RESEARCH INTO THE IMPACT OF HEAVY DUTY VEHICLE OBD REGULATION AMENDMENTS

(2013 onwards) on the Service and Repair Industry

An International Specialised Skills Institute Fellowship.

ANDREA WINKELMANN

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i. Executive Summary

On-Board Diagnostics (OBD) regulations provide a standard list of diagnostic parameters relating to the engine emission systems that must be made accessible to all users. OBD has been compulsory in various forms for passenger cars and light trucks since 1996, however only became mandatory for Heavy Duty Vehicles (HDV) from 2013. The benefits of access to open data flow primarily to independent (or non-manufacturer aligned workshops) and owner operators who maintain their own vehicles and may not have access to expensive manufacturer supplied diagnostic tools.

The growing complexity of automotive systems, along with the incorporation of increased electronics, has made vehicle diagnostic tools indispensable for any workshop and vehicle technician. These tools are a necessity for accurately troubleshooting issues on all vehicle systems that use electronic controls.

On-board diagnostic systems monitor the performance of engine and after treatment systems, that are responsible for controlling emissions.

The OBD system is designed to ensure proper operation of the emission control equipment, alerting the driver in case of malfunctions, so that vehicles continue to meet emissions limits over the vehicle's design life. OBD systems are a valuable tool for vehicle owners and technicians, as they provide important information about engine maintenance needs and direct maintenance efforts toward potentially urgent repairs.

OBD assists in the service and repair of vehicles by providing a simple, quick, and cost-effective way to identify problems by retrieving vital automobile data. OBD systems are also a vital component of inspection and maintenance programs for reducing in-use emissions and cutting down on high-emitting vehicles. In some overseas jurisdictions there are compulsory annual vehicle inspections and part of the pass criteria is no engine or emission system fault.

These advanced features create an ongoing learning curve and challenges for personnel who maintain and operate the latest vehicles. In addition, these advanced features could even automate parts of the maintenance process through the application of telematics and transmission of data to and from the manufacturer.

The benefit of this research being completed prior to a legislative change in Australia, is that groundwork has been conducted which identifies key opportunities and challenges across its application, for industry and government in relation to the introduction of these standards.

ADDRESS THE FOLLOWING ITEMS:

1. Identify the latest technologies in diagnostic functionality, tests and tools

2. Identify links with Intelligent Transportation and Telematics Systems (ITS)

3. Identify considerations for the application of Euro VI vehicle emissions standards in Australia from an industry and regulatory perspective.

Findings

Australia has an aging and highly fragmented and 'independent' heavy transport sector, with approximately 85% of vehicles 'owner operated' and many of those also owner maintained.

The complexity and number of systems of emission control technologies being implemented on heavy duty vehicles to meet Euro VI vehicle emission standards has increased dramatically.

Euro VI vehicle emission standards bring new requirements for the standarisation of OBD codes and increased vehicle life that the emission systems must perform over.

Australia's operating environment poses unique challenges to engine emission system durability and conformance due to our high temperatures and high vehicle loads.

These more complex vehicle systems need to be maintained for longer durations, and will incur higher on-going costs to the operator. As there are a high proportion of owner operators in Australia, emission systems are not 'safety' critical items, and there are no in-service monitoring programs of vehicle emissions, there is a high likelihood that vehicle emission systems will not be maintained according to the manufacturer schedules. This could result in actual pollutant emissions being higher than anticipated despite the introduction of new heavy vehicle emission standards (Euro VI).

The Australian Commonwealth Government is presently considering the adoption and timeframe for implementation of Euro VI heavy vehicle emission standards. This will have the benefit of improving air quality in addition to:

» Improved access to OBD data by independent vehicle repairers and owner operators

» Ability of regulators to implement in-service monitoring of vehicle condition and thereby ensuring on-going compliance with vehicle emission standards.

However, it also comes with a number of risks such as:

» Right to repair – independent vehicle repairers and owner operators may not be provided with the required information (calibrations, software, etc) to update vehicle systems

» Higher maintenance costs for operators and a trend towards operators retaining vehicles for longer

» Lack of understanding and training options available for independent vehicle repairers and owner operators to effectively analyse, rectify and update their vehicles.

It is likely that as Euro VI vehicles increase in numbers, that these issues will need to be addressed from a regulatory standpoint in order to preserve the unique operation of Australia's heavy-duty vehicle fleet.

In addition to standardised OBD, there have been significant advances in manufacturer installed telematics systems. This opens new opportunities and challenges for truck operators. Until very recently, telematic systems were GPS (and or GPS and CAN) based and retrofitted to vehicles to enable Operators to track and monitor their fleet. Their use enabled improvements in safety, driver behavior, fuel consumption and better management of maintenance. Now telematics systems are being routinely installed by the vehicle or engine manufacturer and have the capability to record, transmit, and receive data to and from the manufacturer or third parties.

There are a number of issues in relation to telematics that have not yet been resolved and manufacturers each deploy their own strategy. Whilst telematics provides vehicle owners and operators with increased levels of features and convenience, one of the primary aims is to keep vehicles under manufacturer control, within manufacturer extended networks and maximise opportunities for profit through monitoring, servicing and maintenance.

There is no simple checklist for vehicle owners to authorise or accept the growing intrusion that may come with telematics or the ability for example, for owners to share telematics data with their own independent repairers.

» Data ownership. Who owns and has access to the data?

» Privacy and tracking of vehicles. Who has access to vehicle location and operation, how is this stored and how is it used?

» Forced software updates or changes to vehicle operating characteristics without owner consent. Who authorises and makes automated updates and what role does the vehicle owner play?

The standardised deployment of telematics will enable more advanced vehicle technologies, such as platooning and autonomous trucks to be readily deployed, however there are a range of areas that will require regulatory oversight to ensure operator privacy and protections are in place.

The benefit of telematics is that it may address some of the issues raised previously, that may occur with the introduction of Euro VI and more advanced emission control systems, in that system functionality can be monitored remotely, issues raised with the operator and remote updates and fixes to software and calibrations conducted wirelessly if and when required. This type of approach would reduce the training and knowledge requirements of operators whilst maximising vehicle functionality, however it would also reduce the work available to independent repairers and tend to encourage maintenance tasks to be sent to vehicle OEMs and their certified maintenance workshops.

Conclusion

Overall, the road ahead is positive for new and advanced heavy-duty vehicle features, such as standardised OBD and telematics. This is particularly so if a framework is in place that maximises the benefits to vehicle operators to lower maintenance costs and vehicle downtime, whilst providing pathways to ensure that operators are able to readily understand and accept or decline levels of remote monitoring and service by third parties, such as the manufacturer or independent repairers – which takes into account Australia’s unique heavy vehicle sector.

ii. Glossary of Terms

AUS	Australia
CARB	California Air Resources Board
CAN	Controller Area Network
CO2	Carbon Dioxide
CO	Carbon Monoxide
C.I.	Compression Ignition
CVS	Constant Volume Sampling
C.A.F.E	Corporate Average Fuel Economy
CFR	Code of Federal Regulations
ECU	Engine Control Unit
ETL	Engine Test Lab
EPA	Environmental Protection Agency
EUDC	Extra Urban Driving Cycle
EU	European Union
EURO	European
FEL	Family Engine Limit
FTP	Federal Test Procedure
GPS	Global Positioning System
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HFET	Highway Fuel Economy Test
ISC	In Service conformity
ISSI	International Specialised Skills Institute
LDT	Light Duty Truck
LDV	Light Duty Vehicle
LPG	Liquefied Petroleum Gas
MIL	Malfunction Indicator Lamp
MY	Model Year
NHTSA	National Highway Traffic Safety Administration
NGA	National Greenhouse Accounts factors
NOx	Nitrogen oxides
NTE	Not to Exceed
OBD	On Board Diagnostic
OTL	OBD Threshold Limit
P.I.	Positive Ignition
PM	Particulate Matter
RPM	Revolutions Per Minute
TIC	Truck Industry Council
EC/UNECE	United Nations Economic Commission for Europe
USA	United States of America
UCR	University of California - Riverside
UDDS	Urban Dynamometer Driving Schedule
WHO	World Health Organisation
WHSC	Worldwide Heavy-Duty Steady-State Cycle
WHTC	Worldwide Heavy Duty Transient Cycle

1. About the Fellow

Fellow: Andrea Winkelmann

Qualification: B.Eng Automotive - 1997

Position: Director of Engineering, ABMARC

Andrea Winkelmann, the Fellow, is the Director of Engineering at ABMARC, responsible for leading projects and teams to deliver fuel and emissions test and measurement programs for customers across light, heavy and non-road engine applications.

ABMARC is unique in that it provides policy and regulatory analysis and development, technology and transport modelling, business planning and market insight services in addition to comprehensive test, research and evaluation services covering a range of areas including automotive, engines (on and off road), transport, fuels, emissions, aviation, rail, marine, energy and mining.

Previously, the Fellow was the Assistant Manager and Verification and Validation Program Lead for the Global Zeta Platform at GM-Holden. In this position, the Fellow was responsible for the project management of vehicle/engine testing and vehicle system verification to ensure that emissions standards, diagnostic functions and fail-safe features conform to the relevant regulatory requirements (for both Australian and global programs), whilst contributing to cost reduction activities, ensuring budgets were met and safety (zero harm) and quality targets were achieved.

The Fellow has significant experience in the automotive Industry, starting in Germany where she worked as an automotive mechanic on heavy diesel vehicles for the German Post. Later, the Fellow completed her Engineering degree and moved to the UK, where she worked for seven years across a wide range of areas including: homologation of vehicles and motorbikes for global markets (such as India and Iran), project management and commissioning of new automotive engine test facilities, management of engine test lab and staff, in-vehicle calibration for drivability and enhanced features such as radar cruise control.

In 2005 the Fellow immigrated to Australia, taking up a position with Ford as the Senior Quality Engineer responsible for domestic vehicle warranty issues. In this role, it was her responsibility to manage multiple cross functional teams (from the plant through to finance), liaise with dealers and customers and regularly report project status to the Ford executive group which included the Vice-President of the company.

From a technical perspective, the Fellow has a wealth of knowledge across engineering systems, design, testing, the production process, technical issue resolution/root cause analysis and verification activities for product homologation and quality. The Fellow is black belt qualified (six-sigma), process orientated and places an emphasis on developing standard procedures to increase productivity, accuracy and to ensure quality targets are met.

2. Aims of the Fellowship Program

To investigate the impact of amendments to the Onboard Diagnostic (OBD) Monitoring requirements on Heavy Duty Vehicles (HDV) to the service and repair industry.

1. Identify the latest technologies in diagnostic functionality, tests and tools
2. Identify links with Intelligent Transportation and Telematics Systems (ITS)
3. Identify considerations for the application of Euro VI vehicle emissions standards in Australia from an industry and regulatory perspective

The benefits of this research are to:

» Minimise disruption to businesses during adoption of new technologies and the impact of regulations to the heavy commercial transport sector.

» Enable the development of training guidance for fleets and workshops of the new scan tools and CAN networks used and the additional functionality made available with these tools for root cause analysis and rectification of technical faults.

On-Board Diagnostics (OBD) regulations provide a standard list of diagnostic parameters relating to the engine emission systems that must be made accessible to all users. OBD has been compulsory in various forms for passenger cars and light duty trucks since 1996, however it only became mandatory for Heavy Duty Vehicles (HDV) from 2013. The benefits of access to vehicle data is primarily important to independent (or non-manufacturer aligned workshops) and owner operators who maintain their own vehicles and may not have access to expensive manufacturer supplied diagnostic tools.

