**.

Today, APT sensors are used in far greater numbers than strain gauge sensors. Up to now, they have been considered more practicable, due to a relatively easy installation, and more durable. However, accuracy stability of APT sensors would need frequent re-calibration. Strain gauge sensors have to be glued onto an existing structure and it is known that such organic material decomposes over time. Latest developments from sensor suppliers show that there are solutions already on the market, where the strain gauge sensors are integrated into an existing structure. The stability is considered to be better, since no organic material is used. This of course has a positive influence on the accuracy stability. As a consequence, a same re-calibration cycle of two years as for the Digital Tachograph is possible.

Costs of a product generally **decrease over time** as a function of economies of scale, learning effects and innovations in product and production methods. In case of a **mandatory** introduction, the costs of on-board weighing solutions are expected to go down due to the **higher market penetration**.

For **APT solutions little learning effects** are foreseen, since this technology is already on the market and deployed for quite some time. The strain gauge technology is rather new, so here more learning effects – and thus price drops – are to be expected in case of a mandatory introduction of on-board weighing. Hence, on a **mass-market scale** the price would especially drop for strain gauge approaches, whereby further developments of strain gauge sensors could further reduce the price.⁴⁷

Vehicle manufacturers will be able to **choose which solution** they offer depending on these market developments and customer demands. Having different sensor types on the market also means that

⁴⁷ Private communication by industrial player via email in Nov 2013

mandating on-board weighing systems would **not give rise to a monopoly**, but ensure a fair competition between different manufacturers. This is particularly advantageous in the further development of the technology towards even more accurate and reliable systems.

A clear **distinction must be drawn between installation within new vehicles and retrofitting** vehicles already in use. The catalogue price by vehicle manufacturers reflects the approximate costs for sensors, vehicle unit, cabling and installation within new vehicles. Retrofitting vehicles would likely stay within the scope of today's offerings in the field of weighing solutions, simply because it is a time-consuming process. The labour costs are more dominant than the hardware costs.

It can reasonably be expected that especially the costs for new installations would go further down compared to the prices offered today for optional on-board weighing solutions. This heavily **depends on the integration with other telematic systems** (e.g. Digital Tachograph). It might just as well be that vehicle manufacturers see the profit margin by providing value added services (e.g. enhanced fleet management applications) and would cover the expenses.

An **ultimate price cannot be predicted with any certainty**. For sure, the hardware and installation costs will be below EUR 1'000 as it is already the case today. After-market installation is costly and difficult to tamper-proof. With mandatory equipment, inline fitting during manufacture would become the rule and, especially when the synergies with the Digital Tachograph are fully exploited, costs for the hardware alone may come down to around EUR 500.⁴⁸

Integration and recalibration costs

The hardware and installation costs represent only a part of the total costs of equipping vehicles on a mandatory basis with on-board weighing solutions.

On the one hand, **uncertainty comes with the need for new components**, which are not yet included in current on-board weighing solutions.

Consider for example the **DSRC module** needed for the screening functionality to communicate the weight measurement from the truck to the enforcement officers. Note that the enforcement equipment (e.g. hand-held devices) should be included in the overall investment costs as well. The Member States have to equip their enforcement officers with DSRC communication tools. These costs will likely be shared with the communication tool of the Digital Tachograph, as this device can handle both at the same time (see also section 6.2).

Other new components relate to provisions for **secure and authenticated communication** and the **tamper resistance** of the on-board weighing solution. In future, an integration of on-board weighing devices with braking systems, such as ABS, may be possible (see Annex 4), which could influence costs.

On the other hand, **uncertainty comes with the recalibration**. While for example for the Digital Tachograph the vehicle has to be placed on a rolling road to calibrate the speed, traditional on-board weighing calibration is nowadays performed by actually loading the vehicle.

Every certified workshop demands a different price for recalibration the Digital Tachograph. Placing a vehicle on a testing platform is in the order of magnitude between EUR 50 and 200. Loading a vehicle with different certified weight blocks is a considerably **more complex procedure**. The calibration of a vehicle equipped with load cells costs around EUR 2'000 and can be seen as an upper limit. Though, this is for a system where very high accuracy ($\pm 100\text{kg}$) is required and the vehicle has to be

⁴⁸ Two industrial player stated this fact in Dec 2013 via email and on phone

calibrated by gradual increase of the weights. For systems where accuracies of $\pm 10\%$ are foreseen (as it is required for screening functionality) costs could be reduced. Under certain circumstances two measurements (zero point reference and registered payload weight) could be sufficient.

While administrative procedures for calibrating are the same for both the Digital Tachograph and on-board weighing systems, the actual execution methods vary significantly. **Practical procedures have to be developed** in order to reduce the workload and thus the costs of the calibration process. Therefore, the clarification of costs cannot be evaluated conclusively.

The lead time will have limited influence on the costs, if any. One could argue that the more time is left for finding optimal calibration methods, the more cost-effective they could be designed. Over a period of time every process can be optimised. The same is true for hardware production and installation procedures. But this should be rather considered as potential improvements and not brought into the discussion of finding the appropriate lead time, which should only be dependent on deployment processes (e.g. legislative process, interoperability tests and type approval certificates).

5.5 Costs for enforcement readers

Costs for road-side readers, whether gantry, portable tripod or vehicle mounted are around **a few thousand Euros a piece**. It can be expected that only low volumes will be ordered and therefore the mere equipment price tells little about the total price, which will be dominated by other project and engineering costs.

Readers are not standard catalogue items but usually procured as parts of a larger system. Hence, single unit prices are not easily available. From prices quoted in recent EFC system procurements and especially from maintenance contracts for such systems with lists for spare parts, it can be estimated that a bare beacon head for will cost between € 3 000 to € 5 000 in low volumes, irrespective whether it is for gantry, portable tripod or on-roof mounting. To this costs for communication and signalling components have to be added, plus the appropriate housing and mounting components. All in all this might double the price, especially if also some software development needs to be done. At the roadside, there is more potential for **synergies with other DSRC applications**. High numbers of DSRC gantries have been deployed for tolling purposes. In principle, it would be comparatively easy to upgrade their software and add an application for Tachograph and on-board weighing data readout. Obstacles can be seen on the institutional side, since governance over these installations lies with different institutions, and not with the police, road inspectorate or similar. Also, some adaptations are required, e.g. regarding signalling the results to the control personnel downstream.

Potential synergies between on-board weighing, the Tachograph application and tolling enforcement stations are especially interesting. Such stations are equipped with classification devices (typically laser scanners), with DSRC beacons and with video cameras, see Figure 8 for an example. Three laser scanners for vehicle classification and four DSRC beacons are visible on the front gantry. The rear gantry carries four video cameras plus flashes to capture licence plates. Such an installation would be perfectly suitable for simultaneously checking the Tachograph as well as on-board weighing system. This rich information would **enable very comprehensive checks of heavy vehicle compliance**.⁴⁹

⁴⁹ Cited from the EU Publication: Possible Application of Short Range Communication Technologies in the Digital Tachograph System to Support Vehicles Filtering during Road Controls; Rapp Trans 2011.



Figure 7: Station used for enforcement in tolling.

Conclusion on cost estimates

Most vehicle manufacturers nowadays offer a relatively **low-cost** on-board weighing solution based on **APT sensors**. The sensor industry is able to also offer other solutions. Especially on-board weighing solutions based on the **strain gauge sensor** technology seem to offer an **attractive prospective**.

An **ultimate price cannot be predicted with any certainty**. For sure, the hardware and installation costs of a mandatory on-board weighing solution will be below **EUR 1'000** and might approach the EUR 500 region with inline fitment in mass production. However, these costs represent only a **part of the total costs** of equipping vehicles on a mandatory basis with on-board weighing solutions.

Some **uncertainty comes with the need for new components**, which are not yet included in current on-board weighing solutions, such as a DSRC module or components needed for secure and authenticated communication, and the tamper resistance of the on-board weighing solution. Such costs can be minimal if synergies with the Digital Tachograph are being utilized.

