

Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices:

- a) Accuracy and robustness
- b) Ancillary systems analysis

Pilot testing plan

Author: **Lloyd Davis**
Department of Main Roads

Co-Author: **Dr. Jonathan Bunker**
Queensland University of Technology

Co-Author: **Dr. Charles Karl**
Transport Certification Australia



Prepared by Lloyd Davis, Dr. Jon Bunker & Dr. Charles Karl
Version no. Mk X
Revision date May 2008
Status pilot programme final draft
DMS ref. no. 890/00037
File/Doc no. 890/00037

File string: C:\masters\Lloyd davis\test plan for OBM pilot testing Mk X.doc

Corresponding author contact:

Lloyd Davis BEng(Elec) GDipl(Control) Cert(QMgt) CEng RPEQ
Fellow, Institution of Engineering & Technology
Principal Electrical Engineer
ITS & Electrical Technology
Planning Design and Operations Division
Main Roads

P 61 (0) 7 3834 2226
M 61 (0) 417 620 582
E davis@student.qut.edu.au

© State of Queensland (Department of Main Roads), Transport Certification Australia Ltd & Queensland University of Technology 2008

Table of Contents

1.	Introduction	8
1.1.	Overall objective of OBM feasibility	9
1.2.	Aims & purpose of this test plan	10
1.3.	Organisation of this test plan	12
1.4.	Actions arising from this test plan.....	14
2.	Background.....	15
2.1.	General	15
2.2.	The need for OBM monitoring.....	17
2.3.	The need for OBM testing.....	17
2.4.	IAP Stage 2.....	18
2.5.	Tasks under the Technical Feasibility Assessment for OBM.....	19
2.5.1.	Literature Review of On-board Mass-Monitoring Technologies	20
2.5.2.	Identify Current and Likely Future Applications	20
2.5.3.	Analyse Responses to Request for Comment On-board Mass-Monitoring.....	21
2.5.4.	Report Findings.....	21
2.6.	Technical Feasibility	22
2.7.	Suitability and Interoperability to the IAP	23
2.8.	Summary of this section.....	23
3.	Principles.....	25

4.	Experimental design philosophy	27
4.1.	General	27
4.2.	Reference OBM system	28
4.3.	Modifications to test HVs if air spring equipped	29
4.4.	Choice of test HVs.....	30
4.5.	Choice of sample size	31
4.6.	Tampering.....	31
4.7.	Choice of test loads	32
4.8.	Alterations to the test vehicle	33
4.9.	Test routes	33
4.10.	Test HV stance.....	33
4.11.	Summary of this section.....	34
5.	Experimental requirements	35
5.1.	General	35
5.2.	Equipment.....	36
5.3.	Description of the test requirements, equipment & data – OBM suppliers	37
5.4.	Description of the test requirements, equipment & data – TCA.....	38
6.	Testing procedure	39
6.1.	General	39
6.2.	Detail.....	40
6.3.	Summary of this section.....	45
7.	Societal obligations	47

7.1.	Workplace health & safety.....	47
7.2.	Ethics.....	47
8.	Conclusion	48
	Appendix 1 - Test data recording form.....	49
	Appendix 2. Risk management plan	53
	Appendix 3. Definitions, Abbreviations & Glossary.....	57
	Appendix 4. Ethics	63
	Appendix 5. Sample size	66
	Appendix 6 - Confidentiality and IP agreement.....	70
	References.....	76

Table of Figures

Figure 1.	Overall OBM feasibility project task/activity interrelations (Karl, 2007).	12
Figure 2.	Linkages between feasibility assessment and future work (Karl, 2007).....	23
Figure 3.	Visual interpretation of accuracy & precision.....	62

Executive Summary

A reasonable response to transport industry pressure for increasing efficiency is for road authorities and regulators to allow higher mass limits (HML) heavy vehicles onto the road network. This forms part of an overall strategy to encourage “multi-combination vehicles” or MCVs (Haldane, 2002) onto portions of the road network that can withstand greater mass loadings. One of the tools used currently and increasingly by regulators and road authorities in Australia to monitor heavy vehicles (HVs) is the Intelligent Access Programme (IAP) under the auspices of Transport Certification Australia (TCA). The IAP monitors the location, timing, speed and configuration of a HV using vehicle telematics and usually incorporates GPS satellite tracking.

The first large-scale application of IAP to HVs will be on HML vehicles. To manage the mass aspects of expanded HML access in the meantime, an interim solution involving a self-declaration function allowing transport operators to identify when they were operating at HML will be part of the initial monitoring of HML HVs under IAP. The reason for this was, in setting up IAP Stage 1, the TCA Board realised that an on-board mass monitoring solution for HVs was potentially several years away. In so doing, the TCA Board realised that the long-term solution to managing HV mass would be *via* on-board mass monitoring technology. To this end, TCA’s 2006/07 business plan, endorsed by the TCA board in July 2006, contained two new research projects to ensure the expansion and value adding of its services to the transport industry and road authorities. The projects have identified technical issues regarding on-board mass monitoring systems including:

- ☞ Determination of tare vs. payload using OBM system at an evidentiary level;
- ☞ Accuracy, robustness and tamper issues of OBM components (mass sensors, connections, power supply, display unit etc.);
- ☞ Potential use of electronic brake system (EBS) data to cross-check measurement results from OBM system; and

- ☞ Potential standardization of OBM components to achieve interoperability between trailers fitted from different supplier.

Accordingly, one of these projects will provide a standard to ensure interoperability between any IAP certified prime mover and trailer monitoring devices. The other project will investigate the feasibility of on-board vehicle mass-monitoring devices for IAP use.

This test plan addresses that portion of the feasibility assessment project concerned with:

- ☞ accuracy as determined by measuring OBM outputs vs. certified scales; and
- ☞ tamper-evidence as garnered from changes to dynamic signals from OBM systems, including from electronic braking systems (EBS) and engine control modules (ECM).

To do so it sets out a programme to test suitable and available OBM systems to be reported by the TCA when the on-board vehicle mass feasibility of project is completed in 2009.

1. Introduction

As expressed in its 2006-2007 business plan, Transport Certification Australia Limited (TCA) has four organisational objectives. Under the fourth objective, to enhance product and service offerings, TCA is committed to commence, jointly with the National Transport Commission (NTC), investigating the feasibility of on-board heavy vehicle (HV) mass-monitoring devices for the intelligent access programme (IAP). This task is simply one of many TCA will undertake on its journey to providing its members and the market it serves with a comprehensive set of certified parameters for monitoring HVs. The set of parameters (location, time, speed, tamper-evidence, and proprietary trailer identification) monitored under IAP Stage 1 provides a robust platform on which Australia can commence providing a third level for regulating HV access: “intelligent access”.

On-board mass, along with interoperability between any IAP certified prime mover and trailer monitoring device, expands the range of applications to which IAP can be applied. This ultimately increases jurisdictional confidence in operational compliance and increases the negotiating power of the IAP for transport operators.

To this end, TCA’s fourth objective provides for two projects for enhancing the technical capability of the IAP, *viz*:

- ☞ a project to provide a standard to ensure interoperability between any IAP certified prime mover and trailer monitoring devices; and
- ☞ a project to investigate the feasibility of on-board vehicle mass-monitoring devices for IAP use.

These new research projects will ensure the expansion and value adding of its services to the transport industry and road authorities. The projects have identified technical issues regarding on-board mass monitoring systems including:

- ☞ Determination of tare vs. payload using OBM system at an evidentiary level;
- ☞ Accuracy, robustness and tamper issues of OBM components (mass sensors, connections, power supply, display unit etc.);

- ☞ Potential use of EBS data to cross-check measurement results from OBM system; and
- ☞ Potential standardization of OBM components to achieve interoperability between trailers fitted from different suppliers.

Accordingly, one of these projects will provide a standard to ensure interoperability between any IAP certified prime mover and trailer monitoring devices. The other project will investigate the feasibility of on-board vehicle mass-monitoring devices for IAP use.

1.1. Overall objective of OBM feasibility

The objective in determining technical feasibility of on-board mass is to ascertain the ability to monitor HV mass to an evidentiary level. This objective *via* delivery of a mass measure that can be utilised for a range of policy objectives including evidentiary-level data that can be produced and judged valid in court of law.

The broad purpose of the feasibility assessment is to:

- a) Produce a report that identifies the state-of-the-art in on-board mass-monitoring technologies and the range of commercial and (quasi-) regulatory applications to which it is applied. The state-of-the-art will be determined by an international literature review and survey of both the Australian telematics and transport industries.
- b) Demonstrate the feasibility of on-board vehicle mass-monitoring with consideration to matters of:
 - impact on, and participation of, industry and jurisdictions (usage);
 - accuracy of mass management;
 - cost; and
 - technology (across all its elements).

c) In partnership with the NTC, identify, broadly, what jurisdictions will have to do to accommodate on-board vehicle mass monitoring as a part of an IAP system.

This would cover:

- changes to internal processes and systems;
- changes to legislation/regulation^a; and
- an articulation of the positives and negatives of nationally consistent approaches to the above^a.

d) Identify broadly what TCA will have to do to accommodate on-board vehicle mass monitoring as part of an IAP system.

This would cover:

- changes to the IAP functional and technical specification;
- the certification and auditing regime, and
- the deeds of agreement.

e) Associated with d) above, deliver a draft functional and technical specification for onboard mass-monitoring devices.

The latter project would lead the way for the introduction of mass as an IAP-monitored vehicle parameter.

1.2. Aims & purpose of this test plan

One of the results from the TCA OBM feasibility project will be a determination of the accuracy and tamper-evidence of such systems. This document addresses that portion of the feasibility assessment concerned with:

- accuracy as determined by measuring OBM outputs vs. certified scales; and

- tamper-evidence as garnered from changes to dynamic signals from OBM systems, including from electronic braking systems (EBS) and engine control modules (ECM).

To do so it sets out a programme to test suitable and available OBM systems. It may be seen from Figure 1 (Karl, 2007) that this test plan will produce results that will inform the 4 tasks of the OBM feasibility project.

The results from the testing programme described in this document will contribute to a TCA report that will cover the following issues in four key areas:

Accuracy and robustness:

The test programme will develop and assess accuracy of various OBM systems on a range of rigid vehicles and combinations, with various suspension types in a range of operating environments across jurisdictions.

Additional data:

The test programme will investigate the potential use of additional data from the electronic braking systems (EBS) or engine control modules (ECM) or other dynamic OBM data as validation against data from the static data recorded by these OBM systems.

Human machine interface:

The test programme will develop agreed best practice guidelines and procedures for installation, calibration, operation and maintenance including consideration of tare mass.

Tamper evidence:

The test programme will identify the main areas of potential tamper and development of both technical and business options to work-around these tamper points.

These four key areas for investigation are shown diagrammatically in Figure 1 and detailed further in Section 2.5.4. The task of field testing is the key sub-project that will assesses the technical feasibility of on-board vehicle mass monitoring.

^a It is anticipated that these activities would be part of the NTC work

Queensland has operated IAP-like on-board mass-monitoring trials for several years, and has recently built on this work by undertaking testing on the accuracy and tamper vulnerability of particular on-board mass-monitoring system(s) being used (Davis, 2006).

It is proposed that the testing will leverage off the Queensland work to date to maximise the value of that work and the already established network of contacts.