From 2013, highway engines for all manufacturers of heavy duty vehicles are required to comply to the HD-OBD regulations in both the USA and Europe.

The US EPA & European Union ruling requires that all major emissions control systems be monitored and malfunctions be detected and reported to the driver via the Malfunction Indicator Lamp (MIL). To comply with the new emissions standards, engine exhaust after treatment devices such as diesel particulate filters and NOx-reducing catalysts used on highway diesel engines are required to be monitored and their failure reported. Whilst the MIL is the visual representation on the dashboard to alert the driver, the OBD requirements enable diagnostic tools to be connected to the vehicle's communication network where the specific failure or out of range measurement is reported. Often, the vehicle will continue to operate, but for safety critical features, it may be in a reduced performance mode (also referred as limp-home mode).

The introduction of mandatory ODB in Australia (in conjunction with Euro VI) will not only standardise fault codes for technical issues, but it will also require new standards for diagnostic communication, scan tools for the workshops, in addition to new processes and training of technicians to enable them to read these codes and diagnose faults correctly. Without knowledge of engine, emissions aftertreatment systems, service personnel may find themselves changing components without rectifying the issue.

The benefit of this research being completed prior to a legislative change in Australia, is that groundwork has been conducted that identifies key opportunities and challenges across its application, for industry and government in relation to the introduction of these standards.

3. The Australian Context

SWOT ANALYSIS

Strengths:

- Standardised OBD changes will enable enhanced telematics.
- Improved vehicle maintenance.
- Increased driver safety.
- Reduced costs and increased vehicle utilisation.

Weaknesses:

- Presently, Australia lags overseas emissions regulation (which is linked to OBD introduction) and so implementation of enhanced OBD functionality will be delayed.
- Often OBD is seen as ‘difficult’ for service personnel and fleet operators tend not to implement full capabilities, especially owner operators.
- Multiple scan tools increase cost and complexity for workshops operating different branded trucks.

Opportunities:

- Assist companies, fleets and the vehicle repair and service industry to lower costs by identifying best practice and tools to successfully diagnose faults in shorter time frames in the heavy commercial vehicle segment.
- New OBD requirements will allow single vehicle scan tools to reduce costs.
- Vehicle to vehicle and vehicle to base telematics connectivity for increased productivity.

Threats:

- Australia will lag the rapid change of technology and connectivity of vehicles overseas, reducing productivity and enhanced safety opportunities.
- Perceived complexity of technology and high proportion of owner operators in Australia (who are time limited) will slow its uptake.

4. Identifying Areas of Skills Enhancement

There are examples of areas in Australian professions and industries where there are weaknesses in innovation, skills, knowledge, experience, policies and/or formal organisational structures to support the ongoing successful development and recognition of individuals and the particular sector.

The focus of all ISS Institute Fellowships is on applied research and investigation conducted overseas by Australians. The main objective is to enable enhancement and improvement in skills, knowledge and practice not currently available or implemented in Australia and the subsequent dissemination and sharing of those skills and recommendations throughout the relevant Australian industry, education, government bodies and the community.

OBD has been implemented for Heavy-Duty vehicles in 2007 in the US and 2013 in Europe and has evolved since then. Most truck manufacturers don't readily share vehicle fault information and diagnostic tools and software with independent workshops, therefore workshops and technicians are often not provided the access to training they need or the tools correct to diagnose a system or part failure accurately and repair efficiently.

1. What is Heavy-Duty OBD, and why it is necessary?
Action: Provide an overview of OBD and latest emissions after treatment technology.

2. Investigate Telematics
Action: Telematics technology and its applications, noting how the operator benefits from it.

3. Latest diagnostic tool technology for independent repairers, owner operators & fleet workshops
Action: Compatible scan tools and vehicle information that needs to be available and supported in Australia for future vehicle emission standards.

4. What are additional regulatory and industry issues that may arise with the introduction of Euro VI heavy duty vehicles emissions standards?
Action: Identify considerations for the application of Euro VI vehicle emissions standards in Australia from an industry and regulatory perspective

5. International and Local Learnings

5.1 Summary of the Fellowship Trip

- **42,000** The number of kilometres travelled
- **5** The number of meetings attended with: diagnostic tool developers, vehicle and engine manufacturers and researchers
- **4** weeks abroad
- **1** country – USA
- **7** different States visited
- **1** conference attended

OBD was discussed with engine manufacturers, diagnostic tool developers and research institutes in the USA.

CONFERENCES	University of California, Riverside (UCR) - PEMS conference and workshop	USA
RESEARCH INSTITUTES	Southwest Research Institute	USA
DIGNOSTIC TOOLS MANUFACTURERS	DG Technology	USA
VEHICLE/ENGINE MANUFACTURERS	Volvo	USA
	Cummins	USA
	EMD	USA
AUSTRALIAN ORGANISATIONS	Truck Industry Council (TIC)	AUS
	Elgas	AUS

Table 1- Fellowship Summary

5.2 Overview of The Heavy-Duty Truck Fleet in Australia

Trucks and buses have many of the same regulatory requirements and technology implementation, and as such, the general information for these vehicle types has been grouped into. A heavy commercial vehicle in Australia is defined as a vehicle of more than 4.5 tonnes.

Australia's heavy commercial vehicle sector and regulatory environment is somewhat unique and leads the world in enabling technology and vehicle configurations that improve productivity and safety to be road registered. Since the early 1990s, B-double and B-triple articulated vehicles have been able to operate across most States and Territories in Australia. The B-double configuration offers improvements in efficiency of up to 20 %, or more according to some studies, when compared to transporting the same load using single trailer vehicles. In addition, Australia operates a 'Performance Based Standards' regulatory regime, whereby it enables high performance (efficiency) vehicles to be registered.

Historically, global legislators have focused regulations for heavy commercial vehicles on reducing engine exhaust emissions. As a result, improvements to engine efficiency plateaued in the early 1990s. Emissions performance and fuel consumption improvements are often a tradeoff, with most technical solutions that improve exhaust emissions resulting in an increase in fuel consumption. For example, changes made to fuel injection timing, an effective method to control and reduce NOx emissions, increased fuel consumption by about 5%. A move from the present Euro V standards to Euro VI would add between 200kg and 400kg of weight to the average truck in emissions equipment, and would also be expected to increase overall fuel consumption (on weight increase alone).

There is now a growing trend for legislators to regulate fuel efficiency on heavy commercial vehicles, as seen in the USA with their Phase 1 and proposed Phase 2 efficiency regulations of heavy commercial vehicles. Europe has regulated a measure and report requirement as a likely precursor to CO2 regulation for heavy vehicles.

As Australia is a technology adopter for powertrain technology, some of these vehicle efficiency improvements will be implemented over time.

5.2.1 REGULATION

» The Australian Design Rules (ADRs) govern the technical and safety requirements for vehicles to be registered.

» Australian heavy commercial vehicles are required to comply with Euro V emissions standards. The Government is presently considering adoption of Euro VI standards.

» Fuel quality is governed by the Fuel Quality Determination and is presently the equivalent of Euro V for diesel.

5.2.2 FLEET AGE

Australia has more than 480,000 registered trucks. The average age of Australia's truck fleet and bus fleet has increased over the last ten years to 13.9 years. The heavy rigid fleet is the oldest, with an average of nearly 16 years, followed by the articulated truck fleet at 11.5 years and the light rigid a little over 11 years old. Industry commentary suggests that the B-double and B-triple fleets have an average age of approximately 5 years. Buses have increased from 14 to 14.6 years over the same period. For comparison, the average truck fleet in North America is 6.7 years, U.K. is 7.8 years and Japan is 9.2 years.

The chart below shows new truck sales (excluding buses) and average fleet age from 2005 to 2015. Truck sales declined significantly during and post the global financial crisis. This aging fleet results in lower adoption rates of new technologies that provide improvements for productivity, air quality and safety. It will also result in lower adoption rates of the latest OBD standards when they become a mandatory requirement in Australia.

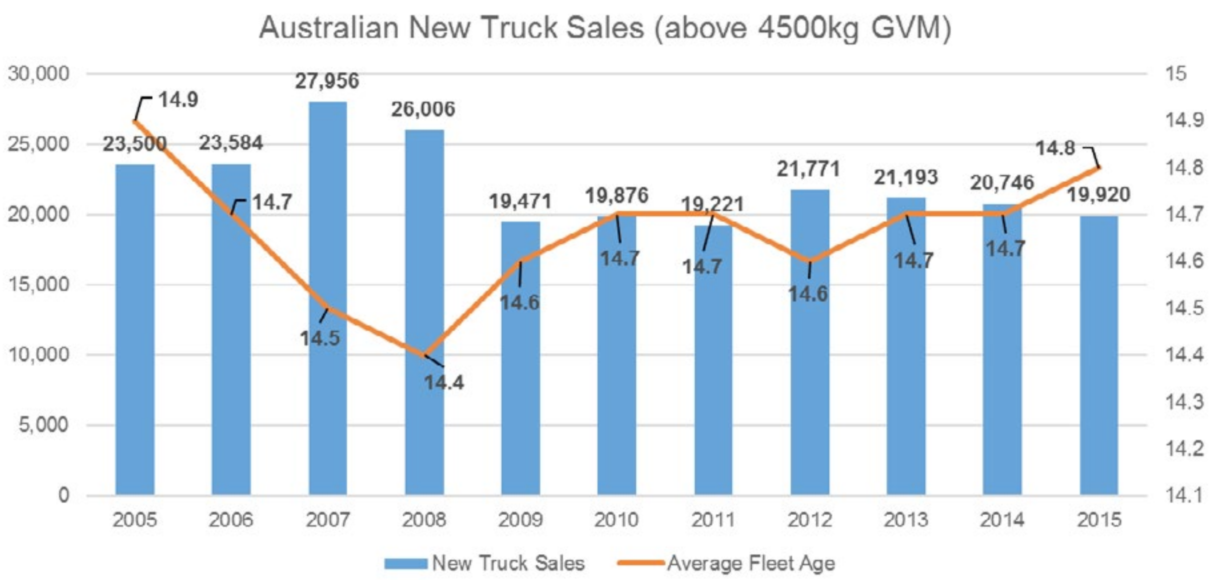


Chart 1 - Truck Fleet Sales and Ave. Age (Source – ABS Vehicle Census)

The table below shows the average vehicle fleet age by segment. Where the light rigid segment has the "newest" fleet of the three followed by the articulated and the heavy rigid fleet.

Vehicle Type	2006	2010	2014	2015	Trend
Light Rigid	10.9	10.9	11.1	11.2	Increasing
Heavy Rigid	15.4	15.4	15.6	15.7	Increasing
Articulated	10.9	10.9	11.4	11.5	Increasing

Table 2 - Truck Fleet Age by Segment (Source: ABS Vehicle Census)

5.2.3 TRUCK OPERATORS

There are two different types of truck operators:

» Hire-and-reward operators (these included owner operators) – these are transport businesses that are mainly focused on providing transport services.

» Ancillary operators – main business activity is outside the transport / logistic area but they have large truck fleets to transport their own goods.

Approximately 70% of all operators have only one truck in their fleet and around 24% have two to four trucks. Less than 1% of all operators have fleets with more than 100 trucks.