On the other hand, **uncertainty comes with the recalibration**, which is time and labour consuming and for which practical procedures have to be developed, if possible in line with currently existing procedures for the digital tachograph.

6 Implementation issues of on-board weighing

6.1 Open in-vehicle platform

An **open in-vehicle platform** seems indispensable to ensure **interoperability** and **continuity** of in-vehicle applications, such as a mandatory on-board weighing solution for enforcement purposes.

Regulatory applications, such as the European Electronic Tolling Service (EETS) and the Digital Tachograph, but possibly also On-Board Weighing, are the most demanding ones regarding interoperability, certification and security. Due to their mandatory nature they can well define **the core of an open in-vehicle platform architecture**. The regulator enjoys large powers and can set the stage. Yet the size of the market of commercial applications is much larger and commercial freight and fleet management applications are decisive for the success of an open in-vehicle platform concept. On this market, the services branches of the vehicle manufacturers and third party service providers compete.

In a study commissioned by the European Commission within the framework of Specific Action 4.1 of the ITS Action Plan⁵⁰, Rapp Trans has recommended steps towards establishing a truly open in-vehicle platform architecture for the provision of ITS services in heavy vehicles. The **core idea** of an open in-vehicle platform is to create an environment where service providers can **access resources** existing in the vehicle and plug into them in some controlled way in order to provide a wide range of freight and fleet management related services. There should be **free and unhindered competition** on the services market for the benefit of the consumer (i.e. the transport company).

Several **recommendations** were proposed for concrete actions that the European Commission should undertake to **facilitate development and realisation** of a truly open in-vehicle platform architecture for heavy vehicles and to **support open and competitive markets** for road transport related telematics services. The recommendations stress, among others, actions to:

- create open access to in-vehicle resources,
- clarify ownership of vehicle data,
- ensure the absence of hindrance for coexisting applications.

6.2 Synergies with the Digital Tachograph

On-board weighing solutions appear to have similarities to the Digital Tachograph. Not only regarding **technical** aspects, e.g. when equipped with a DSRC interface for external readouts by enforcement officers, but also regarding the total process including **organisational** and **political aspects**.

Moreover, **synergies** with the Digital Tachograph are **well-conceivable**, e.g. when embedding the processing unit of an on-board weighing solution into the Digital Tachograph. To this end, first a short introduction into the Digital Tachograph is given below.

The **Digital Tachograph** is a regulatory instrument recording the work and rest hours of drivers for checking compliance with social regulations in road transport. Its specification is laid down in an annex of Council Regulation (EEC) No 3821/85.

⁵⁰ Rapp Trans (2013) Open in-vehicle platform concepts for the provision of ITS services and applications in heavy vehicles, Final Report, ITS Action Plan – Action 4.1, Framework Service Contract TREN/G4/FV-2008/475/01

The European Commission has proposed a **revision** to the Regulation. The amended regulation is now fully agreed and is short for being formally accepted.⁵¹ It introduces a number of fundamental **enhancements** of the functions of the Tachograph:

- a GNSS receiver to record some points of the trip (Article 8)
- a DSRC interface to assist road-side checks (Article 9)
- an ITS-interface to allow third party applications to receive data from the Tachograph (Article 10)

It is important to notice that in the revised Regulation the Parliament explicitly asks the Commission **to consider the inclusion of weight sensors in heavy goods vehicles**, and to assess the potential for weight sensors to contribute to an improved compliance of road transport legislation.

The detailed technical specifications of the "smart tachograph" will be polished as a new annex to the revised tachograph regulation. These specifications are currently prepared by a working group under the auspices of the European Commission Joint Research Centre.

Technical synergies between Digital Tachographs and on-board weighing solutions

Ideally, for accurate weight measurements, the vehicle should be **stationary** without applying any brakes. The Digital Tachograph is the instrument "par excellence" for recording work and rest hours and thus for identifying when the vehicle is stationary – and perhaps is being loaded or unloaded.

Integrated with an on-board weighing solution, this would mean that the final weight value could be stored from the moment the **ignition** is being turned on – and the Digital Tachograph is starting to count the work hours. On the other hand, the Digital Tachograph could start counting the working hours at the moment when the on-board weighing system recognises a specific change in weight loaded. This would allow for seeing the loading time as driving time.

Weight values will be subject to tampering attempts if these data could be used for compliance monitoring and enforcement of certain regulations, such as maximum permissible axle load or cabotage. The Digital Tachograph stores data in an **internal memory** which is protected against tampering. Weight values could be stored in the Digital Tachograph memory, utilising the same mechanisms to protect the weight data **against falsification**.

Technical values from the weight sensors must be transferred to the processing unit and Human Machine Interface (HMI) of the on-board weighing solution. Using the in-vehicle tractor and trailer **CAN network is one option to transfer these data**. Digital Tachographs are connected to the CAN network of the vehicle, thus they can receive weight values via CAN.

Actual **weight information should be visible to the driver** allowing to take appropriate actions (e.g. refusing to drive, if his truck was overloaded). Weight values could be shown to the driver at the Digital Tachograph display and printed via the integrated printer i.e. for enforcement purposes. Any Digital Tachograph must be installed in such a way that the driver can handle the device in a seating position from the drivers' seat, thus the same could apply to the visual indication of weight values.

⁵¹ 2011/0196 (COD): Position of the Council at first reading with a view to the adoption of a Regulation of the European Parliament and of the Council on tachographs in road transport, repealing Council Regulation (EEC) No 3821/85 on recording equipment in road transport and amending Regulation (EC) No 561/2006 of the European Parliament and the Council on the harmonisation of certain social legislation relating to road transport - Adopted by the Council on 15 November 2013

Moreover, using the **DSRC interface** of the Digital Tachograph would allow making available this weight info for wireless external readouts by enforcement officers and not introducing a second communication module.

Current and historical weight values should probably not be accessible to everyone. The Digital Tachograph allows for **protection of weight information against unauthorised access**. Specific access rights can be granted to authorities, vehicle owners or transport companies, drivers or to workshops using the same access control mechanisms as for the protection of driver related data.

Conclusion: The “smart tachograph” offers the potential for processing, recording and visualisation of weight values which are provided by external sensors at low cost, thus **making separate units obsolete. Enhancing the Digital Tachograph** as to become the recording unit of an on-board weighing solution would additionally allow for improved resistance against tampering, access right controls and remote wireless enforcement.

Organisational synergies between digital tachograph and on-board weighing

The regulator may prefer that on-board weighing solutions for compliance monitoring should be installed and maintained only in **trusted workshops**. This is likely to be a prerequisite for the acceptance of weight values which are provided to enforcement authorities. The competent Member State authorities may utilise the same procedure for the authorisation of workshops that are currently in place for the Digital Tachograph and the road speed limiter.

Supervision of authorised workshops and their staff is within the **responsibility of Member State authorities** and already established for Digital Tachographs. The same procedures may also be utilised for the supervision of workshops which are installing, calibrating and checking on-board weighing solutions.

Depending on the required accuracy level, on-board weighing solutions may need to be individually calibrated to each vehicle, similar to the calibration of Digital Tachographs. These calibration tools may be upgraded to allow for the additional calibration of weighing sensors. A periodical re-calibration of the on-board weighing solution is necessary in order to maintain the required accuracy. The regulator may therefore encourage or mandate a periodical check of a proper functioning and calibration. The same requirement applies to Digital Tachographs, which are **checked at least every two years**. Both checks can be **combined** in order to minimise the administrative burden for the transport company. However, legal requirements for the calibration and re-calibration of on-board weighing solutions are likely to increase costs, mainly due to complex system design, type approval requirements and calibration procedures.

A secure data transmission between weight sensor and recording/display unit using **data encryption technology** might be required in order to prevent weight information from being tampered with false data. Digital tachographs already use those technologies in order to protect the communication between motion sensor and recording unit. The same **public/private key infrastructure** (PKI) may also be used for on-board weighing solutions.