The detailed arrangements for this task are dependent on a series of factors that will only be quantifiable after the experimental design is finalised and the availability and suitability of different systems is determined (including the commercial arrangements pertaining to their use and testing).

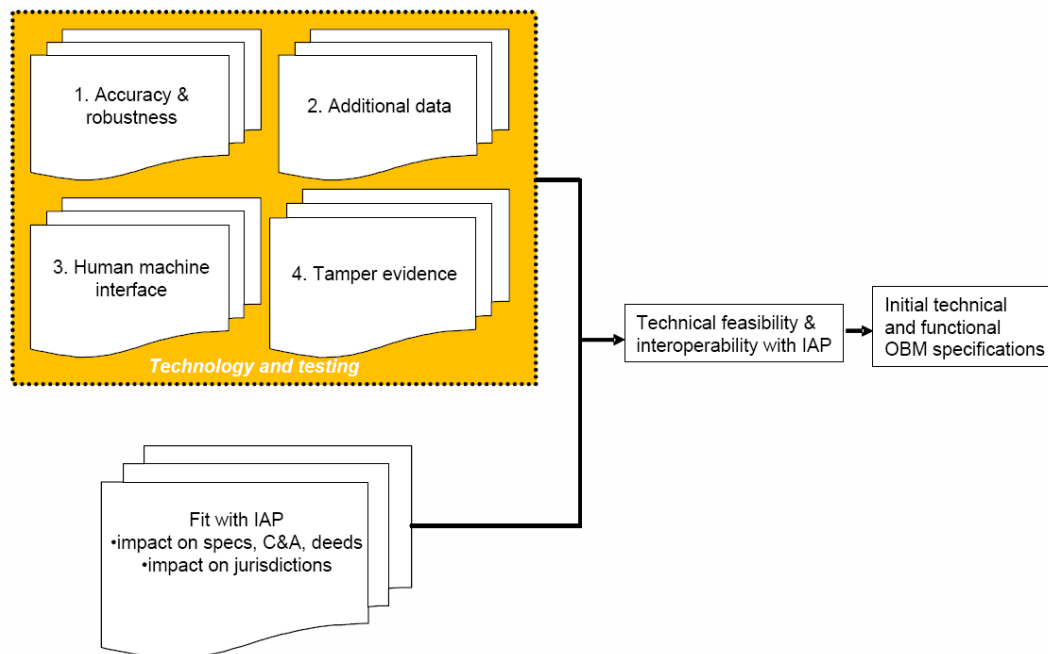


Figure 1. Overall OBM feasibility project task/activity interrelations (Karl, 2007).

1.3. Organisation of this test plan

The testing outlined in this test plan involves determining the performance of HV OBM systems as mentioned above:

- accuracy as determined by measuring OBM outputs vs. certified scales; and

- tamper-evidence as garnered from changes to dynamic signals from OBM systems, including from electronic braking systems (EBS) and engine control modules (ECM).

The divisions in this test plan are designed to lead the reader through the following steps toward the realisation of the testing of OBM for accuracy and to inform tamper-evidence as part of the larger project. Accordingly, the sections associated with the realisation of those aims and objectives are listed in summary here with an indication of the section content to which the reader is directed for detailed commentary on each:

Section 2 provides the background needs that have resulted in the push for OBM testing and the rationale that has led to the current state of events: *viz.*, now that OBM feasibility is being investigated. **Section 2** also outlines the activities such as the literature review undertaken by ARRB and the tasks required under the overall OBM feasibility programme.

Section 3 outlines the values under which this test plan will be realised. This sets out, in the broadest macro view, the fundamental principles of the testing defined by this test plan.

Section 4 provides detail on the design philosophy for the experiments which will form the input data for analysis under this accuracy and tamper-evidence sub-project. **Section 4** includes explanations for the choices made, as embodied in the testing as part of the experimental design, in the process of forming the test methodology. These include the choice of test HVs, how they will stand, rudimentary tamper procedures, alterations to HVs under test and the number of tests to be carried out. It also outlines the provisions for cross-validation of the test measurements against two reference OBM systems as well as certified weighing devices to be used.

Section 5 outlines the experimental requirements for this test plan. This includes the equipment to be used, and the roles and responsibilities of the various parties involved.

Section 6 defines the procedures to be used for the testing under this test plan and includes a cross-reference to Appendix 1 - Test data recording form.

Section 7 defines the mandatory and statutory requirements and obligations as set out under the policies of the authorship organisations with concluding observations in **Section 8**.

Three figures are included in the test plan. The first, Figure 1 above, shows the interlinkages between the OBM feasibility elements and the IAP in general. The second, Figure 2, shows how the OBM feasibility programme tasks are aligned temporally and conceptually with respect to the broader IAP framework. Precision is an assessment of the variation in measurement of the same value. The difference between precision and accuracy is shown as a visual representation in Figure 3 which is also used to illustrate the test plan design philosophy for sample size in Section 4.5.

1.4. Actions arising from this test plan

This test plan has been circulated to jurisdictions. ARRB and TCA have undertaken limited testing in Brisbane in April/May 2008. This test plan has been modified as a result of the learnings from those tests. OBM system suppliers or their representatives have been invited to comment in the requested time-frame. From the results of the test plan and on receipt of the OBM industry comments:

- ☞ this test plan will continue to be modified;
- ☞ a small-scale “pilot” set of tests will be continued by the OBM team;
- ☞ the test plan will be reviewed in light of any learnings from the pilot;
- ☞ the test plan will be modified by the OBM team to incorporate those learnings;
- ☞ a modified test plan will be circulated; and
- ☞ final implementation of full-scale testing involving all vehicles, the OBM team and all OBM suppliers or their representatives will occur.

Timing of these activities will be advised to all stakeholders as the stages of the testing is undertaken. It is envisaged at the time of releasing this version of the test plan that the final round of testing will be in late May to June 2008.

2. Background

2.1. General

Road authorities and transport regulators are under continuous pressure from the transport industry to allow “freight efficient” vehicles onto the road network. Outputs from the final report of the DIVINE project (OECD, 1998) were used in Australia to support the argument that air-sprung HVs should carry greater mass under the micro-economic reform popular in the 1980s and 1990s in Australia. One of these reforms was the mass limits review (MLR) project as implemented under the second heavy vehicle reform package (National Transport Commission, 2003). This was concluded that HVs would be allowed to operate at HML loadings if:

- certain vehicle design standards were met; and
- HVs at HML loadings kept to specified routes (*viz*: the “HML network” in each State).

This resulted in the implementation of HML schemes in various guises in all Australian States. Details vary between Australian States in terms of HML access and conditions but, in terms of additional mass, HML generally allows increases above statutory mass of $\Delta 2.5\text{t}$ on a HV tri-axle group and $\Delta 0.5\text{t}$ on a HV tandem axle group.

The implementation of the various HML schemes in Australia has not stopped the road transport industry pressuring road authorities and transport regulators for more concessions on mass and vehicle combinations, however. The road transport industry’s response to continued pressure from their clients for ever-increasing efficiency generally involves proposing HVs towing more trailers with:

- a greater number of axles or axle groups;
- more gross vehicle mass (GVM);
- greater axle loadings; and/or
- greater axle group loadings.

Fewer prime movers and drivers for a given freight task make these scenarios more attractive financially to transport operators and their clients. Accordingly, increasing numbers of HVs with more trailers, greater axle masses and axle group masses have been rolled out in response to such pressures. The first serious post-HML wave of these types of HVs is now operational although these vehicles have been on the network in various forms since the 1980s (Haldane, 2002) under the generic term “multi-combination vehicles” or MCVs.

In an effort to manage these non-standard HVs (including those operating at HML) and keep them to their permitted routes, regulators and road authorities developed the Intelligent Access Project in the late 1990’s. This project has now borne fruit in the form of a regulatory body, Transport Certification Australia and implementation of the Intelligent Access Programme.

The first tranche of vehicles considered for Intelligent Access Programme monitoring in NSW and Queensland were HML vehicles. Indeed, the agreement between two Australian States and the Commonwealth (Australia Department of Transport and Regional Services, 2005a, 2005b) specified that greater network access for HML vehicles was contingent on their being tracked using GPS technology *via* the IAP. Up until that point, the IAP managers had considered implementation of on-board mass monitoring as a Stage 2 activity within the IAP implementation framework. This was due to the complexity of OBM coupled with an already intricate and exhaustive Stage 1 programme negotiated with 6 Australian States, 2 Australian Territories and set up to monitor location, timing, speed and configuration of HVs.

2.2. The need for OBM monitoring

In light of the growing freight task, asset protection has become an increasingly important issue for transport jurisdictions and regulators. With the demand for higher productivity vehicles driving national agendas such as performance-based standards (PBS), TCA has embarked on a programme of improving the number and value of its services. One of these expansions may be OBM. To this end, this test programme will inform the feasibility of OBM systems with a view to adding that feature to the IAP. Accordingly, this test programme will result in broad potential benefits and applicability to TCA stakeholders as outlined in Section 2.4.

2.3. The need for OBM testing

All Australian States have a Bilateral Infrastructure Funding Agreement (BIFA) with the Australian Government. These are also known as the “AusLink agreements”. Each BIFA is an agreement between individual States of Australia and the Commonwealth which covers arrangements applying to “funding made available by the Australian Government to [all Australian States] under the first five-year AusLink investment programme (2004-05 to 2008-09) and any agreed subsequent changes to, and extensions of, the programme. It also covers agreed arrangements for infrastructure planning, identification of investment priorities, development and assessment of project proposals and evaluation of completed projects” (Australia Department of Transport and Regional Services, 2005b).

An alteration to the focus of TCA occurred with respect to OBM (see Background). This was triggered by NSW’s and Queensland’s BIFA (Australia Department of Transport and Regional Services, 2005a, 2005b) obligations in that HML vehicles be monitored by the IAP.

Specifically Queensland’s BIFA states (authors’ bolding for emphasis):

“74) Accordingly, both parties agree to work co-operatively towards ensuring a structured sensible extension of **HML vehicle** access onto a broader strategic network. It is agreed that further extensions will reflect the following principles:

a) Both parties commit to accelerating the development of the Intelligent Access Program (IAP). Specifically, both parties:

- i. support vehicle tracking with suitable **mass compliance functionality being implemented for all HML vehicles** on a national basis, and eventually to other restricted access heavy vehicle categories; and
- ii. agree that access to **HML will be conditional on an enforceable commitment from all operators to participate in the full IAP process** from the time that it is operational and available.

The Australian Government will provide funding to:

- the National Transport Commission (NTC) and/or Transport Certification Australian Limited, as appropriate, to accelerate this process with a view to ensuring that both route access and mass compliance can be accurately monitored and regulatory breaches enforced.....”

NSW’s BIFA contains the following provisions:

“66) **Access conditions for HML-eligible vehicles** operating on the NSW network shall be as follows:

...c) vehicles **shall be enrolled in a route-compliance monitoring regime using the Intelligent Access Program (IAP)**, from the time that it is operational and available...”

2.4. IAP Stage 2

At its August 2005 meeting, the TCA Board of Directors considered and endorsed Version 1 of the 2005/06 business plan. At that meeting, the Board of Directors agreed to move to Stage 2 of IAP. The move was triggered by the NSW and Queensland obligations under their respective BIFAs to use IAP as a condition to the expansion of their HML network (Australia Department of Transport and Regional Services, 2005a, 2005b). The Board also requested that a revised business plan be

developed to address this move to Stage 2. This decision introduced a new complexity to the IAP domain.