The Truck Industry Council (TIC) estimates that owner-drivers and small business operators account for less than 15% of the industry income but move more than 85% of the road freight in Australia. In most cases the business owner is the person that is responsible for driving and maintaining the vehicle as well as managing the business. The intense competition for haulage contracts in the trucking industry makes it challenging for smaller business operator to re-invest into the business by buying newer prime movers or assisting productivity improvements by implementing telematics monitoring.

5.2.4 HEAVY DUTY VEHICLE EFFICIENCY TRENDS

Historically, global legislators have focused on regulations of heavy commercial vehicles that reduce engine exhaust emissions. As a result of this, improvements to engine efficiency plateaued in the early 1990s. Emissions performance and fuel consumption improvements are often a tradeoff, with most technical solutions that improve exhaust emissions resulting in an increase in fuel consumption.

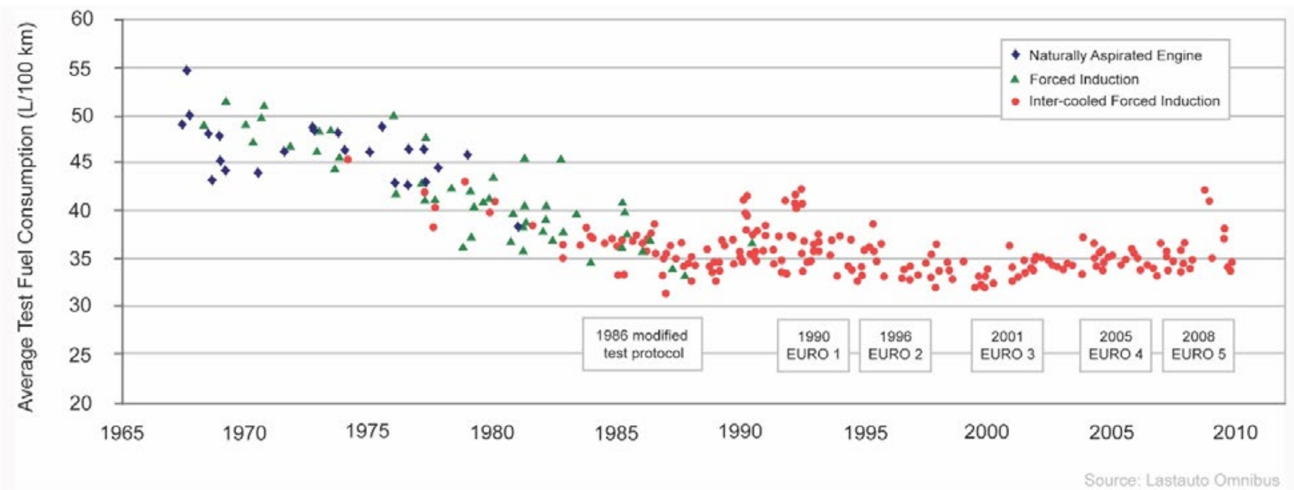


Chart 2 - Heavy Duty Vehicle Efficiency Trends (Source: Lastauto Omnibus)

In Australia, the improvement in freight transport efficiency in the heavy articulated truck sector has been at a rate of approximately 0.6% each year. This improvement has been achieved primarily through advances in logistics and increasing numbers of B-double trucks, rather than from engine or vehicle/trailer based technologies.

There has been no improvement in the efficiency of the rigid vehicle transport fleet over the past 10 years, and this is partly to do with the trend by transport companies to contract owner drivers, resulting in less overall efficiency in the sector and the number of vehicles increasing at a faster rate than the freight task.

5.3 Heavy Commercial Vehicle Emissions Standards

For heavy duty vehicles it is the engine that is "type approved", rather than vehicle itself. This is due to the high diversity of available vehicle configurations that the engine will be applied to compared to the passenger vehicle segment. Emissions are reported in g/kWhr (grams of emissions per unit of work), compared to grams of emissions per kilometer (g/km) for light vehicles. HDV's are often build to customer specific requirements with components sourced from multiple suppliers.

USA, European and Australian emissions standards introduction for HDV's can be seen in the table below:

Heavy Duty Diesel Vehicle Emission Standards														
COUNTRY		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Emission Limits	US EPA 2007 / 2010												
	Emission Limits	Euro IV	Euro V				Euro VI							
	Emission Limits	Euro IV / US04 / JE05V					Euro V / US07 / JE05							

Table 3 – Timeline of Regulation (Source: ABMARC)

The Australian Government is currently undertaking a review to consider whether Australia should adopt Euro VI standards for heavy duty vehicles and the timeline for its introduction. A number of truck manufacturers already import Euro VI compliant vehicles into Australia, despite that there is no regulatory requirement to do so, and provide these available as an option for their customers. Many councils operating bus fleets for public transport are selecting Euro VI buses for their latest replacement vehicles. A number of the larger fleet operators purchase Euro VI trucks as part of their overall environment strategy and to assist in winning transport tenders through their environmental credentials.

The Australian Government accepts alternative test standards to the European requirements for engine certification. These are the Japan JE05 and the US EPA 2007.

Emissions from road transport is the primary reason for the large number of NOx exceedances observed in European air quality monitoring. NOx reductions from the road transport sector have been less than anticipated over the last two decades, partly because transport has grown more than expected, and partly owing to the increased number of diesel vehicles producing higher NOx emissions than petrol-fueled vehicles in the real world.

It is also an issue that 'real-world emissions' often exceed the permitted test-cycle emissions used for certification of vehicles complying with Euro standards. This is particularly true for light-duty diesel vehicles and is in the order of 5 to 20 times greater.

The introduction of Euro VI for Heavy Duty Vehicles will have a significant reduction in allowable NOx and PM emissions. These more stringent limits will lead to additional emissions system technologies being deployed, such as DPF and Selective Catalyst Reduction (SCR), that in turn, increases the reliance on OBD systems to ensure they are operating effectively.

NOx emissions are regulated by the US Federal Government and the European Union for heavy duty diesel on-highway engines as follows:

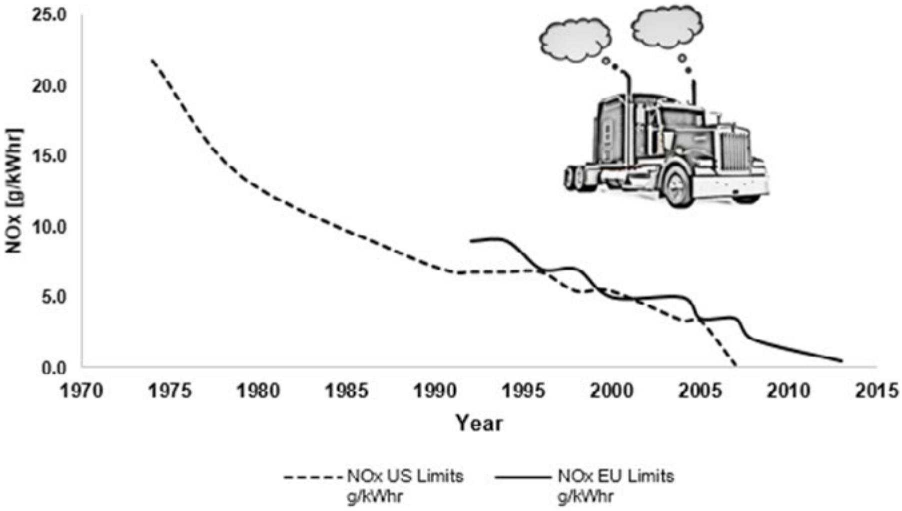


Chart 3 – Decreasing NOx Limits over Time for HDV's (Source: ABMARC)

Typically, smoke and Particulate Matter (PM) both decrease when NOx increases. A decrease in combustion temperature also increases the flame lift-off, which may decrease the PM formation inside the spray. There are also other factors that will impact the increase in PM formation such as sulfur content, fuel density and lubrication oil. The two charts below show the decrease of NOx vs PM limits overtime for the USA and Europe.

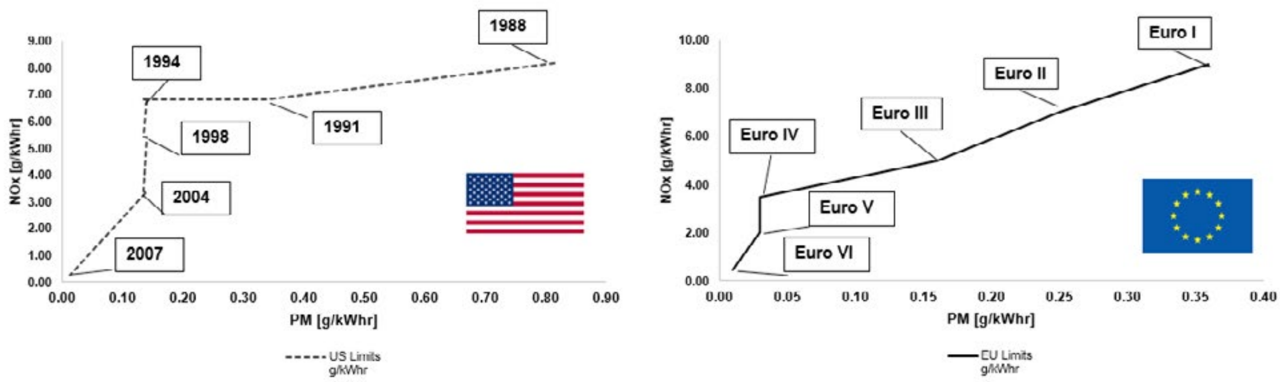


Chart 4 – NOx vs PM for US EPA and European Standards (Source: ABMARC)

The following table shows the timeframe when new regulations were introduced to lower the Sulfur content in automotive diesel fuels.

Diesel Fuel Quality - Maximum Sulfer Content															
COUNTRY		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2015
EUROPE		350 ppm					50 ppm				10 ppm				
USA		500ppm						15 ppm							
AUS				500 ppm				50 ppm			10 ppm				

Table 4 – Overview of Sulfur Content Reduction (Source: ABMARC)

The lower Sulfur levels in the fuel not only reduces PM emissions but also enables the introduction of emission control technologies that provide even greater emission reductions.

5.3.1 OVERVIEW AND COMPARISON BETWEEN EUROPEAN AND US EPA HDV ENGINE EMISSIONS LIMITS

To reduce engine out emissions and meet more stringent European and USA emissions regulations, heavy duty truck manufacturers have introduced new technologies and engine control strategies.

When Euro VI emission limits were introduced, not only NOx was reduced but also PM and other pollutants. Table 5 provides a comparison of emissions regulations between US EPA and Europe.

In addition to changes in emissions limits from Euro V to Euro VI, the "Useful Life of Emission After Treatment Systems" has increased dramatically, standardised access for repairers to on-board diagnostic has been introduced and the emissions test cycle has been changed to a more realistic engine test cycle.