Sealing of the connection between weight sensor and the vehicle may be required in order to prevent weight sensors from being detached from the vehicle. There are attempts to **standardise seals** for the Digital Tachograph. Those seals might also be adaptable for weight sensors. Even the same logistic procedures for the distribution of those seals could be used.

6.3 ITS Interface

In case on-board weighing systems become mandatory, the associated recording equipment (i.e. vehicle unit) has to be prescribed and specified in a Council Regulation. The specifications can be compared to the regulations in place for the installation and application of the Digital Tachograph.

Besides defining the technical design, an **agreement on the data** must be found. On the one hand, it should be clear what data are **recorded** and at which intervals. Storing just the raw sensor data would of course be useless. The weight data must be enriched by at least the time. Furthermore, certain events or status information must be captured (e.g. "vehicle overloaded", "vehicle being loaded", "empty trip").

On the other hand, decisions are required what data are **made available** to both the driver and the enforcers. It is proposed that road side installations and hand held devices can interrogate the on-board weighing system in passing vehicles with short range communication technology (i.e. CEN DSRC) and obtain a set of data that would allow the control personnel to judge whether or not it wants to stop and inspect the vehicle. But also the driver should have at least the information about the current status broadcasted and displayed in the vehicle.

In addition, there is likely a demand in providing certain data as some sort of value added information to independent telematics applications. The major European truck manufacturers have developed the so-called FMS-standard in 2002. The **Fleet Management Systems interface** (FMS-interface) is an optional interface of different truck manufacturers.

For example, the Digital Tachograph broadcasts the following status information at the FMS-interface (not exhaustive)⁵²:

- Indication whether motion of the vehicle is detected
- Indication whether the vehicle is exceeding the legal speed limit
- Indication whether the driver approaches or exceeds working time limits
- Tachograph performance (e.g. sensor availability)
- Vehicle speed

Note that the status information provided at the FMS-interface has nothing to do with accessing the recorded data stored in the Digital Tachograph. Although data transfer is possible over the same bus nowadays, an authentication process is required for accessing the recorded data while the status information broadcasted is readable without any security mechanisms. These technical capabilities do fully comply with the regulation.

A comparable approach is conceivable for an on-board weighing system. A **distinction** could be drawn between **authenticated access** to on-board weighing system data and **broadcasted status information**. Enforcers would need to have access to the raw data enriched with time information, which would only be possible via an encrypted communication channel. Other telematics applications would only be able to make use of the status information.

It should be noted at this point that it is not recommended that the on-board weighing system itself takes part in the screening functionality and decides via some logic whether to communicate "everything is OK" or "I have some indication for infringements". This decision is best left to controllers in a similar way as today, only that the data are made available already from the moving vehicle, avoiding the need to stop them if controllers decide that this is unneeded. Controllers are better off if they are **supplied with a set of data**. They might well decide to focus on a certain severity of infringement on one day (e.g. <2% overloaded) and on another type on another day

⁵² FMS-Standard description, Version 03, 14.09.2012 (available on: <http://bus-fms-standard.com>). The technical protocol and procedures have been standardised and specified in Annex 1B to Regulation (ECC) n°3821/85.

(>10% overloaded). Data on the **fact that a control has taken place** might be written back to the vehicle unit as well.

Moreover it seems important to underline that fair access to such data needs to be provided (if any). To give an example, the FMS interface and connector is currently not a standard item in all truck brands and sometimes comes as a comparatively costly option, which might kick third parties out of the market. It is therefore recommended to create appropriate legal provisions such that **in-vehicle resources** like vehicle and movement data, communication channels and HMI devices are **openly accessible via a standardised and mandatory interface** ("ITS connector") and free of charge to any third party, given the consent of the vehicle owner and the driver.⁵³

6.4 Timing of mandating on-board weighing sensors

Which vehicle categories

Before going into more detail on the timing of mandating on-board weighing sensors, it would be good to discuss **for which vehicle categories** this mandate would apply.

As an example, the Digital Tachograph is mandatory of vehicles falling within category M2, M3, N2 or N3 (according to Directive 70/156/EEC), see Table 3.

M	Power-driven vehicles having at least four wheels and used for the carriage of passengers
M1	Vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat.
M2	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tonnes.
M3	Vehicles used for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes.
N	Power-driven vehicles having at least four wheels and used for the carriage of goods
N1	Vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes.
N2	Vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes.
N3	Vehicles used for the carriage of goods and having a maximum mass exceeding 12 tonnes.

Table 3: UNECE vehicle categories M and N

Assuming a mandatory on-board weighing solution for vehicles falling within category N (i.e. motor vehicles with at least four wheels designed and constructed for the carriage of goods), Figure 8 shows the newly registered commercial vehicles of category N in Europe between January and September 2013⁵⁴. It can be seen that **N1 vehicles** (< 3.5 t) have the **greatest share** in the registration of all commercial vehicles. From January to September 2013, 52'497 N2 (between 3.5 t and 12 t) and 156'786 N3 (above 12 t) vehicles have been newly registered in Europe (EU27 and EFTA countries). In the same time 1'049'599 N1 vehicles were registered, which corresponds to 83 % of all commercial vehicles).

⁵³ ITS Action Plan – Open in-vehicle platform concepts for the provision of ITS services and applications in heavy vehicles. Rapp Trans

⁵⁴ http://www.acea.be/images/uploads/files/20131029_PRCV-1309-FINAL.pdf

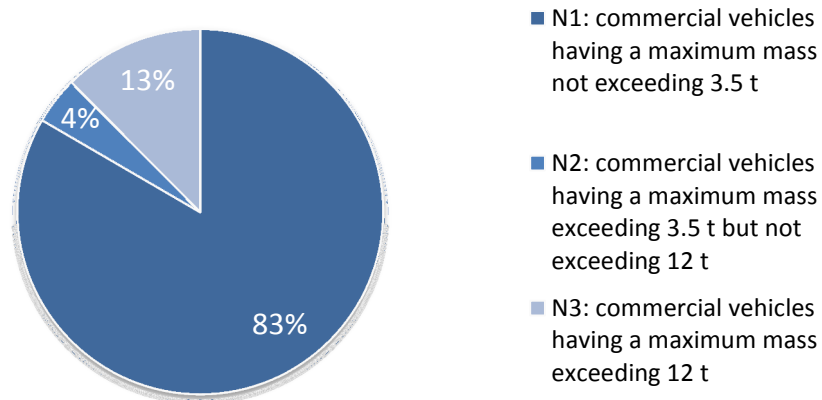


Figure 8: Newly registered commercial vehicles in Europe (EU27 + EFTA) Jan-Sep 2013

It is known that especially N1 vehicles are **often overloaded** due to fierce competition in this sort of environment (fine distribution of goods on city level). Similar to the N2 and N3 vehicles, N1 vehicles make a negative contribution to **traffic safety** and **traffic flow**, because they become under-powered which results in lower speeds on up-hill slopes as well as the risk of congestion, inefficient engine braking and speeding on down-hill slopes. They are also less stable because the braking efficiency is decreasing.

However, due to the **smaller axle loads** and the **smaller kilometre performance** of N1 vehicles compared to N2 or N3 vehicles, the negative impacts of overloaded N1 vehicles are comparatively smaller than those concerning N2 or N3 vehicles.

In addition, a quite different issue would arise, if N1 vehicles would be included in a mandated on-board weighing systems scheme. The high number of N1 would cause problems related to the **organisational aspects** of the cyclical recalibration process.

Hence, for a mandatory on-board weighing system both from an impact perspective and an organisational perspective **vehicle categories N2 and N3 are the most interesting ones**. They often operate in the international transport on trans-European corridors and travel long distances. Compared to light commercial vehicles of the N1 class (below 3.5 t) their axle load is much higher (3.5 t split on two axles gives 1.75 t per axle while 40 t split on 5 axles gives 8 t per axle). Moreover, these categories are more manageable " and used to conform to certain regulations.

Introduction of Digital Tachograph as example

The introduction of the **Digital Tachograph** as a mandatory device (from 1 May 2006 onwards) serves as a **good example** of what is needed to become effective – from the adoption of an agreement between Member States until the new compulsory device is actually there.