As mentioned above, Stage 1 of IAP was designed to manage the location, timing, speed and configuration of a HV. The large-scale application of IAP to HML vehicles requires the management of vehicle mass. Though it was acknowledged that the ideal way to manage mass is *via* on-board mass monitoring technology; in setting up IAP Stage 1, the TCA Board realised that solution was potentially several years away. To manage the mass aspects of expanded HML access in the meantime, the Board endorsed an interim self-declaration function allowing transport operators to identify when they were operating at HML. This is supported currently by a slightly revised National Heavy Vehicle Accreditation Scheme (NHVAS).

The TCA's 2006/07 business plan was endorsed by the TCA board at its meeting in July 2006. That business plan included two projects for enhancing the technical capability of the IAP:

- a project to provide a standard to ensure interoperability between any IAP certified prime mover and trailer monitoring devices; and
- a project to investigate the feasibility of on-board vehicle mass-monitoring devices for IAP use.

2.5. Tasks under the Technical Feasibility Assessment for OBM

This section details the tasks, as part of the background to the OBM test programme, that are defined in the current project plan for the overarching TCA project entitled *Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices*.

2.5.1. Literature Review of On-board Mass-Monitoring Technologies

This literature review will include coverage of the issues canvassed in the TCA Request for Comment On-board Mass-Monitoring (Transport Certification Australia Limited, 2007). This report was produced and paid for by TCA in September 2007.

2.5.2. Identify Current and Likely Future Applications

The range of commercial and (quasi-) regulatory applications to which on-board mass monitoring technologies are applied will be determined by:

- Reviewing the responses to the TCA Request for Comment On-board Mass-Monitoring.
- Engaging with members of both the TCA IAP Focus Group, IAP User Group and the Jurisdictional Liaison Group (JLG).

The focus of this task would be to identify the benchmark for on-board mass-monitoring technologies to address these applications. This will inform the work of the NTC in identification of specific applications based on policy requirements. It is anticipated the range of applications will include:

- certified weights and measures applications a subset of which will likely be enforcement and compliance of vehicle mass limits;
- commercial fleet and freight management;
- asset management applications including, but not limited to, the use of on-board mass-monitoring to manage access to vulnerable road network assets (bridges, culverts, pavements, alignment constraints, etc); and
- envisaged IAP applications.

2.5.3. Analyse Responses to Request for Comment On-board Mass-Monitoring

The responses to the TCA Request for Comment On-board Mass-Monitoring will be analysed and used to:

- augment the literature review; and
- ratify the identified applications.

2.5.4. Report Findings

The report will:

- present the results of the literature review with individual technologies and solutions;
- draw conclusions as to the suitability of different technologies and solutions to address the various applications including implication for Australian Design Rule (ADR) compliance (eg: wiring or engine management requirements associated with providing a tamper proof system);
- incorporate the findings from the analysis of the Request for Comments responses; and
- articulate a way forward listing the costing and technological issues researched in preparation for a continued joint NTC/TCA work on the development of TCA certified on-board mass-monitoring devices.

The report will also cover:

- an overview of the existing approaches to measuring mass;
- definitions of mass and the implication of different definitions in measuring mass (gross mass, mass per axle etc);
- devices available, including claimed accuracies and conditions of operation;

- a report of the devices in terms of being accurate, tamper proof and monitored for compliance (tamper evident);
- an estimation of the costs associated with implementation and operation of devices;
- potential linkages to IAP capabilities;
- identification of the current limitations of the technology; and
- any emerging developments to overcome these limitations (including expected timelines).

2.6. Technical Feasibility

The final report on the OBM industry will then lead into the feasibility assessment as shown in Figure 2 (Karl, 2007) below. TCA's technical feasibility assessment is described in the following subsections. The outcome of the feasibility assessment will be a set of initial specifications for a regulatory OBM system and anticipated impact across TCA and jurisdictional systems from an IAP implementation perspective. The technical feasibility assessment will be complemented by a parallel investigation by the NTC that will focus on the policy issues and implications. The testing regime will comprise the four key areas as outlined previously in Section 1.2 and shown previously in Figure 1.

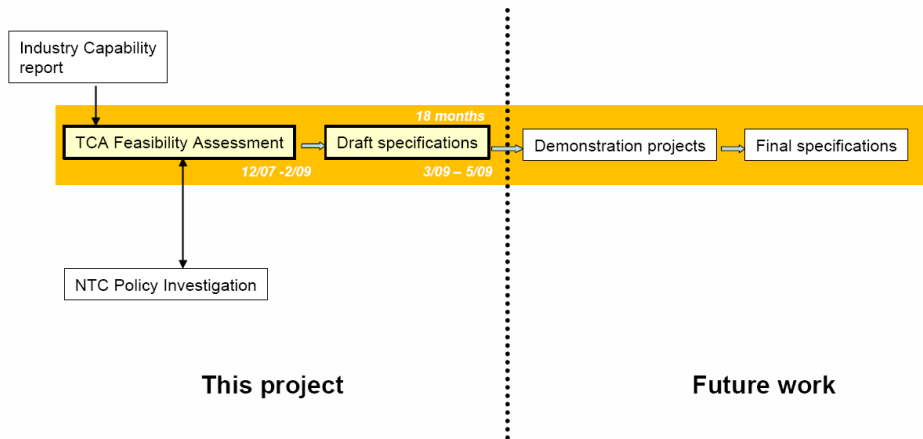


Figure 2. Linkages between feasibility assessment and future work (Karl, 2007).

Field testing under this test plan is a key sub-project that will assess the technical feasibility of HV on-board mass monitoring. Accordingly, a robust experimental design (see Section 4) will be undertaken to test suitable and available OBM systems.

2.7. Suitability and Interoperability to the IAP

A consultancy will be undertaken that will identify, broadly, what TCA will have to do to accommodate on-board vehicle mass monitoring as part of an IAP system (Figure 1). This will cover:

- changes to the Functional and Technical Specification;
- the certification and auditing regime; and
- the deeds of agreement.

2.8. Summary of this section

Stage 1 of the implementation of IAP did not consider OBM as feasible within the project framework. This due to the complexity of introducing a new HV monitoring regime in Australia, the novelty of OBM and the original intent that Stage 1 of IAP would monitor only the location, timing, speed and configuration of HVs.

With its Stage 1 programme almost implemented, TCA is investigating the feasibility of OBM for HVs under Stage 2 of its on-going business programme. Should OBM be implemented under IAP, the first tranche of HVs to be thus equipped and monitored will be HML vehicles. This due initially to the provisions of the BIFAs between the Australian Government and both NSW and Queensland. Other States and Territories have joined with this approach at the Board level of the TCA. This means that two projects for enhancing the technical capability of the IAP have been initiated:

- a project to provide a standard to ensure interoperability between any IAP certified prime mover and trailer monitoring devices; and
- a project to investigate the feasibility of on-board vehicle mass-monitoring devices for IAP use.

The second of these projects, entitled *Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices* will address:

- a) an overview of the existing approaches to measuring mass;
- b) definitions of mass and the implication of different definitions in measuring mass (gross mass, mass per axle etc);
- c) devices available, including claimed accuracies and conditions of operation;
- d) a report of the devices in terms of being accurate, tamper proof and monitored for compliance (tamper evident) including the practical aspects of certifying devices to national accuracy standards;
- e) an estimation of the costs associated with implementation and operation of devices;
- f) potential linkages to IAP capabilities;
- g) identification of the current limitations of the technology; and

any emerging developments to overcome these limitations (including expected timelines).

3. Principles

The testing to be undertaken under this test plan and the associated test programme defined herein will operate under the following principals:

- all parties operate in good faith toward the outcome of this test programme, *viz*; determine the feasibility of using on-board mass systems to monitor HV mass at the evidentiary level and thus achieve the objectives and aims as set out herein;
- all parties will attempt to minimise their expenditure;
- experimental rigour will be applied in the design of the testing. This will include, but not be limited to:
 - ☞ the use of OBM reference systems; and
 - ☞ the supply and cross-validation of manufacturer's suspension data against measured values derived from OBM test data;
- existing, installed OBM systems on working HVs will be the subject of the testing;
- TCA will meet the following costs:
 - ☞ test team/s costs; and
 - ☞ reasonable pre-testing procedures (such as those necessary to determine suspension parameters of nominated test vehicles);
- as the main beneficiaries of OBM monitoring of HVs through the IAP, in-kind support from OBM suppliers or their representatives will facilitate this test programme;
- type and configuration selection of test vehicle/s will be by the TCA OBM team in consultation with the IAP jurisdictions and the IAP Board;
- supply of the test vehicles will be facilitated by the OBM suppliers or their representatives and be as per Section 5.3;

- test sites will be negotiated jointly by the OBM suppliers or their representatives and the TCA OBM team;
- as the primary point of contact between existing OBM systems and the transport operators who use them, the OBM suppliers or their representatives will be key in facilitating negotiations between the owners of the test vehicles and the TCA team;
- in the course of the Participant's participation in the Project, both TCA and the Participant will provide to the other access to certain confidential proprietary information and intellectual property (IP);
- TCA and OBM suppliers or their representatives wish to safeguard their respective rights in and to their respective confidential information and intellectual property; and
- the details of the safeguarding of confidential proprietary information and intellectual property will be as set out in the Deed of Agreement – Confidentiality & Intellectual Property (Transport Certification Australia Limited, 2008) attached in Appendix 6 - Confidentiality and IP agreement

4. Experimental design philosophy

4.1. General

Robust experimental design involves the use of:

- ☞ cross-validation of data;
- ☞ provision of a “control” test group or data-set with which to compare the “test” data set;
- ☞ consistent test procedures;
- ☞ consistent test methodology;
- ☞ reduction, to the greatest possible extent, of variation in external influences between tests; and
- ☞ adequately sized sample sets.

The following section details the testing to be undertaken using this test plan and how it will achieve the requirements for robust experimental design.

This test plan forms part of an overall robust experimental design to test suitable and available on-board mass measurement systems. The overarching drivers for the testing have been outlined previously in Section 2.2 and 2.3. This test plan document defines the experimental methodology to resolve some of the issues with respect to OBM and other systems. To do this the testing described in this test plan covers:

- ☞ accuracy and robustness: Development of test methodology for, and assessment of the accuracy of, various OBM systems on a range of rigid vehicles and combinations, with various suspension types in a range of operating environments across jurisdictions;

- ☞ additional data: Investigation of the potential use of additional data from the electronic braking systems (EBS) or engine control modules (ECM) or the dynamic OBM data as a cross-reference to the static data recorded by other portions of OBM systems; and
- ☞ tamper evidence: Investigation of the feasibility of determining tamper events by examining sudden changes in the dominant frequencies present in EBS, ECM or dynamic OBM data.

4.2. Reference OBM systems

Each OBM system tested will produce its own set of data. These data sets will be measured against the weighbridge or certified scales using the forms in Appendix 1 - Test data recording form.