Item	EPA 2007	EPA 2010	Euro V	Euro VI	Comments
Year of Regulation Implementation	2007	2010	2008	2013	
PM (g/kWh)	0.013	0.013	0.020	0.010	The use of DPF technology is needed to achieve zero PM numbers.
NOx (g/kWh)	0.54	0.27	2.00	0.40	The introduction of SCR in conjunction with DOC and DPF has made it possible to reduce NOx emissions and meet the current limits.
CO (g/kWh)	20.8	20.8	1.5	1.5	Diesel engines are lean combustion engines, and the concentration of CO and HC is minimal. The implementation of DOC will help to reduce CO and HC (NMHC).
HC (g/kWh)	N/A	N/A	0.43	0.13	
NMHC (g/kWh)	0.38	0.19	N/A	N/A	
Fuel Sulfur (ppm)	15	15	10	10	The amount of sulfur in diesel fuel has a significant effect on the performance of advanced emissions reduction technologies, and also can enhance or detract from the emission Current fuel-sulfur requirements in the U.S. (15 ppm) and Europe (10 ppm) are both considered ultralow or "near-zero".

Item	EPA 2007	EPA 2010	Euro V	Euro VI	Comments
Emission Technology	VGT Turbo Fuel Injection Technology Cooled EGR DOC & DPF	VGT Turbo Fuel Injection Technology Sub-System Integration Cooled EGR SCR - Zeolites DOC & DPF	DOC SCR - Vanadium Based Cooled EGR Fuel Injection Technology	VGT Turbo Fuel Pressure Sub-System Integration Cooled EGR SCR - Zeolites DOC & DPF	Various Technologies used in a single or system approach to achieve emissions limits.
Emissions Test Cycle Used	FTP and Supplement Emission Test		ESC	WHSC	Drive-cycle used in the US and Europe to certify the engine families or vehicles.
OBD Requirements	Full OBD Functionality from 2016		Full OBD Functionality for New Vehicles from 2016 and All Vehicles 2017		Full OBD access is required for service and maintenance. Requirements include threshold monitoring (emission control systems), non-threshold monitoring (functional, rational and electrical signals), and OBD testing-validation.
In-Use Testing	Not-to-Exceed (NTE) Testing with PEMS		In-Service Conformity (ICE) Testing with PEMS		In the U.S., NTE requirements have been enforced since2010. ISC requirements start in Europe with the implementation of Euro VI.
Useful Life/ Durability	700,000km or 10yrs		500,000km or 7yrs	700,000km or 7yrs	The requirement refers to whichever comes first. Discrepancy between the standards is reduced, as vehicles more typically reach the mileage limits prior to age limits, but is not eliminated.

Table 5 – Comparison between EU & US EPA Emissions Regulations and Limits

5.3.2 OVERVIEW OF MAIN REGULATED POLLUTANTS

Average Brake Specific NOx

Oxides of nitrogen (NOx) is the sum of nitric oxide (NO) and nitrogen dioxide (NO2). NOx is strongly dependent on combustion temperature, local concentration of oxygen and the duration of the combustion process. A slower ignition and lower combustion temperatures tends to be beneficial for reducing NOx emissions.

Average Brake Specific CO

Carbon monoxide (CO) formation is mainly dependent on the fuel-air equivalence ratio. Usually low during steady state engine operation but often increasing during rich fuel operations such as full load. CO increases steadily with an increase in fuel.

Average Brake Specific NMHC

Non-methane hydrocarbons (NMHC) represent unburnt fuel, which is the result of high air fuel ratios (rich mixtures) or undermixing of fuel that cannot ignite easily or support flame development.

Average Brake Specific PM

Often visible as soot and smoke ejected from an exhaust. Particulate matter is a complex mixture of small solid and liquid particles suspended in the exhaust gas which consist mainly of combustion generated carbon material (soot) on which some organic compounds (mainly from unburned fuel and lubrication oil) have been absorbed.

Emissions Control Technologies

The two main pollutants in a diesel engine are PM and NOx. These two pollutants unfortunately have opposing actions, whereby a reduction in PM (for example higher combustion temperatures) can lead to an increase in NOx and vice versa.

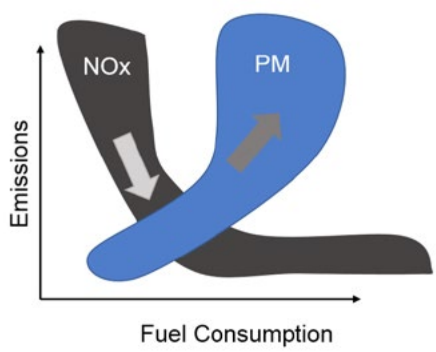


Figure 1 – Relationship between NOx and PM (Source: ABMARC)

To meet Euro VI emission limits not only engine processes, strategies and modifications need to be applied, but also an increased use of exhaust emissions after-treatment technologies will need to be utilised to be able to achieve the more and more stringent targets.

5.3.3 INTERNAL MEASURES - DIESEL ENGINE TECHNOLOGY THAT IS CURRENTLY USED TO REDUCE EMISSIONS:

Fuel Injection Technology

Increased fuel pressure, improved injector design and fuel injection timing can improve mixture formation and therefore reduce particulate matter emissions.

Exhaust Gas Recirculation (EGR)

Exhaust gas is recirculated into the combustion chamber to reduce oxygen concentration which will lower the combustion temperature and therefore NOx concentration. There are two types of EGR, internal and external. Both technologies are lower the peak combustion temperature.

Combustion Chamber Design

Manipulation to the charge air motion can improve mixture formation and hence accelerate the combustion process. The position and design of the air inlet ports are the most important factors plus changes to the piston geometry can influence the air flow inside the combustion chamber. Good air flow (swirl) can reduce PM and if tuned correctly can be used as a PM/NOx trade off in specific engine load conditions.

Air Management Technology

Air management systems can comprise of air filter, turbocharger, supercharger, air temperature control devices. These systems control the air motion, temperature and the pressure of the air entering the combustion chamber. If designed well, these systems ensure that sufficient oxygen is provided to complete the combustion process in the time available and tuning the air charge temperature and air charge density across the range of engine conditions can minimize NOx and PM formation.

5.3.4 EXTERNAL MEASURES – AFTER-TREATMENT TECHNOLOGY CURRENTLY USED IN HDV

To meet the ever more stringent emissions requirements, emissions after-treatment systems are increasingly used in diesel engine applications.

These aftertreatment systems reduce the following pollutants: NOx, PM, HC and CO. In commercial vehicles, SCR has become the main after-treatment technology in conjunction with the catalyst to meet Euro V emissions limits. To achieve Euro VI emission limits, all trucks will need to use technologies such as Diesel Oxidation Catalysts (DOC), DPF and SCR systems. The illustration below provides an overview of technologies presently used to meet Euro VI and EPA 2010 standards.

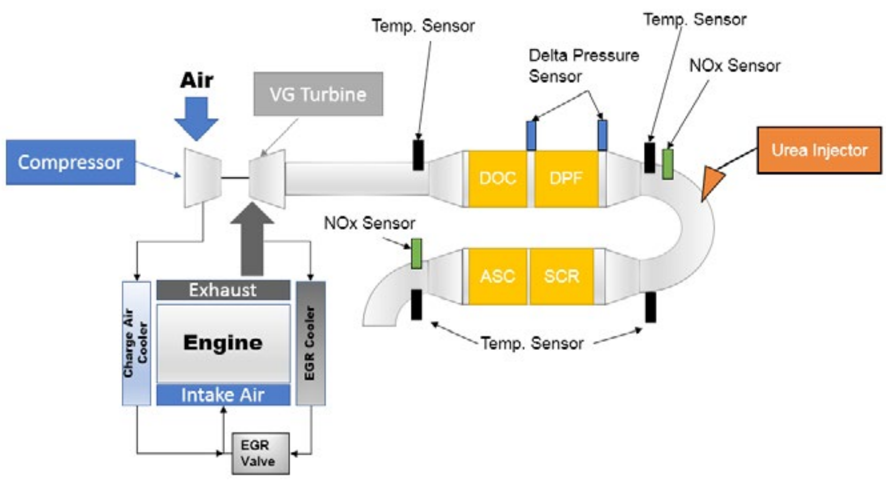


Figure 2 – Overview of a HDV Emissions Aftertreatment System (Source: ABMARC)

Diesel Oxidation Catalyst (DOC)

» Like catalytic converters used on petrol vehicles, diesel oxidation catalysts (DOC) using chemical reactions to reduce emissions. The interior surface is coated with catalytic metals that oxidizes the soluble organic fraction of particulate matter. Carbon monoxide, gaseous hydrocarbons and the liquid hydrocarbons absorbed on carbon particles are one form of PM. DOC technology is used on new trucks but can also be retrofitted to existing fleets. DOC catalysts require a low Sulfur contests in the fuel to operate efficiently.

Diesel Particulate Filter (DPF)

» Diesel particulate filters consist of a ceramic filter element that is capable to trap particles over a broad range of different sizes. The captured soot needs to be burned off (regenerated) in regular intervals to manage the exhaust backpressure. The regeneration process can a passive or active one.

» The passive regeneration requires nitrogen oxide, which can be washcoated on the filter element itself or is provided during the oxidation process of the DOC. DPF will be therefore placed after the DOC in the exhaust system.

» The active regeneration process requires a late fuel injection during the combustion process or a fuel burner upstream of the DPF.

Selective Catalyst Reduction (SCR)

» SCR a catalytic converter that can reduce NOx to nitrogen through the use of an external reducing agent, usually a urea-based liquid known in Europe as AdBlue is used. The fluid is normally stored in a separate tank in the vehicle. An SCR system can achieve high NOx conversion rates depending on the amount of urea (AdBlue) injected.

5.3.5 CONSIDERATIONS AND REFLECTIONS FOR AUSTRALIA

Australia has an aging and highly fragmented and 'independent' heavy transport sector, with approximately 85% of vehicles 'owner operated' and many of those also owner maintained.

The complexity and number of systems of emission control technologies being implemented on heavy duty vehicles to meet Euro VI vehicle emission standards has increased dramatically.

Euro VI vehicle emission standards bring new requirements for the standardisation of OBD codes and increased vehicle life that the emission systems must perform over.

Australia's operating environment poses unique challenges to engine emission system durability and conformance due to our high temperatures and high vehicle loads.

These more complex vehicle systems need to be maintained for longer durations, and will incur higher on-going costs to the operator. As there are a high proportion of owner operators in Australia, emission systems are not 'safety' critical items, and there are no in-service monitoring programs of vehicle emissions, there is a high likelihood that vehicle emission systems will not be maintained according to the manufacturer schedules. This could result in actual pollutant emissions being higher than anticipated despite the introduction of new heavy vehicle emission standards (Euro VI).

5.4 On-Board Diagnostics

The vehicle OBD system monitors and diagnoses the performance of engine and vehicle emissions systems. OBD also has the capability to monitor and report on every single data parameter that can affect the emissions and engine performance.

OBD is a series of algorithms and code within the engine control unit (ECU) and uses information received from sensors to assess the performance of the emission control systems. The sensors themselves do not directly measure regulated pollutants. OBD diagnostics run in the background and will only take action if safety or emission related faults occur. If a fault occurs a warning light will appear on the vehicle instrument panel to alert the driver.

Figure 3 – MIL (Source: SAE International)

OBD also assists in the service and repair of heavy duty vehicles by providing an easy, quick, and cost-effective way to identify issues by retrieving vehicle diagnostic information. OBD data is also used for inspection and maintenance programs (US and Europe) to identify high emitting or faulty vehicles and therefore reduce in-use emissions to improve air quality. In-use, or not to exceed emissions programs are mandatory in some jurisdictions such as Europe and United States, however are not presently enforced in Australia and may not be introduced when Euro VI HDV emission standards come into force.