National transport authorities from European and non-EU countries having a responsibility and interest in the field of road transport, road security and road safety need to have **a good understanding** of the benefits of such on-board weighing systems. Only if this is guaranteed the next objectives to encourage, promote and assist the development and implementation of the corresponding policies at international level can be addressed.

But with having the laws, the **deployment process** is not over yet. The following technical activities to fulfil the requirements described in the corresponding policies are further required:

- Carrying out interoperability tests
- Issuing interoperability certificates
- Providing type-approval certificates

For the Digital Tachograph these tasks are carried out by the European Commission through the **Joint Research Centre** (JRC) of Ispra (Varese, Italy).

To get a feeling about a time horizon for implementing a mandatory on-board weighing system, the new “smart tachograph” serves as a good example. It will become **mandatory 40 months after the technical specifications have been established** in 2017/18, which results in a timescale of 2021 or beyond before it will be implemented.

6.5 Compatibility of OBW and WIM

Current WIM systems are part of **national WIM networks**. They comprise **national, individual systems**. Directive 96/53/EC is focused on **international traffic** and OBW is seen as the best approach to improve the effectiveness in compliance checking. It would also support countries, which not yet have an extensive WIM network.

However, that does not mean that WIM networks will turn meaningless. On the contrary, **WIM networks stay very important** as part of the national enforcement processes, especially for **screening N1 vehicles** (mostly in use for national transport), since OBW would only be introduced for N2 and N3 vehicles. In the end, the holistic approach will be an **enforcement mix** of WIM and OBW, as there seem to be **added value in applying both**.

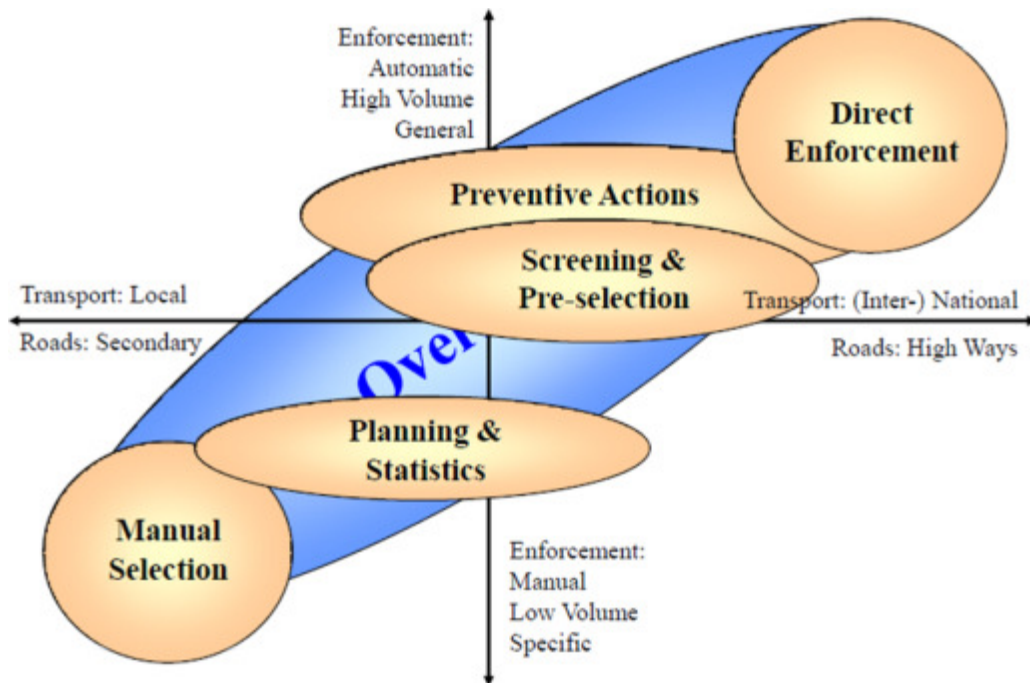


Figure 9: Enforcement mix in Europe's weight monitoring today.⁵⁵

⁵⁵ Van Loo, H. & Jacob, B. (2013) Weigh-in-Motion for Enforcement in Europe, presentation for Workshop on WIM for Enforcement, 28 February 2013 (<http://iswim.free.fr>)

While WIM by itself leads to efficient controls with hit rates above 95% it has its drawback in being bound to local position. The consequences could be the evasion of WIM systems. The OBW approach would solve this issue. Screening and pre-selecting of overloaded vehicles would be possible on all roads. In addition, OBW will help transport companies to know if they are infringing the regulations or not, and what the consequences might be.

Present WIM stations could also be used to verify the weight detected by the OBW system. This **redundancy would certainly increase the significance of the calibration** methods. If the values are diverging, this is a good indication that either the calibration is outdated or the OBW system has been manipulated.

Conclusion on implementation issues of on-board weighing

Today, **technical solutions exist** for all vehicle types. It is a matter of finding a **harmonised calibration** and **certification regime** across Europe.

The “smart tachograph” offers the potential for processing, recording and visualisation of weight values which are provided by external sensors at low cost. **Enhancing the Digital Tachograph** as to become the recording unit of an on-board weighing solution would additionally allow for improved resistance against tampering, access right controls and remote wireless enforcement. In addition the re-calibration cycles of two years could be use further allowing for an alignment of the administrative processes.

The “smart tachograph” will become mandatory 40 months after the technical specifications have been established in 2017/18, which results in **a timescale of 2021** or beyond before it will be implemented. A mandatory on-board weighing solution could be introduced within the same timescale for the vehicle categories N2 and N3.

OBW would then add to the **enforcement mix** of WIM allowing Member States to solve today’s problem that the a weigh-in-motion system cannot be moved to another place once installed.

The creation of appropriate legal provisions such that **in-vehicle resources** like vehicle and movement data, communication channels and HMI devices are **openly accessible** via a standardised and mandatory interface (“ITS connector”) and free of charge to any third party (given the consent of the vehicle owner and the driver) are recommended.

7 Conclusions and recommendations

7.1 Reasonable solution

As outlined in this study, the question for mandating an on-board weighing system is about finding the **optimal balance between accuracy, reliability, practicality and costs**. Moreover, a reasonable solution should be acceptable for different stakeholders, mainly the public authorities, transport companies, vehicle manufacturers, suppliers and of course the driver.

The main reason to better detect infringements is to counteract all sorts of negative issues that arise with overloading, such as road safety, road degradation, environment and competition. Today, weight compliance checks are cumbersome and **the risk to be caught with an overloaded vehicle is currently too low**. Regulatory instruments like permanent weigh-in-motion installations or on-board weighing systems would allow the filtering of suspicious vehicles and support the control personnel.

In order to cover the increasing global reach of European responsibilities to better enforce the weight rules and to reduce the number of overloaded trucks, being able to **measure the weight and access this information at any time, at any location is almost a necessity**.

The latest amendment to the weight and dimensions Directive 96/53/EC brings this problem to the attention of the public and the authorities. The discussion is mainly about the preferred **pre-selection solution**: Will such functionality be ensured via on-board weighing (OBW) or weigh-in-motion (WIM) systems?

One big drawback of WIM systems is the fact that the checking locations would be restricted. A **weigh-in-motion system cannot be moved** to another place once installed. Likewise WIM cannot be used to measure weight as court proof evidence, simply because the accuracy is not yet good enough. This results in the remaining need to identify vehicles that are likely to have committed an offence and that should be checked manually by putting it onto some certified weighing device under closely controlled conditions. Hence, a fully automated weight checking process comparable to that of speed cameras is not deemed feasible in the near future.

Using OBW systems would serve the screening purpose as well and the area, where measures are implemented, would not be restricted. Moreover, such a new approach would **pave the way for additional services, be they of a regulated or private nature**, e.g. upcoming requirements in the transport environment (e.g. mandatory verification of gross weight of containers prior to loading on a ship, or commercial fleet and freight management systems).