As a cross-validation of the data set from each test OBM, particularly for the dynamic data to be recorded, another set of data needs to be recorded. This data needs to be recorded by a system which is universal for all tests, regardless of vehicle. The data from this system will provide a set of static and dynamic reference data. Two OBM systems common to all the tests and vehicles will be used and are termed the reference OBM systems. One of them will record static and dynamic data contemporaneously with the OBM system under test. The other will record static data only. The reference OBM systems will be installed on all test HVs to provide a consistent set of data across all test HVs. One outcome of the use of the reference OBM systems will be the ability to compare the measured mass (MM) reading of the reference OBM systems to the MM reading of the test system and to the reference mass (RM) reading from the weighbridge. Accordingly, three measured mass (MM) readings will be taken per test, one from each of the reference OBM systems and one from the test OBM system. This will be done using three copies of the form in Appendix 1 - Test data recording form.

n.b: the RM will be measured from the weighbridge or other certified scales: there will be three MM readings per test, one for each the reference OBM system and one from the test OBM system.

Accordingly, the reference OBM systems:

- ☞ will be supplied by TCA;
- ☞ will be installed on each test HV by TCA or organisations convenient to TCA constituent members;
- ☞ will be common across all test vehicles; and
- ☞ will record and store a static and dynamic dataset for each test on each test HV.

In summary:

- ☞ the dataset recorded and stored by the OBM reference systems will be used as the common reference dataset *across all test vehicles*. This will be for the purposes of comparison with the static and dynamic datasets recorded from the OBM systems under test; and
- ☞ the measured mass (MM) of the reference OBM systems will be recorded against the reference mass (RM) from the weighbridge or certified scales using the form in Appendix 1 - Test data recording form, no differently from the procedure for the test OBM system, providing a further cross-check under this test regime.

4.3. Modifications to test HVs if air spring equipped

Some test HVs will utilise air-spring pressure to determine on-board mass readings. For those cases, a blanked-off ¼” tee-piece will need to be inserted in the high pressure air line to the air springs of the axle group where pressure is measured to determine the mass on that group. These will need to be connected from all test APTs (in use for the tests) to the high-pressure air spring air lines using auxiliary air line(s) with a ball valve or turncock valve interposed between the tee-piece and the APT. These additional air lines to with the valve installed will enable full or partial closure of the auxiliary air line(s) to all installed APTs for the readings under Step 8 in Section 6.2.

4.4. Choice of test HVs

This test programme will prefer to source HVs with certified road friendly suspension (RFS). This is because:

- the Queensland and NSW BIFAs define HML access to be monitored under the IAP operating environment;
- the requirement to monitor HML vehicles using IAP has prompted an OBM experimental programme to be implemented (of which this document describes a part) through the TCA business plan (refer to Background - Section 2.4 for details);
- HVs operating at HML loadings are required to have RFS; and
- HVs operating at HML loadings are the target group for OBM implementation.

Accordingly, any HV operating at HML loadings will be monitored under the aegis of IAP, potentially using an OBM system. The proposal therefore has RFS & OBM present concurrently on HVs accessing the HML network. Accordingly, under this OBM test programme, it will be preferable to use RFS-equipped HVs. One benefit of this approach is that the suspension manufacturer can provide the RFS characteristics of frequency and damping ratio as part of the RFS certification.

Some jurisdictions are interested in the application of OBM to special purpose vehicles (SPVs) - in particular, cranes. If appropriate vehicles with OBM systems installed are readily available, the testing program will include these SPVs.

Where:

- ☞ HVs without RFS are nominated for testing; or
- ☞ HVs with RFS but without RFS certification are nominated for testing,

these vehicles have their suspensions tested for fundamental frequency and damping ratio characteristics before the tests start. The co-ordination of this testing will be by the project manager.

4.5. Choice of sample size

Reduced error, increased accuracy and increased precision in test programmes arises from repeated measurements. Measurements, necessarily, involve cost. Accordingly, a balance needs to be struck between the number of tests and the acceptable error. This issue is a major influence in the choice of sample size.

For each load condition, *viz*: tare, 1/3, 2/3 and full load; data readings will be taken a number of times to improve the reliability and accuracy of the results.

The sample size has been determined from the process outlined in Appendix 5 and summarised here.

If a 95% level of confidence is chosen and reasonable assumptions are made about:

- ☞ an experimental error value; and
- ☞ the spread of measurements from the population of OBM systems,

this leads to the necessity for 6 readings per load condition. Including the initial test at the start, this means 5 HV runs with a reading of the reference mass (RM) and the measured mass (MM) at the start and finish of each run = 5 repeated readings per test load condition without changing any other variables.

4.6. Tampering

HV regulators regard tampering as a major issue. Controlled tampering during the tests will be carried out to determine if the effects of that tampering can be detected from changes in the data. Accordingly, some basic tampering has been included in Section 6.2 which involves changing the operation of the test vehicle or its systems.

4.7. Choice of test loads

As mentioned in Section 4.5, a large number of repeated measurements is the ideal and reduces error. Measurements, however, necessitate expenditure, complexity, difficulty, resources and time. Accordingly, the compromise when designing experimental methodology will always be between the quantity of tests and experimental error. The quantity of measurements is therefore determined, ultimately, by an acceptable level of error.

For a given number of test load conditions, as a proportion of full load, a certain error is expected when the reference mass (RM) is plotted against the measured mass (MM) for each vehicle and each OBM system. Accordingly, a balance between fairness to the OBM system under test and the complexity, cost and time required to test increased numbers of load conditions needs to be made. The following reasonable assumptions have been made:

- ☞ the OBM system under test will be tested from no-load (tare) to full-scale deflection (FSD); hence tare and full-load will be two of the load conditions; and
- ☞ linearity of the scale of the OBM under test is important; hence two^b more test points (load conditions) are required between tare and FSD.

Equi-spacing these test point across the scale of the OBM under test provides the following four load conditions *viz*:

- ☞ tare;
- ☞ 1/3 load;
- ☞ 2/3 load; and

^b A minimum of one more point between tare and FSD would, in theory, provide a measure of linearity provided the MM vs. RM relationship was linear and not bi-modal. The choice of 4 points eliminates the possibility of a bi-modal MM vs. RM relationship going undetected.

☞ full load.

The intermediate loadings need not be exact since a pragmatic tolerance of (say) +/- 5% will not interfere with the process of plotting the reference mass (RM) against the measured mass (MM) for each vehicle.

Where HVs operating at other than HML loadings, such as statutory mass or concessional loading schemes, are chosen for testing, the maximum load of that HV will be nominated as “Full load” for the testing, partial loads calculated accordingly and all loads noted as such on the form in Appendix 1 - Test data recording form.

4.8. Alterations to the test vehicle

Some OBM system use an algorithm to determine steer axle mass as a proportion of the moment of the load on the 5th wheel. Some OBM systems are calibrated with the fuel tank full. The tests will need to determine whether altering 5th wheel sliders (where fitted) or fuel loads have an effect on pre-programmed OBM algorithms. A basic test altering these variables has been designed into the methodology outlined in Section 6.2.

4.9. Test routes

The suspension of the HV will need to be exercised between test readings to ensure that bushing hysteresis, inter-leaf friction, air bag stretch, etc, are averaged out over the readings. This means that each test HV will be required to perform some travel activity before returning to be weighed again. It would be preferable that the circuit be pre-defined, depending on logistical arrangements.

4.10. Test HV stance

The effect on OBM systems when the HV is standing on different slopes and any effect that brake wind-up may exert on the OBM reading will be measured.

Accordingly, the test method will incorporate taking a reading when the HV is level with the brakes both on and off as well as on different cross-slopes and longitudinal slopes. These are detailed further in Section 6.1.

4.11. Summary of this section

This section has set down the background philosophy for the choices used in the experimental design of this test plan. These have resulted in a requirement for 4 approximately equi-spaced test loads, some travel activity between tests, brake application, OBM readings on differing slopes and 16 measurements per test vehicle per test load condition. Some basic tampering will need to be carried out to determine if data will change as a result during the tests.

5. Experimental requirements

5.1. General

The test programme to be undertaken as part of the project entitled *Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices* and as defined in this document will use resources from Main Roads WA (MRWA), Transport South Australia (TSA), Victorian (VicRoads) and Queensland (Main Roads) jurisdictions. The procurement and deployment of these resources will be co-ordinated by the OBM project manager, Dr. Charles Karl, the TCA and officers seconded to the TCA from member jurisdictions. As well as these resources, HVs fitted with various forms of OBM systems such as air-spring pressure measurement, load cells, ECM- derived or EBS-derived OBM data will be used.

The OBM systems will be tested for:

- accuracy
- precision (repeatability);
- dynamic data and
- tampering, as evidenced by changes in dynamic data.

The following section outlines the equipment and procedural requirements for the test programme.

5.2. Equipment

The following equipment will be required to perform the testing:

Items	No.	Source
Certified scales or weighbridges	t.b.a.	QT, VicRoads, MRWA or access to private weighbridges facilitated <i>via</i> participating OBM system manufacturers &/or suppliers
HV with OBM installed and calibrated to the manufacturer's specifications.	“	OBM system manufacturers &/or suppliers
OBM systems, instrumentation, recording devices, ancillary equipment and wiring attached and installed by the OBM suppliers or their representatives;	“	OBM suppliers or their representatives;
A set of extra air line extension pieces.	1 air line and valve per APT	These to connect all APTs (in use for the tests) to the high-pressure air spring air lines. These additional air lines to have a pneumatic turncock or manual ball valve installed enabling full or partial closure of the auxiliary air line(s) to all installed APTs.
OBM reference system	2 per test HV	TCA
Wheel chocks	“	Participating jurisdiction.
Tamper devices	“	TCA team
Personnel	“	Participating jurisdictions & TCA.
Test loads	3	OBM suppliers or their representatives.
Workplace health and safety equipment	t.b.a.	Governed per participating jurisdiction.

5.3. Description of the test requirements, equipment & data – OBM suppliers or their representatives

The testing will be an experimental process that incorporates the following equipment, activities, data outputs, certifications, locations and associated responsibilities:

- 1) test HVs supplied by the OBM suppliers or their representatives. It is envisaged that this could be facilitated by OBM suppliers or their representatives holding over a HV with a newly-fitted and calibrated OBM system for a few days before delivery or facilitating contact with transport operators working HVs in locations convenient to weighbridges;
- 2) OBM suppliers or their representatives to ensure that test HVs have current registration, safety and any other necessary certification to operate in the jurisdiction where the testing is being carried out;
- 3) test loads supplied by the OBM suppliers or their representatives;
- 4) OBM systems, instrumentation, recording devices, ancillary equipment and wiring attached and installed by the OBM suppliers or their representatives;
- 5) rigorous calibration of OBM systems, over the range of static loading conditions from tare to full-load, by the OBM suppliers or their representatives;
- 6) OBM suppliers or their representatives to witness the testing;
- 7) static and dynamic data recorded at intervals not larger than 1/100th of a second as follows:
 - a) OBM readings comprising:
 - i) for strain gauge-based systems: load cell strain readings;
 - ii) for air spring pressure-based systems; air pressure transducer (APT) readings; and
 - iii) data from the ECM or the EBS from systems utilising such data to determine OBM as nominated by the OBM suppliers or their representatives.