These in-use programs are separate to annual vehicle maintenance and emissions test programs that vehicles are required to pass in order to renew registration. These programs are active in places such as the UK, Germany and California.

OBD systems were first introduced in passenger vehicles (LDV's). General Motors began introducing OBD systems in its vehicles in the 80's. California, which was allowed by the Federal Government to set its own emission rules, because of poor air quality, issued the first requirements for OBD systems starting with the 1991 model year. Europe followed ten years later (DieselNet, 2007).

The first OBD systems that were introduced were relatively basic with no standardisation between manufacturers. Each of the vehicle OEM's adopted a different system to read and communicate engine and vehicle information to proprietary systems. In 1996 the OBD system became standardised in the U.S. and the monitoring and emission limits for emissions control failures were established across U.S. vehicle manufacturers.

On-board diagnostics for heavy-duty vehicles (HDV's) were first introduced in 2005 in Europe. The U.S. Environmental Protection Agency (EPA) began to phase in OBD requirements between 2005 and 2008.

Other countries such as India, Brazil and China have adopted HDV OBD requirements following the European program model.

5.4.1 US AND EU OBD INTRODUCTION SCHEDULE

HD-OBD in the United States is based on vehicle gross weight (GVM). OBD was first introduced on trucks with a weight of 14,000 lbs (6,350kg) or less.

Table 6 presents an overview of the OBD implementation schedules for Europe and the United States of America. The schedule of implementation in the European Union (EU) and the United States tends to converge around 2017. This implies that the most advanced OBD control systems, with the most stringent threshold limits and complete monitoring requirements, will be available at that time.

Year	Country	Regulatory Body	OBD Requirements	Regulation	Comments
2005	USA	US EPA / CARB	EPA 2005 Diesel GVWR < 14000 lbs	Title 40 CFR 86/ 13 CCR 1971.1	
	EU	ECE	Euro IV HDV OBD	Directive No. 2005/55/EC	Euro IV OBD (Stage I) requirements include after-treatment systems monitoring (non-standardized OBD).
2008	USA	US EPA 2008 / CARB	EPA 2005 Diesel OBD (100 percent) for diesel HDV, GVWR <14,000 lbs		
	EU	ECE	Euro V HDV OBD	Directive No. 2005/55/EC	Euro V OBD (Stage II) Additional monitoring requirement plus standardization of OBD communication protocols across vehicle manufacturers.
2010	USA	US EPA / CARB	EPA 2010 Diesel OBD phase-in for diesel HDV, GVWR >14,000 lbs	13 CCR 1971.5	
2013	USA	US EPA / CARB	EPA 2013Diesel Top sales family: Full OBD for all ratings		
	EU	ECE	Euro V OBD & NOX control monitoring 01.01.2013 (New vehicle types) phase-in Euro VI OBD	EC No 692/2008	The new emission limits, comparable in stringency to the US 2010 standards, became effective in 2013 for new type approvals and for all registrations in 2014.
2014	USA	US EPA / CARB	Full OBD for top sales rating and extrapolated OBD for all other ratings		

Year	Country	Regulatory Body	OBD Requirements	Regulation	Comments
	EU	ECE	Euro VI – 01.01.2014 (all vehicle types)	EC No 595/2009 (EU) No 582/2011.	Requires access to vehicle repair and maintenance information. Euro VI OBD phase-in. » More stringent OBD threshold values and type approval based upon the World Harmonized Test Cycle (WHTC). » Adoption of in-use performance ratios (IUPR). IUPRs give an idea of how often the conditions subject to monitoring occurred and how frequent the monitoring intervals occurred.
2015	USA	US EPA / CARB	PM sensor phase-in Urea quality sensor		
	EU	ECE	Euro VI OBD: Until 01.09.2015 for alternative diesel particulate filter (DPF) monitoring. Pressure drop instead of PM sensor		
2016	USA	US EPA / CARB	Full OBD for HDVs, all engines, all vehicles Full PM sensor		
	EU	ECE	01.01.2016 Final OBD Euro VI (new vehicle types)		
2017	EU	ECE	01.01.2017 Final OBD Euro VI (all vehicle types)		

Table 6 – Comparison between EU & US EPA Regulations Requirements

5.4.2 OBD MONITORING

Any engine or emission system component that could adversely impact vehicle emissions is required to be monitored. The following table provides an overview of the monitoring categories:

Catalyst Efficiency	Misfire Detection	Exhaust Gas Sensors
Secondary Air	Fuel System	Engine Cooling Systems
Exhaust Gas Recirculation	Crankcase Ventilation	Direct Ozone Reduction
Cold Start Strategies	Variable Valve Timing	Turbo-/Supercharger
Air Metering Systems	Engine Speed	Fail Safe Systems
Hybrid Systems	Evaporative Emissions Systems	

Table 7 – OBD Monitoring Categories

The OBD system is divided into three main categories:

a. Emissions Threshold Monitoring

b. Non-Threshold Monitoring

c. OBD Testing and Validation

a. The emissions *threshold monitoring* is only required for the main emissions control systems that have been identified by the regulatory bodies (US EPA, CARB and UNEC). These systems vary by jurisdiction, with the most stringent regulation in the US.

   When a fault is detected the information is stored and compared to the relevant diagnostic thresholds. Depending on the severity of the fault, the malfunction indicator light (MIL) is turned on. The OBD emissions limit is set by regulation and can be a multiplier of, or an addition to, the emission limits that the vehicle or engine family is certified to.

   The EU OBD regulations require monitoring and reporting of PM and NOx, whereas the US additionally requires NMHC and CO.

   Ideally, the OBD system would measure vehicle exhaust emissions directly, however this is not practical or cost effective for pollutants other than NOx, and as such, other methodologies are applied.

b. It is not only emission thresholds that are monitored. The ODB system reports on more than 100 signals, which includes monitoring components for; total failure, not achieving a commanded or specific target value, a response rate that is too slow or too fast (i.e. oxygen sensors), circuit continuity and other characteristics for each of the systems that impact exhaust emissions and engine performance.

   The OBD monitoring system needs to be calibrated or designed such that it will detect failures accurately, without reporting a false fail or false pass. The monitoring and reporting needs to occur under normal driving conditions but also needs to be repeatable under any driving conditions. Some monitors run continuously form engine start to engine stop (for example misfire), whilst others need to achieve particular engine or system conditions which have been specified by the manufacturer.

   The EU and US have introduced in-use performance ratios (IUPR). These values provide an indication how often the diagnostic runs per vehicle trip. The minimum IUPR value in the US is 0.1, which means that the diagnostic needs to run at least once successfully during 10 trips.

Some other benefits of OBD is to design more durable and robust emissions control system. The "Use of Life" of emission system has been increased from 500,000km to 700,000km for Euro VI.

OBD also will help to keep emissions low by identifying issues prior to failure and it provides an effective and inexpensive tool for emission inspection.

c. OBD testing and validation ensures the correct setting of the failure code for the established threshold values. In order to determine the proper operation of emission control systems, manufacturers must correlate component and system performance with exhaust emissions to determine what deterioration levels will cause emissions to exceed their calibrated or regulated threshold. This requires extensive testing and calibration for each engine model.

Table 8 provides the timeline for implementation and phase in for Euro emissions and OBD regulations.

EU OBD Threshold Limits							
Emissions Standard	Engine Configuration	Implementation Date	NOx limit [mg/kWh]	PM [mg/kWh]	CO [mg/kWh]	IUPR	Regen Quality & Consumption Monitoring
Euro IV (Stage 1)	CI (incl Dual Fuel)	2005 / 2006	7.000	100	-	-	-
Euro V (Stage 2)	CI (incl Dual Fuel) & SI	2008 / 2009	7.000	100	-	-	-
Euro VI (Stage 1 - Phase In)	CI	31-Dec-13	1.500	Performance Monitoring	-	Phase-In	Phase-In
Euro VI (Stage 2 - Phase In)	CI & SI	1-Sep-15	1.500	-	7.500	Phase-In	Phase-In
Euro VI General Req.	CI & SI	31-Dec-16	1.200	25	7.500	General Req.	General Req.

Table 8 – Timeline for EU OBD Implementation for HDV

5.4.3 OBD FAULT ACTIVATION AND STORAGE

In addition to fault and non-compliance detection, the OBD system is also required to have the capability of storing the data under which circumstances (engine or vehicle condition) the fault occurred in order to assist in identifying and rectifying the fault.

The stored information is kept in a folder referred to as "freeze frame data". A diagnostic trouble code (DTC) will identify the malfunction system or component. Each component has a unique trouble code as an identifier.

Separate status codes or readiness codes will be set depending on the priority of the system in question. The severity classes are called "Type A", "Type B1", "Type B2" and "Type C". Each fault class indicates the servility of a failure with regards to its impact on emissions. An error of the second highest class "Type B1" can be converted into an "Type A" fault if the issue is not corrected in a defined time period.

The malfunction indicator lamp (MIL) is activated in different ways for different severity types.

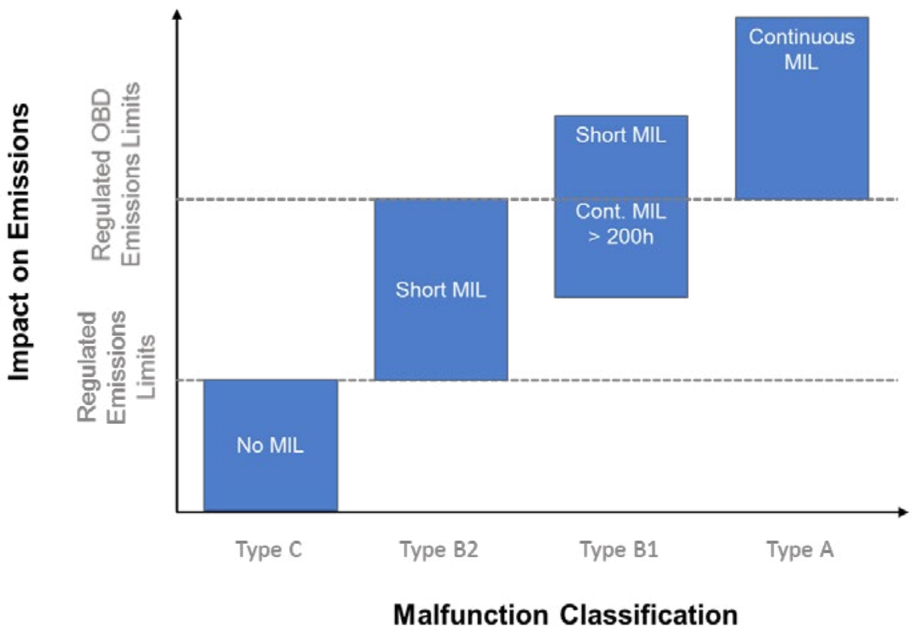


Figure 4 – OBDII Fault Types and MIL settings (Source: ABMARC)

Below is a list of all main emissions systems that are required to be monitored and reported on. This table also provides the diagnostic fail threshold limits for European and US EPA emissions regulations.