There are many similarities between on-board weighing (OBW) and weigh-in-motion (WIM) solutions. In the end, both technologies measure heavy vehicle mass (or weight) without stopping the vehicle and hence reduce the inefficiency in compliance checking. However, compared to WIM, OBW has some unique aspects:

- OBW can provide mass monitoring regardless of the vehicle location
- OBW stays with the vehicle, hence tamper monitoring is required for regulatory use
- Calibration of OBW needs to be regularly verified; the period of verification typically varies from 12 to 36 months depending on the operating environment and the desired accuracy.

7.2 Required accuracy needs

Technical solutions for measuring weighing on-board exist for all vehicle types. The accuracy depends on different variables like for example sensor quality and calibration process. A highly accurate system and, hence, high costs are not necessarily required, if the approach is pre-selection for enforcement.

The COST 323 initiative serves as good reference (see Annex 2) for finding the answer about the accuracy needs. It defines WIM for screening functionality according to accuracy **class B+(7) or B(10)**, which means $\pm 10\%$ (or better).

Generally, the following accuracy levels are expected to be feasible in combination with the respective calibration procedures:

- Assuming a **10% accuracy level** which allows for **pre-selection** for enforcement (i.e. according to COST 323 accuracy class B+(7) or B(10)) would mean an accuracy check or recalibration at least **every two years** (similar to the checks of the Digital Tachograph, see also section 6.2).
- Assuming a **5% accuracy level** which allows for **pre-selection** for enforcement and **direct enforcement** (i.e. according to COST 323 accuracy class A(5)) would mean an accuracy check or recalibration at least **once or twice per year**.
- Assuming a **1-2% accuracy level** which allows for **direct enforcement** would mean an accuracy check or recalibration at least **every 3-6 months**. For example, the IAPm program in Australia requires such high accuracy level. Here recalibration is performed on an "as needed" basis (where a vehicle or component fails a verification test, the device must be recalibrated) with a minimum of at least once every 6 months⁵⁶.

7.3 Costs

Most vehicle manufacturers nowadays offer a relatively low-cost on-board weighing solution based on APT sensors. In addition, the sensor industry solutions based on the strain gauge sensor technology seem to offer an attractive prospective. From a technological point of view, on-board weighing systems for providing the screening functionality (accuracy levels below $\pm 10\%$) come at reasonable costs below EUR 1'000.- per vehicle and might come into the EUR 500 cost region when the regime is introduced on a mandatory basis, meaning that OWB systems are line-fitted during standard series production.

The **uncertainty comes with the calibration**. Organisational procedures which stem from the Digital Tachograph could be used as well for on-board weighing systems (e.g. same workshops, same calibration cycles, etc.). However, practical procedures have to be developed in order to reduce the workload and thus the costs of the actual calibration process. These procedures could be integrated in the existing procedures for the digital tachograph.

⁵⁶ Based on information provided by Peter Girgis, General Manager Operations, Project Director Electronic Work Diaries, Transport Certification Australia (TCA)

8 Abbreviations

APT	Air Pressure Transducer
CAN	Controller Area Network
CEN	European Committee for Standardization
DSRC	Dedicated Short-Range Communication
EETS	European Electronic Tolling Service
GNSS	Global Navigation Satellite System (such as GPS or GALILEO)
GVW	Gross Vehicle Weight
HMI	Human to Machine Interface
IAP	Intelligent Access Program
ISO	International Standards Organisation
ITS	Intelligent Transport Systems
OBW	On-board Weighing
WIM	Weigh in Motion

9 Contributing stakeholders

We are grateful for the input received by (in alphabetic order)

Continental AG

DAF

Daimler

DIGI SENS AG

Iveco

MAN

Mercedes

SCANIA

Sense-Tech Weighing Systems ApS

Transport Certification Australia

Vlastuin

Volvo

Annex 1: Approaches towards on-board weighing

On-board weighing could contribute to improved weight compliance in road transport in various ways. **Four basically different approaches** are conceivable:

5. In-vehicle weight display for drivers
6. Voluntary active demonstration of weight compliance
7. Mandatory on-board weighing for pre-screening
8. Mandatory on-board weighing for direct enforcement

The four approaches clearly differ in **effectiveness** and in the required equipment **accuracy** and **calibration**, but ultimately they differ in the **policy** pursued.

1. In-vehicle weight display for drivers

Weighing systems with axle weight sensors that report the readings to a data processing unit in the driver cabin and display it to the driver are an equipment option for heavy vehicles that is offered on many truck and trailer models. Such weighing systems are often used in transports where loading or axle weight distribution needs to be controlled.

Such on-board weighing systems **help the driver to be aware of overloading** in situations where the total mass of the transported goods is unknown, especially for bulk or loose material, such as gravel, sand, garbage, manure, wood and wood chips, etc. If the amendments of Directive 96/53/EC are adopted, also for containers, the transport company has joint liability with the shipper for correct weight declaration, which is important e.g. for correct weight distribution when delivering containers for shipping on waterways. In these applications, there is high interest of the transporter to have knowledge and control over the loaded weight.

While such on-board weighing installations support drivers in loading correctly, such voluntary, informative-only displays fall short of achieving the goal of avoiding overloading. It can be assumed that only companies that have a compliance culture anyway will install such systems. In this case the on-board weighing system assists them in correct weight distribution amongst the axles, in avoiding unintended overloading and in accounting for the transported mass for billing purposes. Companies that take competitive advantage by stretching the rules will not voluntarily equip themselves.

In-vehicle weight displays also are not in line with the intention expressed in COM(2013) 195, the proposed amendment to the weight and dimensions Directive 96/53/EC, which asks Member States to encourage equipping vehicles with on-board weighing systems to enable the weight data to be communicated from a moving vehicle to a controlling authority.

Therefore, **voluntary installation of in-vehicle weight displays for drivers will not improve weight compliance** compared with today and is not a recommended route to follow.

2. Voluntary active demonstration of weight compliance

Annex 3 of this report gives examples of voluntary schemes that go further than simply displaying weight to the driver. Both the Intelligent Access Program (IAP) in Australia and the PrePass system in the USA are voluntary schemes, where **vehicle operators are offered incentives to actively demonstrate compliance**. In both schemes, on-board weighing systems are installed on participating heavy vehicles and communicate the weight readings to the authorities. Companies thereby actively demonstrate their compliance to the rules and in return receive certain benefits. In the US PrePass system, the main benefit is that vehicles that communicate weight compliance via a

short-range radio link (DSRC) to road-side checking stations may pass such stations without being stopped – except for rare random sample checking. Otherwise vehicles would be led out to a special lane, to queue up for being checked. Usually this takes at least half an hour. In the US such checks frequently are set up at state borders. For an interstate truck the time savings by avoiding being stopped down may be very substantial, paying back the investment in the on-board weighing equipment and the monthly services fee rather quickly.

In Australia, weight compliance is one pillar of the wider Intelligent Access Program, where similar incentives are granted, such as better access to infrastructure. This may mean, e.g., that vehicles participating in the IAP scheme may use roads that they would otherwise not be allowed to use because of higher weight limits of the vehicle.

The weight measured by the on-board weighing system would be communicated via a DSRC to road-side stations and might be used for pre-filtering purposes in compliance checking campaigns. Like in the US PrePass system, one immediate benefit for the transporter would be that he usually can **bypass such checking stations** and gain productive time for the vehicle. Other benefits are conceivable: Road owners, especially private concessionaires, might offer lower toll tariffs for vehicles demonstrating weight compliance, since these vehicles will not excessively strain the road infrastructure. Such reductions are currently not foreseen in European legislation such as Directive 1999/62/EC⁵⁷ and its later amendments, but might be added in future revisions.

The benefit of being able to bypass road-side checks might not be high enough as an incentive since checks are rather infrequent. Hence some **additional encouraging measures** need to be introduced in order to promote take up of such a voluntary arrangement. For example, in Lyon (France), recently a strategic work plan has been discussed that foresees studying the possibility of **opening bus lanes** to heavy goods vehicles “with optimized load” in urban delivery⁵⁸ (see also Annex 2).