- 8) a copy of all raw data from the OBM under test:
 - (a) during the static tests; and
 - (b) from the on-road test runs in a digital format

supplied to the TCA team by the OBM suppliers or their representatives; and
- 9) raw data digital format: raw data variable vs. a linear time-series able to be readily mapped to commercially-available spreadsheet software^c such as Microsoft Excel[®] or MATLAB[®] *without macros or other post processing*.
- 10) The location of the test routes, flat measurement surface and the sloping site(s) may vary depending on logistical arrangements between jurisdictions, OBM suppliers or their representatives, HV availability and TCA personnel. The suitability of the routes, flat areas and the sloped areas for measurements will be determined by consensus between TCA personnel and OBM suppliers or their representatives.
- 11) HV manufacturer's VSB11 testing data or certification to VSB11 supplied by the OBM suppliers or their representatives (who may wish to source sufficient VSB11 information from vehicle manufacturers).

5.4. Description of the test requirements, equipment & data – TCA

- 1) Where HVs without RFS or HVs with RFS but without RFS certification are nominated for testing, these vehicles will have their suspensions tested for fundamental frequency and damping ratio characteristics before the tests start. This testing will be by the project manager.
- 2) Two OBM systems, nominated as *the OBM reference systems*, will be supplied by TCA and installed on each test HV by TCA or organisations convenient to TCA constituent members.

^c Excel is the product of Microsoft Corporation; MATLAB is the product of The MathWorks, Inc.

6. Testing procedure

6.1. General

The overall methodology will be to measure the reference mass (RM) of the supplied HV and its measured mass (MM) using the forms in Appendix 1 for the reference OBM systems and the test OBM system. The axle/axle group RM from the reference OBM systems and the test OBM system will be recorded a number of times for the following HV stances:

- (a) flat, brakes not released (i.e. just come to a stop);
- (b) flat, brakes released;
- (c) parked uphill;
- (d) parked downhill;
- (e) parked on a slope with a lean to the left; and
- (f) parked on a slope with a lean to the right.

To ensure that the suspension of the HV is suitably exercised between test readings, the HV will travel a pre-defined circuit and return to the original weighing station or another weighing station. Differences in readings for the latter option will be evident and these will be compensated for, in the event of this eventuality, by the use of the reference OBM systems. The pre-defined circuit need not be lengthy, just sufficient to exercise the HVs suspension and dependant on logistical arrangements. The circuit may be part of the test HV's normal activities and route or comprise driving off the weighbridge, onto the network and up to normal operating speed, U-turn and back onto the weighbridge.

In addition to these data in a) to f) above, the dynamic data from the reference OBM systems and the test OBM system will be recorded.

The measurement and recording process for the data will be undertaken using:

- certified scales as supplied by jurisdictions participating in this test programme or commercial weighbridges commissioned for the purpose;
- HVs with the reference OBM systems and the test OBM system installed (HVs and test OBM systems supplied by OBM suppliers participating in this test programme); and
- personnel from the TCA and participating jurisdictions.

The scales may vary depending on logistical arrangements in each State, OBM supplier and jurisdiction. As part of the analysis phase, the RM will be compared with the measured mass (MM) in the 3 HV stances as read from the reference OBM systems and the test OBM system (including ECM and EBS data) installed in each test HV. This will be to determine the accuracy of the system under test by comparing the RM reading with the MM reading for:

- the HV on level ground;
- brake application (i.e. brake wind-up sensitivity);
- the HV nose-up;
- the HV nose-down;
- the HV with a lean to the left; and
- the HV with a lean to the right.

The dynamic data will be analysed for frequency and range dynamics using Fast Fourier Transform (FFT) and other techniques as evidence of tampering.

6.2. Detail

- 1) The test HV(s) will be delivered to a nominated site and allowed to cool down from normal operation (cold start) with:
 - (a) a full fuel tank;

- (b) the turntable slider (if fitted) in the position that it was in when the OBM was calibrated;
 - (c) the reference OBM systems; and
 - (d) the OBM system under test installed.
- i) While using the Appendix 1 - Test data recording form, TCA personnel and/or other OBM team members record:
- (a) the registration number;
 - (b) vehicle make and model;
 - (c) axle group(s) of the HV under test; and
 - (d) the readings from the OBM under test
- ii) repeat Step 1) i) a) – d) above *for the reference OBM systems* using a separate copy of the form in Appendix 1.

2) For the test cases of:

- Tare;
- 1/3 load;
- 2/3 load; and
- full load

on the HV, TCA personnel and other OBM team members carry out the following procedure; and record as per Step 1) parts i) and ii) above before run 1, i.e. the “Start” section of the form in Appendix 1:

- ☞ each test load;
- ☞ the OBM system under test; and
- ☞ the reference OBM system(s):

- a) record the odometer reading;
- b) direct the HV onto the scales and request that the brakes remain applied when the HV comes to a stop;
- c) weigh the HV under test on the certified scales;
- d) record the reading on the scales: this will be defined as the reference mass (RM) for that loading (e.g. tare, 1/3, 2/3 and full loads);
- e) record the reference OBM system readings and the test OBM system reading of the test vehicle: this will be the measured mass (MM) for the test case of “start, at rest, flat terrain, brakes on”;
- f) with suitable wheel-restraints in place, request that the brakes be released;
- g) record the reference OBM system readings and the test OBM system reading of the test vehicle: this will be the measured mass (MM) for the test case of “start, at rest, flat terrain, brakes off”;
- h) Test HV directed to park on a convenient slope, previously agreed to by all parties and measured for angle by the OBM team.
- i) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for the test case of “start, at rest, uphill (or downhill, depending on logistics);
- j) Test HV to reverse its arrangement with respect to the slope; and
- k) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for the test case of at “start, at rest, downhill” (or “uphill”, depending on logistics).
- l) Test HV directed to park crossways on a convenient slope, previously agreed to by all parties and measured for angle by the OBM team.
- m) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for the test case of “start, at rest, slope leaning to left” (or “right”, depending on logistics);

- n) Test HV to reverse its arrangement with respect to the slope; and
 - o) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for the test case of at “start, at rest, slope leaning to right” (or “left”, depending on logistics).
- 3) Test HV to proceed on the pre-defined circuit.
- 4) TCA personnel and other OBM team members carry out the following procedure; and record as per Step 1) parts i) and ii) above for:
- ☞ each test load;
 - ☞ the OBM system under test; and
 - ☞ the reference OBM systems:

when the HV returns:

- a) record the odometer reading;
- b) direct the HV onto the scales and request that the brakes remain applied when the HV comes to a stop;
- c) weigh the HV under test on the certified scales;
- d) record the reading on the scales: this will be defined as the reference mass (RM) for that loading and that run (e.g. tare, 1/3, 2/3 and full loads);
- e) record the reference OBM system readings and the test OBM system reading of the test vehicle: this will be the measured mass (MM) for that run and the test case of “at rest, flat terrain, brakes on”;
- f) with suitable wheel-restraints in place, request that the brakes be released;
- g) record the reference OBM system readings and the test OBM system reading of the test vehicle: this will be the measured mass (MM) for that run and the test case of “at rest, flat terrain, brakes off”;

- h) Test HV directed to park on a convenient slope, previously agreed to by all parties and measured for angle by the OBM team.
 - i) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for run y and the test case of “at rest, uphill” (or “downhill”, depending on logistics);
 - j) Test HV to reverse its arrangement with respect to the slope; and
 - k) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for run y and the test case of “at rest, downhill” (or “uphill”, depending on logistics).
 - l) Test HV directed to park crossways on a convenient slope, previously agreed to by all parties and measured for angle by the OBM team.
 - m) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for run y and the test case of “at rest, slope leaning to left” (or “right”, depending on logistics);
 - n) Test HV to reverse its arrangement with respect to the slope; and
 - o) Record the reference OBM system readings and the test OBM system reading: this will be the measured mass (MM) for run y and the test case of “at rest, slope leaning to right” (or “left”, depending on logistics).
- 5) Test HV and TCA personnel proceed to Step 3) & Step 4) for 8 (or, if turntable slider is fitted, 9) runs.
 - 6) For the 6th run, interfere with the proper operation of the air suspension (if fitted) by altering the ride height valve adjustment by a suitable amount;
 - 7) Test HV and TCA personnel proceed to Step 3) & Step 4).
 - 8) For the 7th run, block up totally, partially or otherwise interfere with the proper operation of first element transducers (i.e. those providing the signals from the primary HV component that is used to determine mass on the OBM system) to simulate readily-available tampering techniques. This will be done:

- a) using suitably-sized wedges under the strain gauges for load-cell based OBM systems;
 - b) using the manual ball valve/turncock listed in Section 5.2 in the air-lines to the APTS for OBM systems measuring air-spring pressure; or
 - c) employing other means as may be devised to alter the signals from the OBM first element transducers.
- 9) Test HV to proceed on the pre-defined circuit and, upon return, repeat Step 4).
- 10) If a turntable slider is fitted, make an 8th run with the following adjustment:
- shift the slider to the opposite end of its travel from the position in which the OBM system was calibrated.
- 11) Test HV to proceed on the pre-defined circuit and, upon return, repeat Step 4) and return the slider to the position in which the OBM system was calibrated.
- 12) If a turntable slider is not fitted, make an 8th run (which will be the 9th run if a slider is fitted) with the following adjustment:
- drain the fuel tank leaving just enough fuel to complete the run.
- 13) Test HV and TCA personnel proceed to Step 3) & Step 4).

6.3. Summary of this section

The procedures in this section will allow the following analysis to be made:

- Differences between the RM and the MM for two cases of brake application (on and off) for 2 cases of OBM system over 20 readings and after on-road travel of the test HV;
- Differences in the RM over time to ensure that compensation may be made for any drift or inaccuracy in:
 - the calibration of jurisdictional scales;

- the OBM readings due to fuel tank empty vs. full; and
- the OBM readings due to fuel use,
- Alterations to the dynamics of the signals from the OBM due to:
 - rudimentary tampering;
 - shifting the 5th wheel (if turntable sliders are fitted); and
 - air-spring ride height adjustment.

Cross-validation of the manufacturer's VSB11 characteristics against measured frequencies in the test HV suspension will augment investigations into in-service HV suspension testing under the auspices of the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT.

7. Societal obligations

7.1. Workplace health & safety

QUT has a workplace health and safety system. TCA has its own workplace health and safety system in place. The testing will be done across at least 3 road transport jurisdictions. Each jurisdiction has its own workplace health and safety system in place. When working in any particular jurisdiction, team members will abide by the provisions of that jurisdiction's workplace health and safety system and be guided by the knowledge provided by team members to whom that jurisdiction is their "home" jurisdiction. To the extent that QUT can control a project involving other jurisdictional activities *via* the TCA overarching project, a risk analysis has been performed. It is contained in Appendix 2.

7.2. Ethics

Please see Appendix 4.

8. Conclusion

The issue of on-board mass (OBM) measurement for HVs is now prominently on the national agenda of Australian transport jurisdictions.

A project entitled *Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices* under the aegis of TCA is underway to determine the feasibility of OBM for HVs under the IAP. The results of the programme as outlined in this test plan will inform that project with regard to accuracy, robustness, use of data from other on-board electronic systems and tamper evidence. Further investigations and analysis of dynamic data will be undertaken to enhance the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT, particularly the previously defined investigations into in-service HV suspension testing.

.

.