OBD Requirement	Euro IV/V Stage 1 and 2	Euro VI	US EPA / CARB
Implementation Year	**2005 and 2008**	**2013 to 2016**	**2010 to 2016**
Diesel Threshold Monitoring and OTL Ratios	NOx and PM	NO (3.2x–2.6x) and PM (2.5x)	NO (3.0x–2.5x), PM (5.0x), NMHC (2.0x), CO (2.0x)
Catalyst—Diesel Oxidation Catalyst	Removal and major failure	Conversion efficiency for hydrocarbons	NMHC catalyst conversion, DPF heating
Lean NO trap (LNT) or NO absorber	Not explicit	Conversion efficiency and reductant delivery if used	Conversion efficiency, NO OBD threshold limits (OTL) monitoring and reductant delivery if used
SCR System	Conversion efficiency; OBD threshold limits (OTL) for NO; major failure (removal; electrical failure of sensors and actuators)	Conversion efficiency—OTL for NOx; reductant delivery (quantity, quality, consumption rate)	Conversion efficiency; NO OTL monitoring; reductant delivery (quantity, quality, consumption rate), response of control system
SCR Urea System	Monitoring of urea quantity, quality, and consumption	Monitoring of urea quantity, quality, and consumption	Monitoring of urea quantity, quality, and consumption

OBD Requirement	Euro IV/V Stage 1 and 2	Euro VI	US EPA / CARB
Implementation Year	**2005 and 2008**	**2013 to 2016**	**2010 to 2016**
DPF System	Conversion efficiency; OBD threshold limits (OTL) for PM; major failure (removal; electrical failure of sensors; clogged filter)	Conversion efficiency—OTL for PM; major failure (removal; electrical failure of sensors; clogged filter); regeneration	Filtering performance—PM and NMHC OTL monitoring; pressure differential; regeneration (frequency, completion), missing substrate; active regeneration (fuel delivery); response of control system
Combined deNOx + DPF	Conversion efficiency and thresholds for NO and PM; major failure	Not available information	No available
Fuel Systems	Monitoring quantity, timing, and circuit integrity	Pressure, quantity, timing, control	OTL monitoring, pressure, quantity, timing, response of control system
Air Boost Systems	Mass air flow; boost pressure and inlet manifold pressure	OTL monitoring, flow rate, response, cooler operation, control; VGT-commanded geometry	OTL monitoring, flow rate, response, cooler operation, response of control system; VGT-commanded geometry
EGR Systems	Monitor for malfunctions conducing to exceeding emission thresholds. No explicit mention of EGR cooling systems	OTL for NO; flow rate, response; EGR cooler performance	OTL monitoring, flow rate, response, cooler operation, response of control system
Valve Timing Systems—VVT	Not explicit	VVT target and response	PM, NMHC, and CO OTL monitoring; VVT target and response of control system
Engine Cooling Systems	Not explicit	Thermostat and total failure	Thermostat, engine coolant temperature, circuit malfunction
Sensors and Actuators	Monitor for electrical disconnection—circuit integrity	Proper operation; voltage, circuit integrity, monitoring capacity	OTL monitoring for exhaust gas sensors; performance (voltage, current); circuit continuity, feedback control, monitoring capacity

Table 9 – Comparison between EU & US EPA OBD Monitoring

5.4.4 OBD COMMUNICATIONS PROTOCOLS

There are different communication protocols used for different vehicle applications.

These protocols define how information is transmitted across a "Controller Area Network" also known as CAN-Bus. CAN-Bus is a network designed to allow microprocessor based electronic control modules to communicate to each other over the same network.

CAN was originally developed by Bosch in the early 1980's, when they designed a communication system between three ECU's in a Mercedes passenger vehicle.

CAN does not define how the information is presented to the end-user. This has the advantage that CAN-Bus can be used across a variety of different applications and industries:

- Heavy Duty Vehicles
- Busses
- Locomotives & Trains
- Agriculture & Forestry
- Marine Systems
- Mining Equipment
- Military Vehicles
- Truck Trailer Connections
- Fleet Management Systems (FMS)
- Industrial Automations
- Medical Equipment

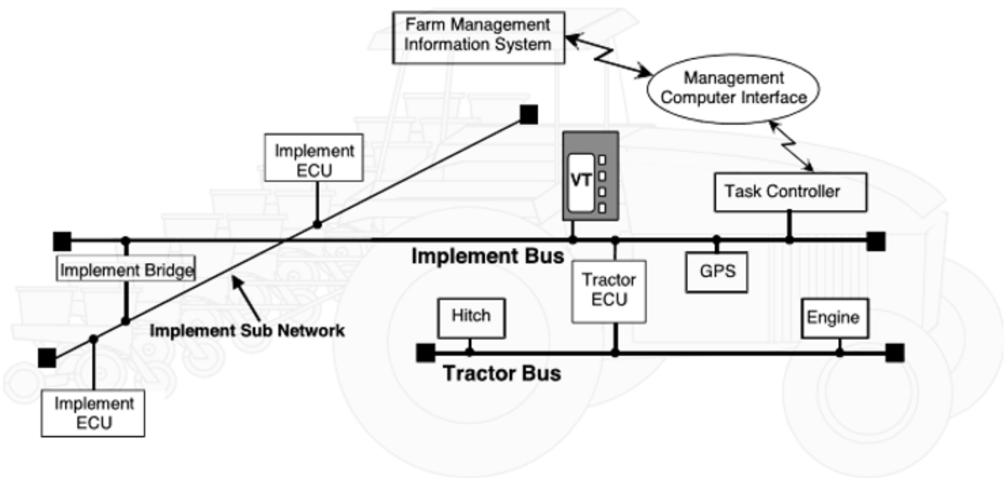
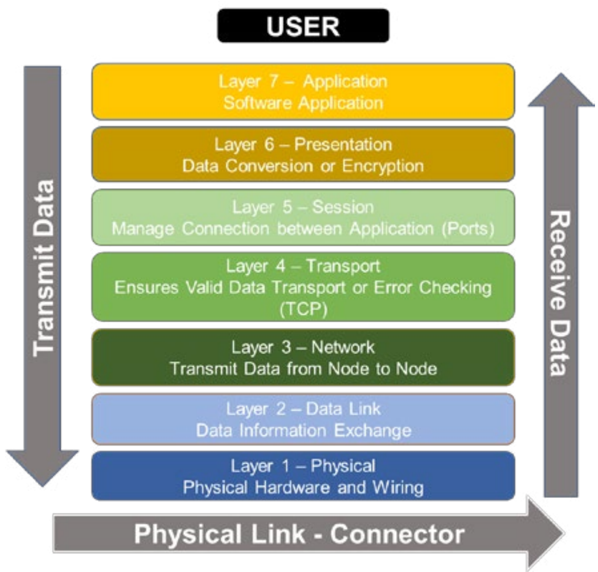


Figure 5 – Overview of a CAN-Bus application (Source: SAE International)

Shortly after its introduction, the CAN protocol was standardised in ISO Standard - 11898. The ISO 11898/CAN Protocol is only the bottom two layers (layer 1 and 2).

Figure 6 – ISO 11898 based CAN Protocol Layers



Other standards such as CAN Open and SAE J1939 are supplements to the ISO CAN standard and define the higher-level layers. Different software and protocols are used in order to communicate with these layers.

5.4.5 TYPES OF PHYSICAL LAYERS

The physical layer consists of two dedicated wires for communication that connect a number of ECU's or Devices within a vehicle network. The number of connected devices is constrained to a maximum electrical load of the CAN Bus. The two-wires are generally twisted and shielded to balance the signal and reduce noise. The most common physical layers on a vehicle CAN-Bus are high-speed CAN and low-speed CAN.

Predominately safety and emissions related devise are communicating via the high-speed CAN-Bus, i.e. ABS, ESP, communication to and from the ECU, and all emissions relevant systems.

Non-critical so-called fault tolerant devices communicate via the low-speed CAN-Bus. For example, the radio, dashboard, AC and so forth.

5.4.6 DATA LINK LAYER

The Data Link Layer allows all modules to transmit and receive data on the bus. Each module is given a unique CAN ID (messenger), either 11-bit or 29-bits. The highest priority message gets through first, the priority of a message is part of the unique identifier.

All modules will also respond to a broadcast message. The maximum data throughput defined by the standard is 1Mbit/s and common rates are 125Kbits/sec for Can Open and 250Kbits/sec for J1939.

Depending on the vehicle application (light-duty or heavy-duty), different hardware or software will be used.

The most common CAN protocols are:

- CANopen used for embedded applications and used for Military applications.
- DeviceNET is used for industrial applications.
- SAE J1939 used for heavy-duty-vehicles and developed by the SAE.
- ISO 15765 CAN for light-duty vehicles.

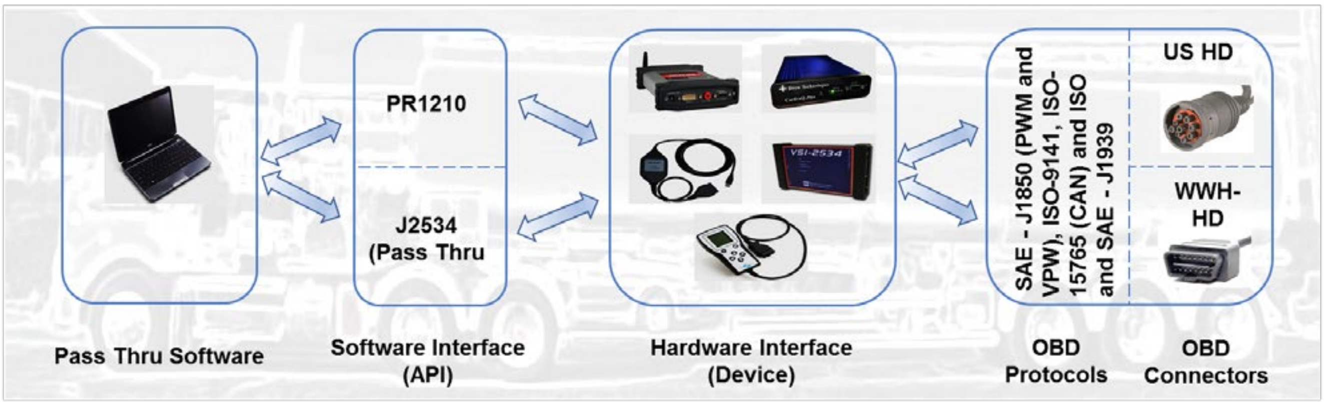


Figure 7 – Overview of Communication Process (Source: ABMARC)

5.4.7 ODB STANDARDISATION

Standardisation ensures that the information from the OBD system is communicated in a standardised format (SAE and ISO standards) which allows any independent repairer to access the data.

This assists to maintain emission control systems and helps technicians to correctly diagnose and repair complex systems, which eliminates unnecessary (in-correct) repairs.

5.4.8 DIFFERENCES BETWEEN DIFFERENT OBD DIAGNOSTICS STANDARDS

» The J1979 (LDV) and J1939 (HDV) OBD reporting is completely different due to different communication concepts but it will provide the same results.

» The ISO 27145 WWH-OBD for HDV adopts both the J1979 and J1939 standard.

» ISO 27145 covers the US and EU OBD requirements.

» The primary difference between the US and the EU requirements for HDV is the fault memory manager and the DTC status information.

» Both ISO 27145 and J1939 are using the same CAN communication layer; ISO 15765.