Naturally, such **self-declarations of weight need to be trust-worthy**. In essence this leads to the requirement that on-board weighing devices need to be properly **calibrated and certified by a recognised body**, including recalibration and recertification in regular intervals. Also, a certain minimum resistance against tampering would be required from the on-board weighing system. Accuracy requirements would not be overly high.

Such a scheme is **rather attractive in principle** and would be a policy that bears little risk of being attacked thanks to its voluntary nature. But first a situation as described above – increased compliance checking density (e.g. inspection facilities after each 100 km) or financial incentives (reduced toll charge) – would have to be generated that would increase the pressure on fleet managers to demonstrate compliance voluntarily. Only such changing circumstances and political priorities for handling overloaded vehicles would lead to an environment where an active demonstration of weight compliance could save drivers and their companies valuable time on the road, thereby reducing fuel and operating costs, while increasing productivity.

In practice, though, requirements on setting up a harmonised incentive scheme across Europe, in introducing a calibration and certification regime, crating interoperable specifications for the DSRC interface and for the on-board weighing system security measures are quite high and challenging to implement. Not to forget that a high number of weigh-in-motion (WIM) systems at many locations would need to be installed to reach a high compliance check density. Such systems cost around EUR 100'000 per site. The pay-back on the other hand would likely be limited since again only the “companies of good will”, i.e. the ones that are compliant anyway, would participate.

Considering the work and costs involved in setting up such a regime, the improvement in compliance might **not be worth the effort**.

⁵⁷ Directive 1999/62/EC of the European Parliament and of the Council of 17 June 1999 on the charging of heavy goods vehicles for the use of certain infrastructures

⁵⁸ In: Communauté urbaine de Lyon - Conseil de communauté du 18 février 2013 - Délibération n° 2013-3488

3. Mandatory on-board weighing for screening

As stated above, voluntary on-board weighing schemes will likely not reach the desired goal to generate a substantial reduction in overweight transports, at least not if there is no sufficient economic incentive for fleet managers to show compliance. A mandatory scheme certainly would.

The **requirements for the public authority to enforce the weight and dimension rules are increasing**. They must consider how to improve the overall goals they want to achieve, e.g. reduced maintenance costs for road infrastructure, reduced environmental impact from road transport, improved road safety, more efficient use of the road transport system.

This also has to cover the **increasing global reach** of European responsibilities. To give an example, a new regulation is set to be introduced to international shipping after the International Maritime Organization (IMO) member states voted in the amendment to its Safety of Life at Sea regulations that will make it mandatory for **containers to be weighed** or have their stated weight otherwise verified.⁵⁹ This could already be done on the container trailer itself.

Mandatory on-board weighing would be a new tool that could solve many needs. Reading out the current weight of a truck via some short-range communication would be an instrument that would support the enforcers in their daily work and would improve the filtering of suspicious vehicles.

At this point it is important to understand that, although the foreseen on-board weighing solution can be very accurate (within 5%), it would be used as an indication only. Enforcers would use this sort of **screening functionality** to flag down and stop the suspicious vehicles and guide them to the closest available certified weighing scale. A fully automated weight checking process comparable to that of speed cameras is not deemed feasible.

The same measurements could be obtained by increasing the existing weigh-in-motion systems. Since the costs per system are very high and the density would need to be at least tripled, the benefits for the Member States are limited, simply because the checking locations would be restricted. A weigh-in-motion system cannot be moved to another place once installed.

One big advantage of having the weight measurement inside every truck would give the enforcers the possibility to use hand-held device to **read out the weight information at any time, at any location** and outside organised campaigns. As soon as an officer sees a vehicle which looks suspicious to him, he can check the weight on the fly.

In order to implement a mandatory on-board weighing for screening the following requirements have to be met:

- Low cost equipment. As shown later, this is quite bearable and would come even down, if produced in mass.
- Calibrated and certified equipment.
- Standardised communication interface

Today, technical solutions exist for all vehicle types. It is a matter of **finding a harmonised calibration and certification regime** across Europe. The processes that exist for the installation and calibration of the Digital Tachograph can be considered as a starting point, since both systems are comparable in many ways. While in the case of the Digital Tachograph it is the pulse sensor that needs to be connected to some vehicle unit and tested, it would just be the weight sensor in case of an on-board weighing system. Both could be done by the same notified bodies. Even the calibration cycles could be exactly the same (i.e. every two years)

⁵⁹ <http://www.ecsa.eu/news-and-media/9-latest-news/70-mo-moves-to-make-container-weighing-mandatory>

The gist of the European Commission proposal expressed in **COM(2013)0195** is to better detect infringements related to overloading. The introduction of on-board weight systems that are able to communicate the weight data to the inspection authorities was first recommended only, but is now part of the latest proposed amendment to the weight and dimensions Directive ("*New N2 and N3 vehicles shall be fitted with onboard weighing devices (total weight and axle load) that enable the weight data to be communicated at any time from a moving vehicle to an authority carrying out roadside inspections or responsible for regulating the transport of goods. This communication shall be through the interface defined by the CEN DSRC standards EN 12253, EN 12795, EN 12834, EN 13372 and ISO 14906. The information shall also be accessible for the driver.*"⁶⁰).

On-board weighing for screening would be very beneficial for the checking process, and hence reducing overloaded vehicles on European roads and **should be considered mandatory**.

4. Mandatory on-board weighing for direct enforcement

As stated above, mandatory on-board weighing could be used for screening. Reading out the current weight of a truck via some short-range communication could improve the filtering of suspicious vehicles. However, a **fully automated weight checking process** would be ideal for achieving highly efficient controls of high traffic volumes.

For **legal purposes** such as direct enforcement of legal weight limits (e.g. fining on the spot), the **accuracy** of weighing solutions needs to be **very high**. In most European countries, the accuracy must lie within $\pm 5\%$ for 95% of vehicles checked. For WIM installations this corresponds to accuracy class A(5) of COST 323 (see Annex 2: COST 323). In general, it is a great **challenge** to use such WIM technologies for direct enforcement, because of this high accuracy requirement. In very few countries, such as Taiwan, WIM⁶¹ is used for direct enforcement with tolerances of up to 30%⁶².

It is evident that also **on-board weighing** solutions to be used for direct enforcement of overloading in Europe need to fulfil the high accuracy requirement. Although the accuracy claimed for current on-board weighing systems is rather high, the level attained in praxis is **not (yet) deemed sufficient** for direct enforcement.

Moreover, on-board weighing solutions for direct weight enforcement purposes have **more stringent requirements** than the systems that are used nowadays by fleet owners to manage freight operations. When used for weight enforcement purposes, such systems should:

- achieve **sufficient per-truck accuracy levels** to support pre-selection and enforcement of vehicle weight limits (in future perhaps even direct enforcement)
- provide **evidence of the vehicle identification** to be used by compliance officers
- be **certified** and **tamper proof** and fulfill certain **standards** and procedures (to be developed in Europe)

Mandatory on-board weighing for direct enforcement would enable a fully automated weight checking process, which could be regarded **an ideal future state**. This state, however, is not yet in reach due to several technical and organisational deficiencies that need to be solved first. Given the improving technology, the synergies with other approaches (i.e. Digital Tachograph) and the falling costs, this fourth approach could become an option **in the long run**.

⁶⁰ COM(2013)0195 – C7 0102/2013 – 2013/0105(COD)

⁶¹ The High speed (HS-) WIM variant, see also Section 3.3

⁶² Van Loo, H. & Jacob, B. (2013) Weigh-in-Motion for Enforcement in Europe, presentation for Workshop on WIM for Enforcement, 28 February 2013 (<http://iswim.free.fr>)

Annex 2: COST 323

COST 323 is one of the actions supported by the COST Transport part of the European Commission's Transport Directorate. Following a proposal of the FEHRL group (Forum of European Highway Research Laboratories 1999), COST 323 was initiated in 1992. Since 1993 it has been run by the Management Committee, a group of scientific and technical experts, **to promote the development and implementation of weigh-in-motion techniques and their applications**, and to facilitate an exchange of experiences between different European countries. COST 323 does not constitute an official standard but provides **technical specifications** for WIM users and manufacturers and a reference upon which standardisation committees can draw.