Appendix 1 - Test data recording form

Vehicle details																	Comments (e.g. type of OBM system, how many load cells or APT's)																							
Reg. number				Make				Model				Axle configuration ⁴																												
												Steer (S)		Drive (D)		Trailer 1 (T1)																		Trailer 2 (T2)						
Tare load test	Start								Run 1								Run 2								Run 3								Run 4							
	Odometer reading (km)																																							
(tonnes)	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2
Flat, brakes on.																																								
Flat, brakes off.																																								
Slope – uphill: 1 in																																								
Slope – downhill: 1 in																																								
Slope – LH lean: 1 in																																								
Slope – RH lean: 1 in																																								
	Run 5								Run 6								Run 7								Run 8								Run 9							
Odometer reading (km)																																								
(tonnes)	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2
Flat, brakes on.																																								
Flat, brakes off.																																								
Slope – uphill: 1 in ...																																								
Slope – downhill: 1 in ...																																								
Slope – LH lean: 1 in ...																																								

⁴ e.g. tri-axle semi with single drive axle and single steer axle on the prime-mover will be 113, two tri axle trailers on a B-Double with tandem drive and single steer axle on the prime-mover will be 1233; an 8x4 rigid will be 22. Note: if desired, the form may be amended so that details of individual units in combination can be recorded, as well as individual axle group masses, provided that the original intent of the data to be recorded is not altered.

2/3 load test	Start								Run 1								Run 2								Run 3								Run 4							
Odometer reading (km)																																								
(tonnes)	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2
Flat, brakes on.																																								
Flat, brakes off.																																								
Slope – uphill: 1 in																																								
Slope – downhill: 1 in																																								
Slope – LH lean: 1 in																																								
Slope – RH lean: 1 in																																								
	Run 5								Run 6								Run 7								Run 8								Run 9							
Odometer reading (km)																																								
(tonnes)	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2	RM S	MM S	RM D	MM D	RM T1	MM T1	RM T2	MM T2
Flat, brakes on.																																								
Flat, brakes off.																																								
Slope – uphill: 1 in																																								
Slope – downhill: 1 in																																								
Slope – LH lean: 1 in																																								
Slope – RH lean: 1 in																																								

Appendix 2. Risk management plan



RISK MANAGEMENT PLAN

Before Commencement –**YOU MUST**- refer to the [Risk Management Guide](#).

The purpose of 'Risk Management' is not to make QUT risk adverse but to pro-actively manage risks to ensure the safety, health and wellbeing of all QUT staff, colleagues, students and visitors.

Project Title: Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices: Accuracy and robustness, Ancillary systems analysis

Project Type (tick appropriate box)							
UG Project	<input type="checkbox"/>	PG Research Project	<input checked="" type="checkbox"/>	Staff Research Project	<input type="checkbox"/>	Commercial	<input type="checkbox"/>
UG Class Exercise	<input type="checkbox"/>	PG Class Project	<input type="checkbox"/>	Integrated Project	<input type="checkbox"/>	Work Activity	<input type="checkbox"/>
Project Discipline (tick appropriate box)							
Engineering Systems	<input type="checkbox"/>	Design	<input type="checkbox"/>	Urban Development	<input type="checkbox"/>	Research	<input checked="" type="checkbox"/>
Teaching & Learning	<input type="checkbox"/>	Faculty Operations	<input type="checkbox"/>	External Relations	<input type="checkbox"/>	Other (detail below)	<input type="checkbox"/>
Other.....							

Project/Work Details (Specify extent of project)	
The external activities for this research are as follows: Heavy vehicles (HVs) will be weighed at certified weighing stations or with the use of jurisdictional enforcement scales at various sites in Qld, Victoria & Western Australia. The HV's on-board mass (OBM) systems will be read and recorded. The HVs will then be directed to park on a slope and drive to a different weigh station, scale weighing area or return to the original weighing platform area. This for different test masses ranging from tare to full load. The dynamic data from the OBM system will be read and recorded by the OBM systems during travel. This will yield conclusions on the accuracy, precision and tamper-evidence of current OBM systems with a view to having their functionality included in large-scale HV remote monitoring.	
Proposed commencement date	1/3/8
Project Team Members & Contact phone numbers	Lloyd Davis, Main Roads 3834 2226 Dr. Jon Bunker, QUT 3138 5086 Dr. Charles Karl, Transport Certification Australia 03 8601 4699
Project Location (site, room, etc)	Various designated HV weighing stations locations in Victoria, Qld and Western Australia

RISK CALCULATOR (see guide for explanation on use)					
LIKELIHOOD	CONSEQUENCES				
	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC
ALMOST CERTAIN	MODERATE	HIGH	EXTREME	EXTREME	EXTREME
LIKELY	MODERATE	HIGH	HIGH	EXTREME	EXTREME
MODERATE	LOW	MODERATE	HIGH	EXTREME	EXTREME
UNLIKELY	LOW	LOW	MODERATE	HIGH	EXTREME
RARE	LOW	LOW	MODERATE	HIGH	HIGH



RISK ASSESSMENT REGISTER

Complete Table for all identified hazards. Where a 'Documented Control' exists, place the details in the Control Measures column.

All Control Measures MUST comply with State & Federal Legislative Requirements

Hazard or Task	Assessed Risks (List all risks associated with the Hazard or Task)	Appropriate control measures	Risk Level	Date Implemented	Valid Until	Individuals Consulted	Approver Signature
			Initial				
<i>Direct HV to move onto weigh platform or portable enforcement scales and take mass reading.</i>	<i>HV movement resulting in crushing, injury, death.</i>	<i>Workplace Health and Safety measures of the jurisdiction or facility in which the testing is being carried out. This will involve, but not be limited to or by: safety vests, flashing lights, "buddy" system, on-site and electronic communication, sun protection, water bottles and traffic control by appropriately qualified personnel.</i>	High	1/3/8	1/3/9	Dr. Charles Karl Lloyd Davis	
			low				
<i>Read on-board mass system reading.</i>	<i>HV movement resulting in crushing, injury, death.</i>	<i>Workplace Health and Safety measures of the jurisdiction or facility in which the testing is being carried out. This will involve, but not be limited to or by: safety vests, flashing lights, "buddy" system, on-site and electronic communication, sun protection, water bottles and traffic control by appropriately qualified personnel.</i>	High	1/3/8	1/3/9	Dr. Charles Karl Lloyd Davis	
			low				
<i>Direct HV to move to designated sloping area and record on-board mass system reading.</i>	<i>HV movement resulting in crushing, injury, death.</i>	<i>Workplace Health and Safety measures of the jurisdiction or facility in which the testing is being carried out. This will involve, but not be limited to or by: safety vests, flashing lights, "buddy" system, on-site and electronic communication, sun protection, water bottles and traffic control by appropriately qualified personnel.</i>	High	1/3/8	1/3/9	Dr. Charles Karl Lloyd Davis	
			low				
<i>Install tamper devices in OBM transducers.</i>	<i>HV movement resulting in crushing, injury, death.</i>	<i>Workplace Health and Safety measures of the jurisdiction or facility in which the testing is being carried out. This will involve, but not be limited to or by: safety vests, flashing lights, "buddy" system, on-site and electronic communication, sun protection, water bottles and traffic control by appropriately qualified personnel.</i>	High	1/3/8	1/3/9	Dr. Charles Karl Lloyd Davis	
			low				

<i>Outdoor activity.</i>	<i>Sunburn, dehydration</i>	<i>Workplace Health and Safety measures of the jurisdiction or facility in which the testing is being carried out. This will involve, but not be limited to or by: safety vests, flashing lights, "buddy" system, on-site and electronic communication, sun protection, water bottles and traffic control by appropriately qualified personnel.</i>	Moderate low	<i>1/3/8</i>	<i>1/3/9</i>	Dr. Charles Karl Lloyd Davis	

Make additional copies of this page as required

APPROVAL			
Conducted By	Name	Signature	Date
Approved By	Name	Signature	Date

Individuals approving this document accept responsibility for the appropriateness of controls and for the validity of the Risk Management Plan.

This document is to be kept by the Approver for the duration of the project, then forwarded to the Faculty Health & Safety Officer

Appendix 3. Definitions, Abbreviations & Glossary

Terms, abbreviations and acronyms	Meaning
Accuracy	Accuracy is the relationship between a measured value and a reference. Increasing system accuracy comes from the measured value approaching the reference. See Figure 3.
APT	Air pressure transducer. A device for emitting an electrical signal as a proportional surrogate of input air pressure.
ARRB	Australian Road Research Board – now privatised, has changed its name to ARRB Group Limited.
ARTSA	Australian Road Transport Suppliers Association.
ATC	Australian Transport Council. “The Australian Transport Council (ATC) is a Ministerial forum for Commonwealth, State and Territory consultations and provides advice to governments on the coordination and integration of all transport and road policy issues at a national level.” http://www.atcouncil.gov.au
ATRF	Australasian Transport Research Forum. A conference for presentation of papers and colloquia on matters of transport planning, policy and research.
BIFA	Bilateral Infrastructure Funding Agreement. Also known as the Auslink agreement. An agreement between individual States of Australia and the Commonwealth which “covers arrangements applying to funding made available by the Australian Government to Queensland under the first five-year AusLink investment programme (2004-05 to 2008-09) and any agreed subsequent changes to, and extensions of, the programme. It also covers agreed arrangements for infrastructure planning, identification of investment priorities, development and assessment of project proposals and evaluation of completed projects.” (Australia Department of Transport and Regional Services, 2005b).

Body bounce	<p>Movement of the sprung mass of a truck as measured between the axles and the chassis. Results in truck body dynamic forces being transmitted to the road <i>via</i> the axles & wheels.</p> <p>Usually manifests in the frequency range 1 – 4Hz.</p>
CoG	Centre of gravity. The point at which a body's mass may be said be concentrated for purposes of determining forces on that body.
Damping ratio	How much the shock absorbers reduce suspension bounce after the truck hits a bump. The damping ratio, zeta (ζ) is given as a value under 1 (e.g. 0.3) or a percentage (e.g. 30%).
Δ	Greek letter "delta" – denoting increment.
DIVINE	Dynamic Interaction between heavy Vehicles and INfrastructurE.
DoTaRS	Department of Transport and Regional Services. An Australian Government department.
EBS	Electronic braking systems
ECM	Engine control module
Eigenfrequency	Frequency of a body at one of its vibrational resonance modes.
FFT	Fast Fourier transform. A method whereby the Fourier transform is found using discretisation and conversion into a frequency spectrum.