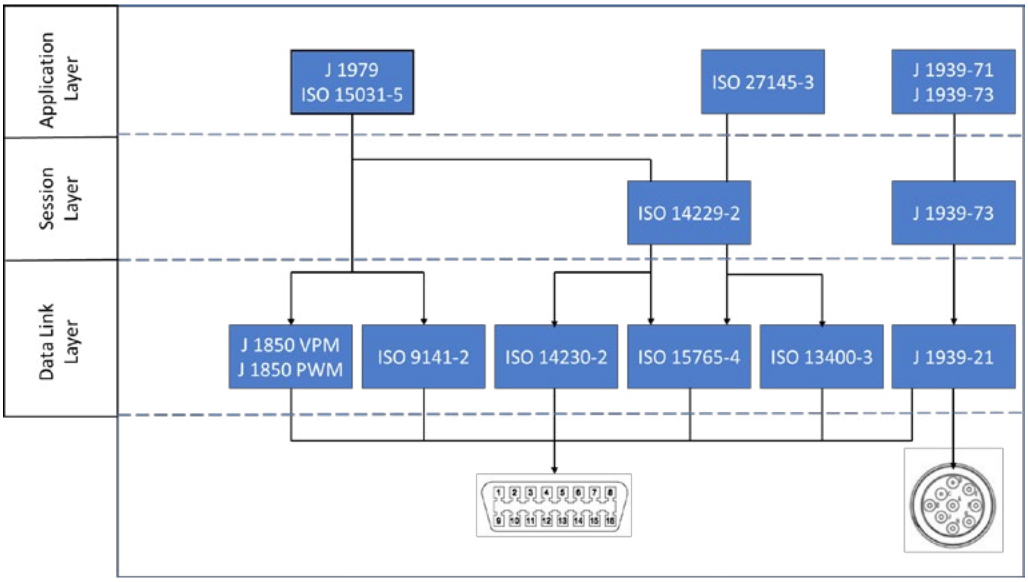


Figure 8 – Flowchart of OBD Scan Tool

5.4.9 FAULT CODE SETTING COMPARISON

Different standards have different ways to identify fault types as it can be seen below. The LDV standard is common across all OEM's worldwide. The HD standards differ between different standards and protocol used.

ITEM	SAE J 1979 LDV	SAE J 1939 HDV	ISO 27145 HDV
Pending DTC, Type A, B1, B2, C	Mode 7	DM 06 DM 41, DM 44, DM 47, DM 50	Read DTC Information + Status Mask + Severity Mask
Confirmed / Active DTC (MIL ON), Type A, B1, B2, C	Mode 3	DM 12 DM 42, DM 45, DM 48, DM 51	Read DTC Information + Status Mask + Severity Mask
Previously Active DTC (MIL OFF), Type A, B1, B2, C	Mode 3	DM 23 DM 43, DM 46, DM 49, DM 52	Read DTC Information + Status Mask + Severity Mask
Permanent DTC	Mode A	DM 28	N/A

Table 10 – Fault Code Setting Comparison

5.4.10 SCAN TOOL REQUIREMENTS

The communication protocols for scan tool devices for light and heavy vehicles are listed below:

US LDV	SAE J 1979
US HDV	SAE J 1979 or SAE J 1939
UN/ECE LDV	ISO 15031-4 (SAE-J 1979)
UN/ECE HDV	ISO 26715 – 3
	SAE J 1939-73

Table 11 – Scan Tool Communication Protocols

To reduce cost and complexity to the independent service and repair industry, scan tools should be able to support all of the three standards SAE J 1979, SAE J 1939 and ISO 27145.

The functional requirements on any service/scan tool is to report out on the following:

» Readiness Status

» Data Stream

» Freeze Frame Data

» Fault Codes

» Test Results

» Vehicle Information (VIN Number, ECU calibration)

» In-Use Performance Ratio Tracking

» Engine Run Time Tracking

5.4.11 HDV SERVICE DIAGNOSTIC TOOLS

Not every technician working on a truck is associated with a dealership or vehicle brand and has instant access to the correct service tool.

Most fleet operated workshops, smaller repairers and owner operators have limited or no-access to all of the required manufacturer service tools. As the technology in trucks becomes more and more advanced (when even replacing brakes is no longer only a mechanical operation as it may involve re-setting of diagnostic features inside the OBD system), not having access to a functioning service tool and the appropriate software that provides access to vehicle information will make it extremely hard for non-OEM aligned or authorised service and repairs to be carried out. Not being able to carry out service and repairs correctly may in turn create unacceptably high risks for safety of both the driver and general community.

Access to “standardised” vehicle information in Australia is not yet clear, as the standard requiring it (Euro VI) has no implementation timeline as yet. In addition, the standardised vehicle information does not cover all of the data and material required by workshops to properly repair and maintain vehicles or enable them to implement software updates and fixes.

Between the US and Europe, there are regional differences in approach to data:

» European manufacturers tend to build and offer customers a complete vehicle, with little in the way of individualisation available. This means that European manufacturers are able to develop a ‘closed’ system for CAN communications between sub components and this makes it more challenging for non-OEM service diagnostic tools to access vehicle information beyond the mandated list of parameters.

» The philosophy of US manufacturers is very different to European manufacturers. Customers purchasing US vehicles can highly individualise the truck at the point of purchase. Therefore, the communication protocol used in the US is required to be flexible, so that the whole system can be fitted as plug-and play. The information therefore provided freely on the CAN bus is generally far greater than for European trucks.

» European and US manufacturer also use different OBD standards and connectors which increases the complexity.

5.4.12 OBD TECH TOOLS

OBD tech tools, are devices that allow service personnel to connect to the vehicle's OBD system. There is a considerable variety of OBD scan tools available, from those with basic read only features to "OEM" service tool capabilities. OEM tools are often the he best tool to purchase, however will be limited to a manufacturer and are typically more expensive that third party systems.

When selecting a third-party scan tool provider, consider scan tool manufacturers that have links to OEMs and those that provide training courses on the tool and OBD systems.

Below is a list of features and accessibility of diagnostic tools that should be taken in consideration when making an investment in a scan tool:

» User friendly, fast and reliable.

» Coverage of the Tool and compatibility across different Manufacturers including "older" model years. (Freightliners, Kenworth, Volvo, Scania, Daimler, Mack, International and others).

» Access to Maintenance functions

  » Read & Clear Fault Codes (DTC)

  » Access Trip Data (Vehicle & Driver Performance)

  » Ability to Create Vehicle Reports

» Licensed OEM coverage for all major systems and sub-systems

» Wiring diagrams

» Monthly subscription fee to OEM information

» Regular updates and customer support

» Real-time data streaming for better root cause analysis

The price of advanced workshop based scan tools ranges between AUD $10,000 to AUD $25,000 depending on options. There is often an annual license fee associated with the tool, that will ensure updates to OEM software for new vehicle and engine types.

Presently, only dealerships have access to calibration updates, with the momentum to freedom to use any maintainer and accessibility to vehicle information from Euro VI onwards that might change.

5.4.13 CONSIDERATIONS AND REFLECTIONS FOR AUSTRALIA

The Australian Commonwealth Government is presently considering the adoption and timeframe for implementation of Euro VI heavy vehicle emission standards. This will have the benefit of improving air quality in addition to:

» Improved access to OBD data by independent vehicle repairers and owner operators

» Ability of regulators to implement in-service monitoring of vehicle condition and thereby ensuring on-going compliance with vehicle emission standards

However, it also comes with a number of risks such as:

» Right to repair – with independent vehicle repairers and owner operators not being provided required information (calibrations, software, etc) to update vehicle systems

» Higher maintenance costs for operators and a trend towards operators retaining vehicles for longer

» Lack of understanding and training options available for independent vehicle repairers and owner operators to effectively analyse, rectify and update their vehicles

It is likely that as Euro VI vehicles increase in numbers, that these issues will need to be addressed from a regulatory standpoint in order to preserve the unique operation of Australia's heavy-duty vehicle fleet.

5.5 CONNECTED TRUCKS – TELEMATICS

5.5.1 OVERVIEW OF TELEMATICS

Telematics is a combination of the words Telecommunications and Informatics. It is the technology of sending, receiving and storing information relating to remote objects, such as vehicles, via a telecommunication device.

GPS based Fleet Telematics is a way of monitoring the location, movement, status and behaviour of a truck which can be extended to a fleet. This is achieved through a combination of GPS receiver and an electronic mobile communication device installed in each truck. In the past, these systems were often fitted as an aftermarket option. Nowadays, telematics is a standard line-fitted part either developed by the OEM or by an approved third party. By 2020 it is expected that telematic technologies will be present in almost 100% of all new commercial vehicles sold.

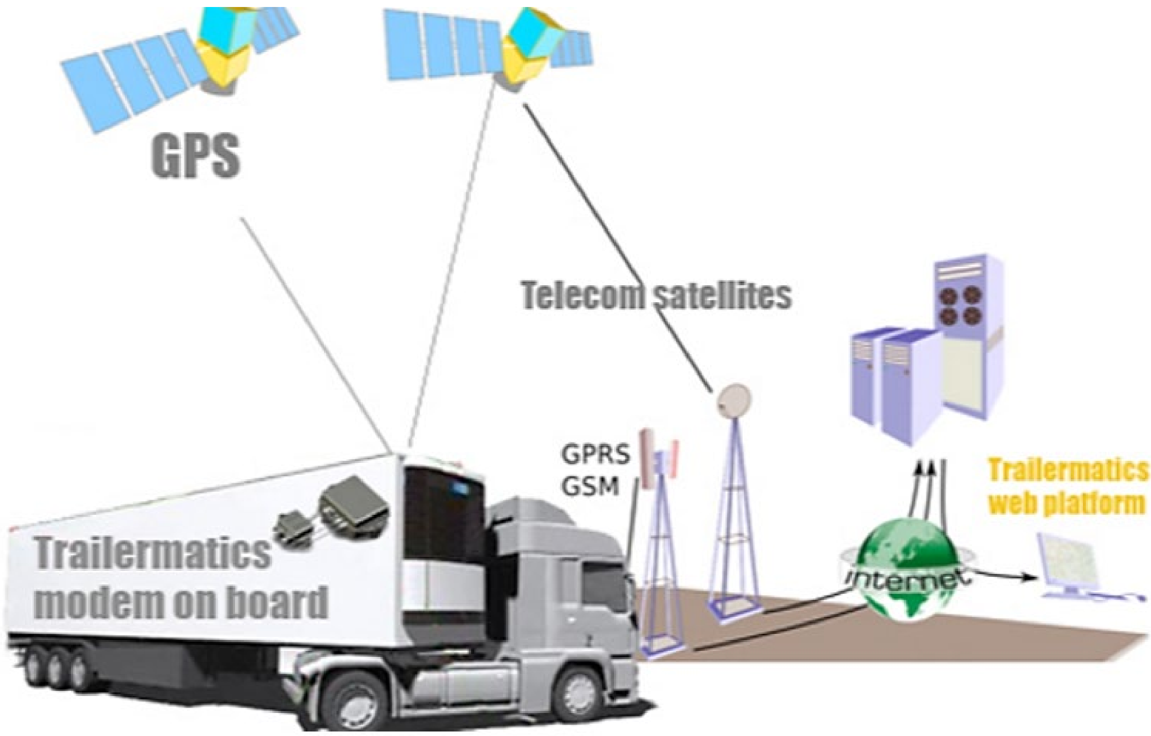


Figure 9 – Connected Truck (Source: Trailermatics)

The use of telematics improves maintenance and repairs, fuel efficiency, security, road safety, communication, and navigation.