The main **objectives** of the COST 323 action are:

- complete an inventory of WIM requirements in Europe
- collect and evaluate existing WIM information
- undertake preliminary work on the development of a European technical specification on WIM
- agree mechanisms and protocols for a pan-European database of WIM sites and data
- collect and disseminate scientific and technical information
- exchange experiences and conclusions from other international projects.

COST 323 defines WIM systems by classes based on their **level of accuracy**. These classes are defined as follows, where the numbers in brackets indicate the confidence interval width:

- Class A(5): Legal purposes such as enforcement of legal weight limits.
- Class B+(7): Enforcement of legal weight limits in particular cases, if the Class A requirements may not be satisfied, and with a special agreement of the legal authorities; efficient pre-selection of overloaded axles or vehicles.
- Class B(10): Accurate knowledge of weights by axle groups, and gross weights, for: infrastructure (pavement and bridge) design, maintenance or evaluation, such as aggressiveness evaluation, fatigue damage and lifetime calculations, pre-selection of overloaded axles or vehicles, vehicle identification based on the loads.
- Class C(15) or D+(20): Detailed statistical studies, determination of load histograms with class width of one or two tonnes, and accurate classification of vehicles based on the loads; infrastructure studies and fatigue assessments.
- Class D(25): Weight indications required for statistical purposes, economical and technical studies, standard classification of vehicles according to wide weight classes (e.g. by 5 t).
- Additional Classes E(30), E(35), etc. are defined for WIM systems which do not meet the Class D(25) requirements. These classes may be useful to give indications about the traffic composition and the load distribution and frequency.

Annex 3: Examples of innovative weight compliance overseas

1. On-board mass (OBM) monitoring in Australia

The **Intelligent Access Program (IAP)** is a **voluntary** program which provides heavy vehicles with access or improved access to the Australian road network. In return, heavy vehicles enrolled in the IAP will be **monitored** by vehicle telematics solutions for compliance with specific access conditions (see also Figure 10). The IAP is administered by Transport Certification Australia (TCA), on behalf of the Australian Federal, State and Territory governments.

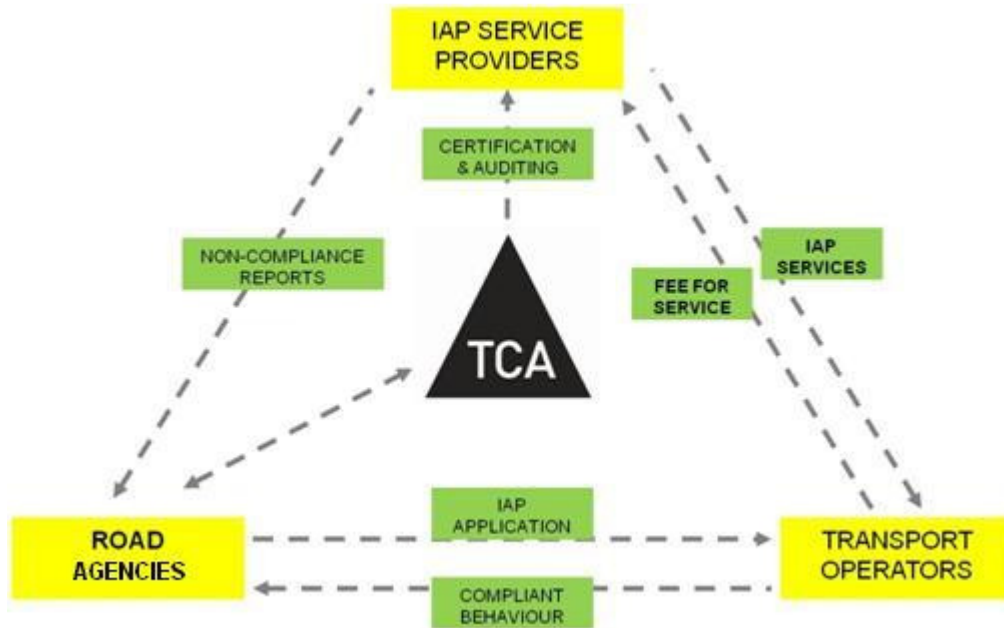


Figure 10: Monitoring of heavy vehicles within the Intelligent Access Program (IAP)

Within the IAP approach in Australia, **regulated applications** are deployed as **services**. The user wants to demonstrate the road authorities his compliance voluntarily through a service provider in return for clear benefits given by the road authorities.

The IAP service provider is required to monitor a vehicle operating under an IAP Application and report any non-compliant activity against the Intelligent Access Conditions (IAC) to the relevant road authority.

Currently, the IAP has the capability to monitor three parameters: route, time, speed and weight. Even though a vehicle is monitored continually, the road authority is only interested in data that demonstrates possible non-compliance.

The in-vehicle unit transmits data records to the IAP service provider on a regular basis (at least once per day) within a secure environment. The IAP service provider's system tests this incoming data for completeness, consistency and accuracy, raising the appropriate alarm when problems are detected.

TCA recently **extended** the IAP to include **mass monitoring** utilising on-board mass monitoring (OBM) systems. The integration leverages the same infrastructure and operating environment that jurisdictions have become familiar with in operating the other IAP access applications. TCA is working to achieve a **single national standard** for interoperability between existing in-vehicle units (IVUs) and OBM systems. This will allow vehicles enrolled in the IAP to interface with any **TCA Type-Approved™ OBM system**, meeting a pre-condition set by road agencies for provision of enhanced access to the road network.

OBM test report

In 2008 – in preparation of IAPm – TCA conducted a **test program** on commercially available OBM systems in Australia⁶³. The program received full support from the domestic OBM industry. A total of twelve OBM systems from eight suppliers were tested across five Australian States. Both air pressure transducers (APT) and load cell based systems were involved in the test.

In conclusion, the tests have found that the **commercial OBM systems** have **sufficient accuracy** for all types of regulatory applications in Australia. Tampering can be addressed via the use of dynamic data and therefore it is possible to specify an evidentiary standard OBM system. The development of such specifications is now underway by TCA.

With regard to the **European context**, the following considerations apply:

- All the systems tested showed accuracies within approximately ± 500 kgs, corresponding to $\pm 2\%$ of weighbridge for an axle group at full load condition. This reflects the focus on vehicle combinations of ~ 50 tons (timber, crushed rocks, ...) during the tests. For current goods transport in Europe, the **relative accuracy** will be somewhat **lower**.
- **Dynamic data** was also recorded for each test. "It was found that static measurements were more accurate than dynamic data. However dynamic data was found to be an important dataset for an OBM system as it provided additional information that could be useful as a quality indicator in an evidentiary OBM specification. As all OBM systems are able to generate dynamic data, this is clearly another source of information that can be DT."

2. PrePass system in the USA

PrePass is the **weigh station bypass system** in the majority of states in the USA. It enables participating transponder-equipped commercial vehicles to electronically comply with state safety, weight, and credential requirements. **Cleared vehicles** are allowed to bypass designated weigh stations, port-of-entry facilities and agricultural interdiction facilities. They may proceed at highway speed, eliminating the need to stop (see Figure 11). That means greater efficiency for shippers and improved safety for all highway users.