<p>Fourier transform</p>	<p>A method whereby the relative magnitudes of the frequency components of a time-series signal are converted to, and displayed as, a frequency series. If the integrable function is $h(t)$, then the Fourier transform is:</p> $\phi(\omega) = \int_{-\infty}^{+\infty} h(t)e^{-i\omega t} dt$ <p>Where:</p> <p>ϕ is the Fourier series;</p> <p>ω is the frequency in radians/s; and</p> <p>$i = \sqrt{-1}$</p> <p>(Jacob & Dolcemascolo, 1998).</p>
<p>GVM</p>	<p>Gross vehicle mass.</p>
<p>HML</p>	<p>Higher mass limits. Under the HML schemes in Australia, heavy vehicles are allowed to carry more mass (payload) in return for their suspension configuration being “road friendly”. See VSB 11.</p>
<p>HV</p>	<p>Heavy vehicle.</p>
<p>Hz</p>	<p>Hertz. Unit of vibration denoting cycles per second.</p>
<p>IAP</p>	<p>Intelligent Access Programme. The Intelligent Access Program (IAP) is defined by the TCA as third generation HV access to the Australian network. This approach is intended to complement ‘general’ and ‘restricted’ access with a further layer of ‘intelligent’ access. The IAP voluntary programme provides HVs with improved access to the Australian network. This with the proviso that HVs thus benefited are monitored using GPS tracking or other forms of vehicle telematics to ensure compliance with improved access conditions. (Transport Certification Australia, 2005).</p>

MCV	Multi-combination vehicle. HVs with general arrangement or GVM greater than that of a semi-trailer.
MM	Measured mass. Three MM readings will be taken per test, one reading from each of the the reference OBM systems and one from the test OBM system.
NHVAS	National Heavy Vehicle Accreditation Scheme. A voluntary scheme that certifies transport operators against a set of industry-specific quality assurance requirements. Membership of this scheme is a pre-requisite for HML.
NRTC	National Road Transport Commission. A national body set up by the States of Australia to facilitate economic reform of the road transport industry. Became the NTC earlier this decade.
NSW	New South Wales.
NTC	See NRTC
MRWA	Main Roads Western Australia.
OBM	On-board mass. A generic term describing the systems used to monitor a HV for its mass using on-board telematics. EBS and ECM systems are included within this generic definition.
OECD	Organisation for Economic Co-operation and Development
Participants	On-board mass suppliers, their representatives in Australia or the non-TCA parties to the confidentiality agreement in Appendix 6.
PBS	Performance-based standards http://www.ntc.gov.au/viewpage.aspx?page=A023114004005800200
Precision	Repeatability in measurement data. Precision is an assessment of the variation in measurement of the same value. The more precise measurements are, the closer together their measured values. See Figure 3.
QDMR	Queensland Department of Main Roads

QT	Queensland Transport
QUT	Queensland University of Technology
Reference system	An OBM system supplied by TCA and installed on all test HVs to provide a consistent set of data across all test HVs for the purposes of comparing the MM of the reference system to the MM of the test system and the RM. Note that there will be three MM readings per test, one from each of the reference OBM systems and one from the test OBM system.
RFS	“Road-friendly” suspension. A HV suspension conforming to certain limits of performance parameters defined by VSB 11. (Australia Department of Transport and Regional Services, 2004)
RM	Reference mass. The mass reading from the certified scales. See measured mass (MM).
RTA	Roads and Traffic Authority, NSW
SPV	Special purpose vehicle (e.g. cranes or low-loaders)
TCA	Transport Certification Australia Limited. Established in 2005 as a public company. TCA members are the road authorities of the Australian, State, and Territory governments. TCA supports the development and implementation of the IAP and administers the IAP including legislative, policy and administrative issues. (Transport Certification Australia Ltd, 2007).
Test system	OBM The OBM system under test.
TSA	Transport South Australia
VSB 11	Vehicle Standards Bulletin 11. A document issued by DoTaRS that defines the performance parameters of “road-friendly” HV suspensions.
WiM	Weigh-in-motion. Technology that uses sensors in the road to measure the wheel-force of vehicles.

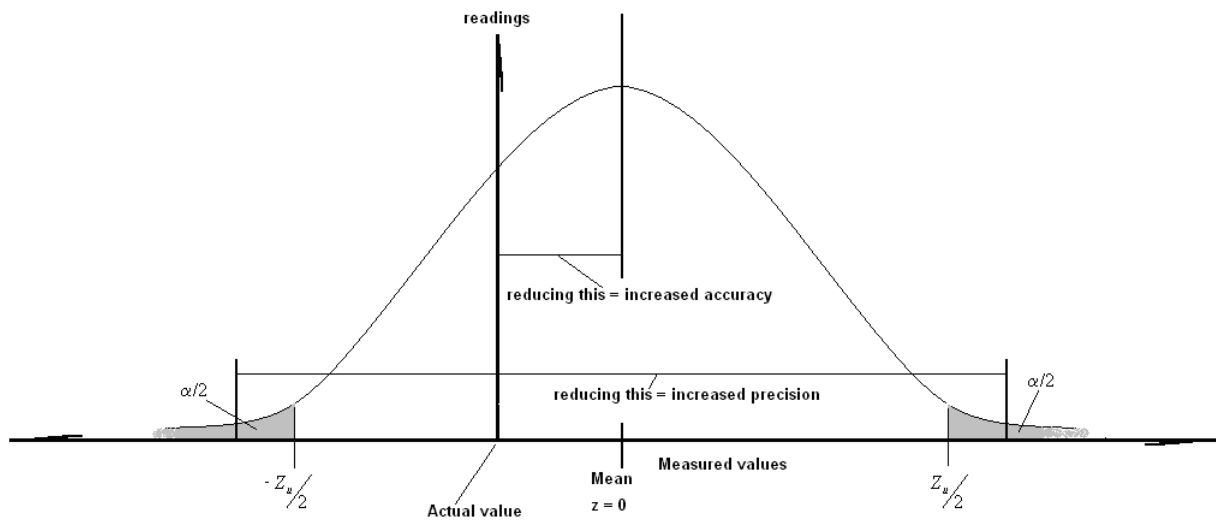


Figure 3. Visual interpretation of accuracy, precision and tails used to derive critical values for degrees of confidence.

Appendix 4. Ethics

This testing programme will employ the same methodologies and processes used in the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT. With respect to the four main areas of ethical concerns at QUT, neither this test programme, nor the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT involves testing of or on:

- animals;
- genetically modified organisms;
- organic or inorganic biohazard material; or
- human subjects.

With respect to the final point above, the following definition of scientific research has been proposed (Margo, 2001) with respect to “human subject” research:

“The defining elements of research are a scientific hypothesis and the systematic collection of data to support or disprove the hypothesis.”

The definition of what constitutes a “human subject” is not provided in the National Statement on Ethical Conduct in Human Research (Australia Government, 2007). This term is, however, used but not defined in the QUT research ethics policy (Queensland University of Technology, 2008). In the absence of an Australian or institutional definition of “human subject” and so as to provide protection to “human subjects” involved in research, the following US statute definition is provided as follows:

“Human subject means a living individual about whom an investigator (whether professional or student) conducting research obtains

(1) data through intervention or interaction with the individual, or

(2) identifiable private information. Intervention includes both physical procedures by which data are gathered (for example, venipuncture) and manipulations of the subject or subject's environment that are performed for research purposes. Interaction includes communication or interpersonal contact between investigator and subject. Private information includes information about behaviour that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects." (United States Government Department of Health and Human Services, 2007).

Since the testing outlined in this test programme and the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT does not involve:

- any hypotheses or collection of data:
 - involving;
 - gathering information on;
 - gathering information for the purposes of;
 - concerned with; or
 - associated in any way with

proving or disproving any hypothesis regarding the essential, basic, defining, necessary or fundamental features or aspects of the humanity of the people involved with or conducting the testing, neither this test programme nor the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT involves "human subjects" even given the lack of definition of this term under the provisions of the National Statement on Ethical Conduct in Human Research issued in 2007 (Australia Government, 2007).

Since the previous test programme used in the joint QUT/Main Roads project *Heavy vehicle suspensions – testing and analysis* currently underway at QUT, when submitted to the QUT research ethics office, resulted in an “exempt” ruling (Lamb, 2007), this test programme will proceed on a similar basis and utilise that ruling.

Appendix 5. Sample size

Assuming that the spread of the readings from the test cases in the proposed testing, viz: tare, 1/3, 2/3 and full load; will have a normal distribution around a mean value, an appropriate sample size (number of readings per load condition) may be found for a desired accuracy value and level of confidence that the mean of the population of OBM systems, as a whole, will not differ from the measured mean of the OBM system under test.

The process of determining sample size requires input values such as the expected (or known from previous trials) standard deviation of the experimental measured values, desired accuracy of the data and level of confidence regarding that accuracy.

The number (n) of samples (runs) may then be determined from the following formula (Snedecor & Cochran, 1967):

$$n = \left[\frac{\left(\frac{Z_u}{2} \right) \sigma}{E} \right]^2$$

Equation 1

Where:

n = sample size (number of readings);

$\frac{Z_u}{2}$ = the critical value of the standardised normal (z) distribution used to determine the level of confidence;

σ = is the standard deviation of the population data; and

E = the desired accuracy (specified error) of the test. This is the pre-defined acceptable difference between the mean of the experimental data and the mean of the total population^e.

^e In this case, the total population will be the total population of OBM systems.

The value of $Z_{\alpha/2}$ is determined by the choice of the level of significance known as α which is, in turn, used to derive the level of confidence. The level of confidence is usually denoted as a percentage that can be visualised as being bounded by the critical values of $\pm Z_{\alpha/2}$ under the normal population distribution curve in Figure 3 and related to half of the level of significance ($\alpha/2$) therein. The level of confidence is a value (or percentage) of certainty that the mean of the sample data will be within the specified error of the mean of the entire population.

The level of confidence is denoted:

$1 - \alpha$ as a value; or

$(1 - \alpha) \times 100$ as a percentage.

For instance, a value of $\alpha = 0.1$ provides a level of confidence of 0.90 or 90% that the mean value in the sample readings will be equal to or smaller than the desired error of the population mean (Snedecor & Cochran, 1967).

Previous versions of this test plan have used a value for standard deviation σ of 350 kg (Davis, 2006). During the first portion of the pilot testing in Brisbane a maximum value for σ was measured for OBM readings at 130kg for loads approximating 20t. The results for the maximum value of E was 140kg for loads of approximately 20t. The following calculations to choose the number of readings use these learnings accordingly.

To find the number of readings required to determine the mean accuracy of OBM systems for:

a level of confidence of 95%; and

a standard deviation σ of 130 kg^f; with

a desired maximum error E of 140kg between the test data mean accuracy and the population mean accuracy;

let:

$\alpha = .05$ (i.e. a 95% level of confidence);

$\sigma = 0.13$; and

$E = 0.14$

=> the area in the region to the left of $Z_u/2$ and to the right of $z = 0$ in Figure 3 is:

$$0.5 - (0.05/2) = 0.475;$$

the table of the standardised normal (z) distribution (CTQ Media LLC, 2008) gives a

$Z_u/2$ value of 1.96;

Substituting into Equation 1:

$$n = \left[\frac{1.96 * 0.13}{0.14} \right]^2$$

$$\Rightarrow n = 3.3$$

∴ the number of readings for these experimental parameters for each load condition, viz: tare, 1/3, 2/3 and full load; will be:

$$n \text{ (rounded up)} = 4.$$

^f i.e. assuming here that 95% of the population of OBM systems return a mass reading within a maximum range of 260kg either side of the mean. This is a deliberately conservative assumption. *n.b.* this 95% is not the same 95% that was chosen for the degree of confidence in this exercise but relates to the fact that 95% of a normally distributed population will lie between a range two standard deviates either side of the mean.

Allowing for a conservative approach to surety, given that 4 is a low number, by adding a margin of (say) 50% to 4; this makes the number of readings $4 + 2 = 6$. Including the initial test at the start, this means 5 runs with a reading of the RM and the MM at the start and finish of each run gives 6 repeated readings per test load condition without changing any other variables. It is noted that the conservative approach with 6 readings will either increase the level of confidence or reduce the value of E to approximately 100kg should no margin be necessary. This issue will be determined after the pilot testing is finalised and reviewed for the ultimate test regime.