Presently, it is typically larger fleets who have adopted telematics technology. Currently more than 40% of the Australian truck fleet utilises telematics, with an annual growth rate of 5% to 6%.

A recent regulation change in the US requires all truck operators to transition to electronic logging devices (ELD) by the end of 2017/2019. The ELD is a more accurate device to record actual hours of service (HOS), which is currently attained using written logs or onboard devices.

Many fleet operators find the volume of information that is accessible via telematics to be too large for correct and useful analysis, as the physical file sizes exceed the capability of standard programs and require dedicated database servers to store the data. Working with telematics data requires some expertise involving vehicle and device manufacturers. Not all telematics systems operate in the same way. Variation in the data can complicate how it is combined across vehicles within a fleet, so experience with both telematics systems as well as data analysis is important to extract business relevant information.

In recent years' fleet management companies increased dramatically around the globe. These companies specialise in compiling data and providing reports for fleets.

Some of the more dominant players in the fleet management market are Verizon Telematics, Omnitracs, TomTom Telematics, Geotab, OnCommand, and Trimble Navigation. A list of OEM's that already provide factory fitted telematic systems are: Volvo Trucks, Daimler Trucks, Fleetboard, MAN, DynaFleet, Scania, Paccar, Hino, Isuzu, and Tata.

5.5.2 BENEFITS OF TELEMATICS

» Data collected from trucks can be used by manufacturers to improve designs and streamline maintenance procedures, in line with vehicle usage.

» Provide more efficient and reliable record keeping for example, for fatigue management and vehicle compliance.

» Traffic Management; through notification to drivers of bad weather or traffic congestion.

» GPS tracking alerts 24/7 to locate stolen vehicles or raise alarms if the vehicle is involved in an accident.

» Safety Analytics to improve driver behavior to improve fuel efficiency and safety.

» Tyre Management.

» Service, Maintenance & Repair, information of faulty components can be sent to the maintenance department, parts ordered and nearby dealership booked to reduce downtime.

Additional advantages are in Vehicle to Vehicle (V2V) Communication for platooning and autonomous vehicle technologies, Vehicle to Infrastructure (V2I) for traffic management and user charge systems.

More efficient and reliable record keeping for example fatigue management and V2V enables vehicles to broadcast their position, speed, steering-wheel position, brake status, and other data to vehicles within a few hundred meters. Other road users can use the information to build a detailed picture of what's unfolding around them, detecting situations that even the most careful and alert driver, or the best sensor system, would miss or fail to recognise. This has the capability to significantly reduce road death and trauma.

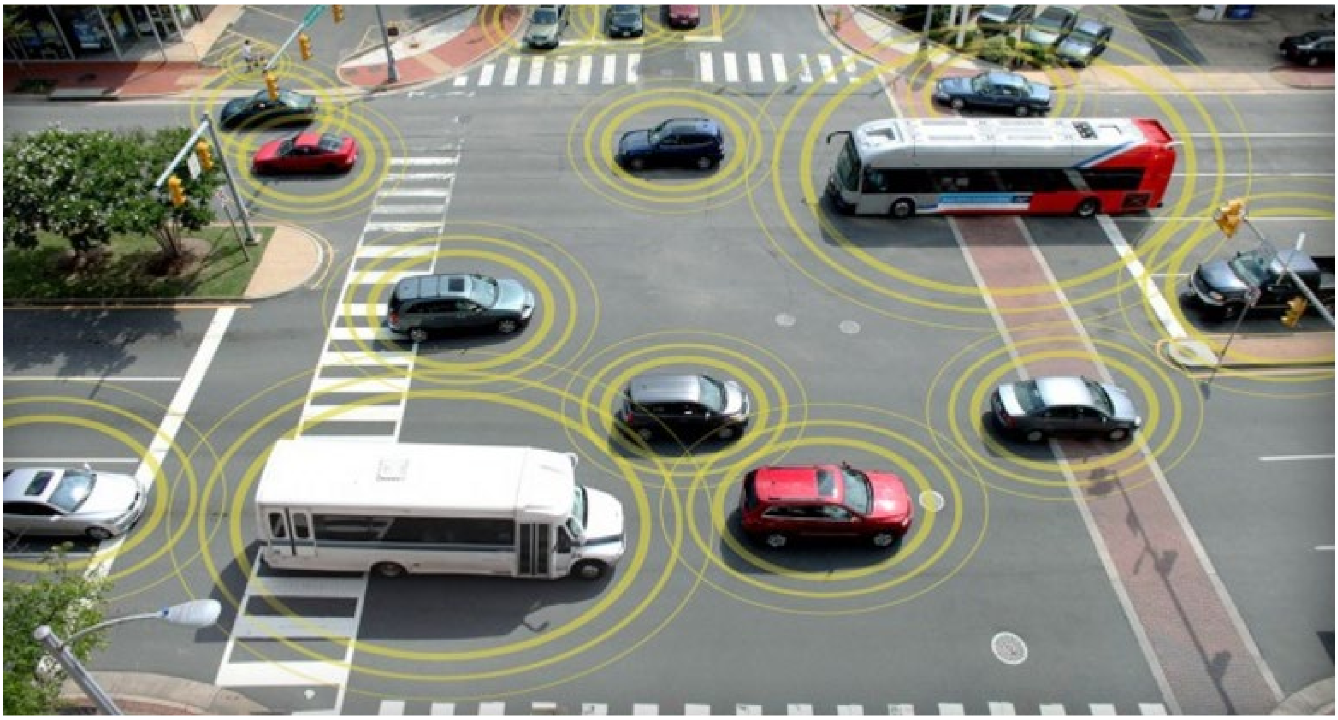


Figure 10 – V2V Communication (Source: National Highway Traffic Safety Administration)

With V2I, vehicles can transmit data to infrastructure, enabling traffic management centers to implement traffic control measures such as dynamically regulated speed limits and alternative route suggestions and distribute information on hazardous situations to the rest of the integrated traffic system.

5.5.3 REMOTE DIAGNOSTIC

Remote diagnostics using telemetry allow issues to be automatically logged, sent to the manufacturer in real-time for diagnoses, remotely fixed or to have a service request registered.

This feature could reduce training requirements and costs, maximise vehicle operability and improve productivity, however is likely to reduce the number of independent repairers and contain service and repair activities to manufacturers.

Figure 11 – Remote Diagnostics (Source: Demand Detroit)

5.5.4 CONSIDERATIONS AND REFLECTIONS FOR AUSTRALIA

Until very recently, telematic systems were GPS (and or GPS and CAN) based and retrofitted to vehicles to enable Operators to track and monitor their fleet. Their use enabled improvements in safety, driver behavior, fuel consumption and better management of maintenance. Now telematics systems are being routinely installed by the vehicle or engine manufacturer and have the capability to record, transmit, and receive data to and from the manufacturer or third parties.

There are a number of issues in relation to telematics that have not yet been resolved and manufacturers each deploy their own strategy. Whilst telematics provides vehicle owners and operators with increased levels of features and convenience, one of the primary aims is to keep vehicles under manufacturer control, within manufacturer extended networks and maximise opportunities for profit through monitoring, servicing and maintenance.

There is no simple checklist for vehicle owners to authorise or accept the growing intrusion that comes with telematics or the ability for example, for owners to share telematics data with their own independent repairers.

» Data ownership. Who owns and has access to the data?

» Privacy and tracking of vehicles. Who has access to vehicle location and operation, how is this stored and how is it used?

» Forced software updates or changes to vehicle operating characteristics without owner consent. Who authorises and makes automated updates and what role does the vehicle owner play?

The standardised deployment of telematics will enable more advanced vehicle technologies, such as platooning and autonomous trucks to be readily deployed, however there are a range of areas that will require regulatory oversight to ensure operator privacy and protections are in place.

Telematics may address some of the issues raised that may occur with the introduction of Euro VI and more advanced emission control systems, in that system functionality can be monitored remotely, issues raised with the operator and remote updates to software and calibrations if and when required.

This type of approach would reduce the training and knowledge requirements of operators whilst maximising vehicle functionality, however it would also reduce the work available to independent repairers and tend to feed maintenance back to vehicle OEMs and their certified maintenance workshops.

6. Appendix – Vehicle Classification

Vehicles are generally broken up into two or more categories for emissions regulations. The main two categories are Light Duty Vehicles (LDV), these are often passenger cars, and Heavy-Duty Vehicles (HDV).

The following glossary defines terms used in the emissions regulations table:

PC Passenger Car

MDPV Medium Duty Passenger Vehicle

LDV Light Duty Vehicle

LDT Light Duty Truck

MDV Medium Duty Vehicle

HDV Heavy Duty Vehicle

GVWR Gross Vehicle Weight Rating

S.I. Spark Ignition

C.I. Compression Ignition

P.I. Positive Ignition (Europe - Petrol, LPG, NG, ethanol, etc engines)

The following classifications apply to vehicles in Europe with four or more wheels, as used in this report.

Passenger Carrying	M1	< 8 Passengers
	M2	> 8 Passengers, < 5 tonnes
	M3	> 8 Passengers, > 5 tonnes
Goods Carrying	N1	< 3.5 tonnes
	N2	3.5 to 12 tonnes
	N3	> 12 tonnes

The U.S. and Europe both classify vehicles according to mass. The following table describes these classifications.

Vehicle Classification by Mass			
Regulatory Body	**Category**	**Class**	**Weight**
EUROPE	LDV	M1, M2, N1, N2	< 2,160 kg
	HDV	M3, N3	> 2,160 kg
U.S. (EPA)	LDV/LDT		< 8500 lb GVWR
	MDPV		< 10,000 lb GVWR
	HDV		> 8500 lb GVWR
U.S. (CARB)	LDT		< 6,000 lb GVWR
	MDV		6,000 to 14,000 lb GVWR
	HDV		> 6,000 lb GVWR

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My sincere thanks to the Perpetual Foundation and Eddy Dunn Endowment. The aim of the Eddy Dunn Endowment International Fellowship is to promote the acquisition of higher-level skills and an appreciation of international best practice in the traditional trade fields, with a particular interest in mechanics. It is intended to examine innovative approaches that demonstrate potential benefits for the Fellow and for Australian industry and enterprises. The research conducted throughout this Fellowship has advanced both my personal knowledge and understanding of heavy vehicle OBD and telematics and will also support industry and enterprises in Australia through the application of its learnings.

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Employer Mentor

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Report Writing Mentor

Sarah Roberts, Board Member, Society of Automotive Engineers Australia

9. Organisations Impacted by the Fellowship

Government:

- National Heavy Vehicle Regulator
- Department of Infrastructure and Regional Development
- All state based vehicle regulators, such as VicRoads and RMS
- Australian Competition and Consumer Commission

Industry:

- Heavy vehicle importers and manufacturers
- Owner operators
- Transport fleet operators

Associations:

- Australian Trucking Association (ATA)
- Australian Road Transport Suppliers Association (ARTSA)
- Society of Automotive Engineers – Australasia (SAE-A)
- Australian Heavy Vehicle Repairers Association (AHVRA)
- Truck Industries Council (TIC)
- Intelligent Transport Systems (ITS)

Education and Training:

- Automotive Skills Australia
- All State based TAFE institutions

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ISS Institute
Level 1, 189 Faraday Street
Carlton VIC 3053

T 03 9347 4583
E info@issinstitute.org.au
W www.issinstitute.org.au

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