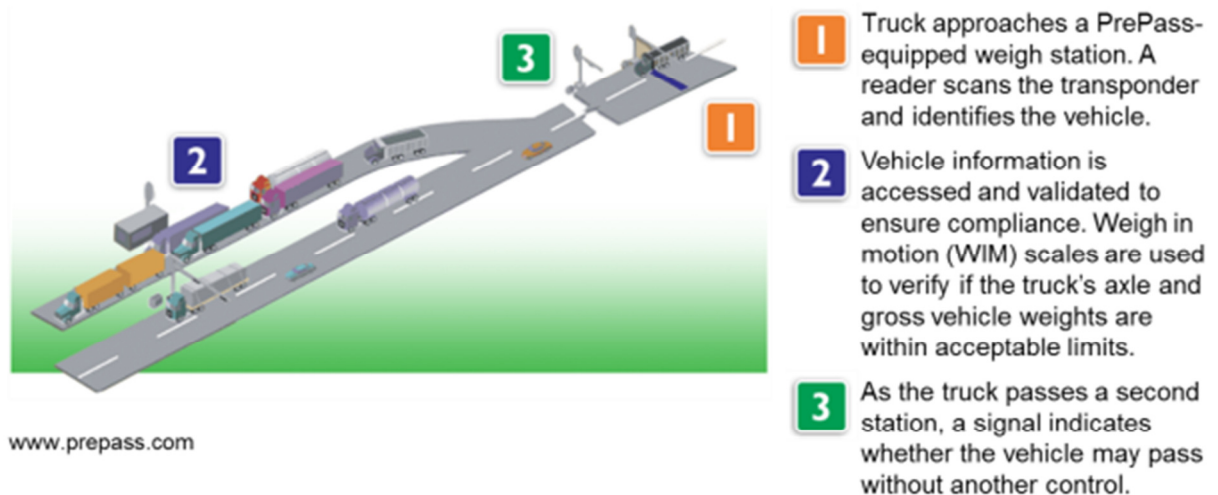


Figure 11: PrePass system in the USA

⁶³ On-Board Mass Monitoring Test Report (Final), May 2009, Transport Certification Australia

Recently the 5.9 GHz DSRC technology has been selected to power the next generation of PrePass transponders⁶⁴. The old generation consists of 915 MHz transponders. The 5.9 GHz technology has been selected by U.S. Department of Transportation as the technology standard for its Connected Vehicle Program.

Users need to **subscribe** to the PrePass Service and pay a monthly fee, but the PrePass transponders are provided free of charge. Vehicles participating in the PrePass program are **pre-certified**. Customers' safety records and credentials are routinely verified with state and federal agencies to ensure adherence to the safety and bypass criteria established by PrePass and member states.

3. Other potential weight compliance approaches

A potential approach of weight compliance in urban areas can be found in **Lyon**, France. Recently a strategic work plan has been discussed that foresees studying the possibility of **opening bus lanes** to heavy goods vehicles "with optimized load" in urban delivery⁶⁵.

For **weight enforcement**, a significant gain of security and efficiency could be reached if the pre-selection command ("Exit at next enforcement area") could be delivered to the driver cabin and displayed to the driver (e.g. see Figure 12).

Also relevant in this area are the developments in the transport of containers, where **mandatory container weighing** may be probable from 2016 onwards⁶⁶. Shippers could then be required to prove the actual weight of each container before loading it onto a ship. The revision of Directive 96/53/EC now foresees that if the shipper's statement indicating the weight of the container is missing or incorrect, the shipper shall incur liability in the same way as the haulier if the vehicle is overloaded.



Figure 12: Provision of pre-selection command to the driver (left: ⁶⁷, right: ⁶⁸)

⁶⁴ <http://media.prepass.com/news.php?include=143982> (19 October 2012)

⁶⁵ In: Communauté urbaine de Lyon - Conseil de communauté du 18 février 2013 - Délibération n° 2013-3488

⁶⁶ <http://www.verkehrsrundschau.de/obligatorische-container-waegung-ab-2016-wahrscheinlich-1245531.html> (16 May 2013)

⁶⁷ ASF (2013) Des panneaux dynamiques pour les contrôles douaniers de poids lourds, presented at the ATEXPO Conference, ATEC-ITS, Paris, France 2013, 30-31 January 2013

⁶⁸ Klein, E. & Dolcemaskolo, V. (2013) Optimisation du contrôle des surcharges par couplage de technologies, presented at the ATEXPO Conference, ATEC-ITS, Paris, France 2013, 30-31 January 2013

Annex 4: Integration of on-board weighing sensors in ABS systems

Overloading significantly decreases the **braking performance** of a vehicle. European legislation recognized the tremendous improvement in safety standards achieved by the anti-lock braking (ABS) system, making ABS a mandatory requirement for certain vehicle types.

The regulations for braking systems incl. ABS can be found in the UN/ECE Regulation R13, Council Directive 71/320/EEC and the General Safety Regulation⁶⁹ (and their later amendments).

Motor vehicles of categories M2, M3, N2 and N3 with not more than 4 axles shall be equipped with ABS of Category 1. Trailers of categories O3 and O4 shall be equipped with ABS in accordance with certain requirements⁷⁰. These trailer ABS systems are denoted as either Category A or Category B. Category A systems are comparable to Category 1 for motive vehicles. Trailers in the European Union can have a lesser level of ABS control than motive vehicles, because Category A is not mandated. However, motive vehicles and trailers accredited for dangerous goods haulage are required to have Category 1 / Category A ABS.

Figure 4 displays the step-by-step development of various braking systems according to information from WABCO, one of the leading producers of electronic braking, stability, suspension and transmission control systems or heavy duty commercial vehicles⁷¹.

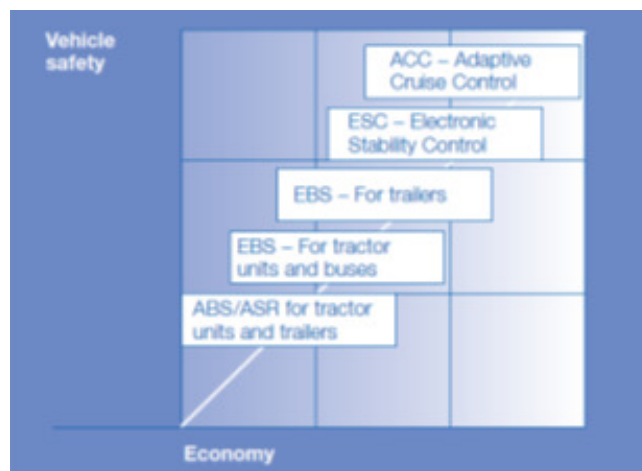


Figure 13: ABS & EBS: step-by-step more safety and economic viability.

ABS was launched into volume production in commercial vehicles in 1981. In 1987, ABS was extended to include anti-slip control (ASR) whereby traction was improved significantly by means of brake intervention. This was followed by the introduction of the electronically controlled braking system (EBS) in 1996. Attempts to improve the rollover resistance of commercial vehicles have been achieved through extending the functions of ABS and EBS. Dynamic Drive Control combined with EBS delivers yet another increase in vehicle safety.

⁶⁹ General Safety Regulation (GSR): Regulation (EC) 661/2009 of the European Parliament and Council concerning typeapproval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor

⁷⁰ Category O3: $GTM \geq 3.5t < 10t$; Category O4: $GTM \geq 10t$; Category N2: $GVM \geq 3.5t < 12t$; Category N3: $GVM \geq 12t$; Category M2: Greater than 8 passengers and $GVM < 5t$; Category M3: Greater than 8 passengers and $GVM \geq 5t$.

⁷¹ http://www.wabco-auto.com/fileadmin/Documents/Media_Center/Press_Releases/EBS.pdf

ABS works with **wheel speed sensors** for constantly monitoring the rotational speed of each wheel to prevent wheel lock under braking. Evolutions of ABS, such as EBS⁷², electronically control the front-to-rear brake bias. Here, additional sensors are added to help the system work, such as a **steering wheel angle sensor** and a **gyroscopic sensor**. In a longer perspective, on-board weighing sensors may be integrated by the vehicle manufacturers, e.g. as **integrated electronic components for trailers**⁷³. However, an integration of on-board weighing devices with braking systems, such as ABS, is not recognised in the current developments.

⁷² Depending on its specific capabilities and implementation other terms include: electronic brakeforce distribution (EBD), traction control system, emergency brake assist and electronic stability control (ESC)

⁷³ For example, see SCANIA Ile de France, Le freinage de l'air comprimé à l'ère de l'électropneumatique, Training course 2008.