Appendix 6 - Confidentiality and IP agreement

DEED OF AGREEMENT

CONFIDENTIALITY & INTELLECTUAL PROPERTY

This Agreement is made the [] of [] 2008 between

TRANSPORT CERTIFICATION AUSTRALIA LIMITED AC N 113 379 936 of Level 12, 535 Bourke Street Melbourne Victoria 3000 Australia ("TCA")

-and-

[] **PTY LTD** ACN [] of
[] ("the Participant")

Background:

TCA administers the Intelligent Access Program ("IAP") and other related public-purpose road reform programs on behalf of the road traffic authorities of Australia's State, Territory and Commonwealth governments. The IAP provides for the offering, to the operators of heavy transport vehicles, of enhanced access to the public road system in exchange for the operators' agreement to certain conditions of access. The conditions of access include the monitoring by global positioning system ("GPS"), of the movement of participating heavy vehicles for compliance with other conditions of access, such as permitted days and hours of access and permitted route.

In the course of administering the IAP and as a further enhancement of the program, TCA is currently calling for expressions of interest in the participation, with TCA and other parties, in the development of a system for the evidentiary-level monitoring and reporting of vehicle mass within the IAP ("the Project"). The Project will involve:

- ☞ testing of equipment and systems for accuracy and robustness;
- ☞ inclusion of additional data for mass monitoring;
- ☞ identification of best practice for installation, calibration, operation and maintenance of such equipment and systems; and
- ☞ procedures for tamper evidence.

The Participant has expressed an interest in participating in the Project.

In the course of the Participant's participation in the Project, both TCA and the Participant will provide to the other access to certain confidential proprietary information and intellectual property.

TCA and the Participant each wish to safeguard their respective rights in and to their respective confidential information and intellectual property.

TCA and the Participant hereby agree as follows:

1. Provision of Confidential Information by TCA and the Participant to Each Other

1.1 To enable the Participant to participate in the Project as aforesaid, TCA shall provide to the Participant access to such equipment, technical information, technical specifications and like material as it has in its possession and believes to be necessary to the Participant's participation in the Project.

1.2 All unpatented equipment, technical information, technical specifications and like material provided by TCA to the Participant for the purposes of the Project, whether written, verbal or in electronic form, and including specifically, but without limitation, project plans (including plans for the Project), test plans, test results and reports shall (as between TCA and the Participant) be "TCA's Confidential Information" and shall remain at all times the sole and absolute property of TCA.

1.3 "TCA's Confidential Information" shall not include any information or material which prior to the date on which it was first received by the Participant from TCA was (other than by virtue of breach of an obligation of confidentiality owed to TCA by the Participant or by a party from whom the Participant received it) known to or in the possession of the Participant or was in the public domain.

1.4 To facilitate its own participation in the Project as aforesaid, the Participant shall provide to TCA access to such equipment, technical information, technical specifications and like material as it has in its possession and believes to be necessary to its participation in the Project.

1.5 All unpatented equipment, technical information, technical specifications and like material provided by the Participant to TCA for the purposes of the Project, whether written, verbal or in electronic form, and including specifically, but without limitation, project plans, test results and reports shall (as between TCA and the Participant) be "the Participant's Confidential Information" and shall remain at all times the sole and absolute property of the Participant.

1.6 “The Participant’s Confidential Information” shall not include any information or material which prior to the date on which it was first received by TCA from the Participant was (other than by virtue of breach of an obligation of confidentiality owed to the Participant by TCA or by a party from whom TCA received it) known to or in the possession of TCA or was in the public domain.

2. TCA’s Use of the Participant’s Confidential Information

2.1 For the duration of the period in which TCA has possession of the Participant’s Confidential Information, and until the Participant’s Confidential Information is returned by TCA to the Participant, TCA shall:

- (a) Utilise the Participant’s Confidential Information only for the purposes of the Project;
- (b) Not use the Participant’s Confidential Information for any other purpose, and
- (c) When not utilising the Participant’s Confidential Information, store it in a secure manner in a secure location.

2.2 TCA acknowledges and agrees that it will receive and hold the Participant’s Confidential Information in strict commercial confidence as the property of the Participant; will not pass the same to any third party without the prior written consent of the Participant, and will not attempt to copy, decompile or reverse engineer any computer hardware, computer software or computer firmware or any equipment forming part of or otherwise supplied with the Participant’s Confidential Information.

3. The Participant’s Use of TCA’s Confidential Information

3.1 For the duration of the period in which the Participant has possession of TCA’s Confidential Information, and until TCA’s Confidential Information is returned by the Participant to TCA, the Participant shall:

- (a) Utilise the TCA’s Confidential Information only for the purposes of the Project;
- (b) Not use TCA’s Confidential Information for any other purpose, and

(c) When not utilising the TCA's Confidential Information, store it in a secure manner in a secure location.

3.2 The Participant acknowledges and agrees that it will receive and hold the TCA's Confidential Information in strict commercial confidence as the property of TCA; will not pass the same to any third party without the prior written consent of TCA, and will not attempt to copy, decompile or reverse engineer any computer hardware, computer software or computer firmware or any equipment forming part of or otherwise supplied with TCA's Confidential Information.

4. Intellectual Property Developed in the Course of the Project

TCA and the Participant enter into this Deed of Agreement and the Project on the basis that in addition to the provisions of clauses 1, 2 and 3 which will apply with respect to confidential information generally, the following principles shall apply with respect to intellectual property (that is, to all rights arising from intellectual activity and capable of protection by statute, common law or equity and including copyright, discoveries, inventions, patent rights, registered and unregistered trademarks, design rights circuit rights and all like rights and interests):

Project Intellectual Property: TCA will own the intellectual property in the overall solution, if any, developed during the course of the Project for the evidentiary-level monitoring and reporting of vehicle mass within the IAP, and the Participant hereby assigns all of its rights and interests in the overall solution to TCA.

New Intellectual Property Developed During The Project: In the event that a party develops during the course of the Project any new intellectual property which is not Project Intellectual Property within the definition appearing above, then that new intellectual property shall be the property of the party which develops it, and where that party is the Participant then it will (if requested by TCA) negotiate with TCA in good faith and enter into a license of that new intellectual property to TCA for use in the overall solution.

Background Intellectual Property: Unless otherwise agreed in writing, any existing intellectual property rights of a party which are used in the development of the overall solution, will remain the property of that party, and where that party is the Participant then it will (if requested by TCA) negotiate with TCA in good faith and enter into a license of that intellectual property to TCA for use in the overall solution.

5. Acknowledgment of Participation of Other Parties in the Project

The Participant acknowledges that TCA may invite other parties to submit expressions of interest in participating in the Project. Nothing in this clause, however, shall operate so as to diminish the rights and obligations of each of TCA and the Participant with respect to the other's confidential information and intellectual property as set out in clauses 2, 3 and 4 of this Agreement.

6. Return of the Confidential Information and Intellectual Property

6.1 Both TCA and the Participant hereby agree and undertake that upon the written request of the other, it shall forthwith return to the other all of the confidential information and intellectual property as received by it from the other. Where one party has consented to the other making of copies of the first party's confidential information and/or intellectual property, and copies have been made, then all of the copies shall also be returned with the original confidential information/ intellectual property.

7. No Public Announcement

The Participant must not make or authorise any public announcement or communication relating to the Project without the prior written consent of TCA.

8. This Agreement is executed as a Deed.

Signed for and on behalf of

Transport Certification Australia Limited

by:

(signature):

(insert full name):

who is an Authorised Person:

Signed for and on behalf of

[

(insert name of the Participant)

by:

(signature):

(insert full name):

who is an Authorised Person:

] Pty Ltd

References

- Australia Department of Transport and Regional Services. (2004). *Certification of road-friendly suspension systems; Road-friendly suspension certification requirements*. Canberra, ACT, Australia: Australia. Department of Transport and Regional Services.
- Australia Department of Transport and Regional Services. (2005a). Bilateral agreement between the Commonwealth of Australia and the State of New South Wales 2004 - 2009. Retrieved 7 Sept, 2007, from http://www.auslink.gov.au/publications/policies/pdf/NSW_Bilateral.pdf
- Australia Department of Transport and Regional Services. (2005b). Bilateral agreement between the Commonwealth of Australia and the State of Queensland 2004-05 – 2008-09. Retrieved 7 Sept, 2007, from http://www.auslink.gov.au/publications/policies/pdf/Qld_bilateral.pdf
- Australia Government. (2007). *National Statement on Ethical Conduct in Human Research*: Australia Government, Canberra ACT.
- CTQ Media LLC. (2008). Table of the Standard Normal (z) Distribution. 2008, from <http://www.isixsigma.com/library/content/zdistribution.asp>
- Davis, L. (2006). *Heavy vehicle suspension testing: on-board mass measurement system accuracy & tamper-vulnerability*. Brisbane, Queensland, Australia: Queensland Department of Main Roads.
- Haldane, M. J. (2002). *Assessing the impacts of multi-combination vehicles on traffic operation*. Queensland University of Technology, Brisbane, Queensland, Australia.
- Jacob, B., & Dolcemascolo, V. (1998). *Dynamic interaction between instrumented vehicles and pavements*. Paper presented at the International Symposium on Heavy Vehicle Weights and Dimensions, 5th, 1998, Maroochydore, Queensland, Australia.
- Karl, C. (2007). *Project Plan: Technical Feasibility Assessment of On-Board Mass-Monitoring (OBM) Devices*. Melbourne: Transport Certification Australia Major Projects Division.
- Lamb, J. (2007). Ethics clearance. email: jd.lamb@qut.edu.au. In L. Davis (Ed.). Brisbane, Queensland, Australia: QUT.
- Margo, C. E. (2001). When is surgery research? Towards an operational definition of human research. *Journal Medical Ethics*, 27(1), 4.
- National Transport Commission. (2003). Transport reforms higher mass limits (second heavy vehicle reform package). Retrieved 6 Sept 2007, from <http://www.ntc.gov.au/Project.aspx?page=A0240030550000002000325>
- OECD. (1998). *Dynamic interaction between vehicles and infrastructure experiment (DIVINE)*. (Technical report No. DSTI/DOT/RTR/IR6(98)1/FINAL). Paris, France: Organisation for Economic Co-operation and Development (OECD).

Queensland University of Technology. (2008). D/6.3 Research involving the participation of humans. Retrieved 11 Jan 2008, from http://www.mopp.qut.edu.au/D/D_06_03.jsp#D_06_03.01.mdoc

Snedecor, G. W., & Cochran, W. G. (1967). *Statistical methods* (6th ed. ed.): Ames, Iowa : Iowa State University Press.

Transport Certification Australia. (2005). About the Intelligent Access Program. from http://www.tca.gov.au/Content_Common/pg-The-Intelligent-Access-Program.seo

Transport Certification Australia Limited. (2007). *Heavy Vehicle On-Board Mass Monitoring: Capability Review* (Report). Melbourne, Victoria, Australia.

Transport Certification Australia Limited. (2008). Deed of Agreement – Confidentiality & Intellectual Property. Melbourne, Victoria, Australia.

Transport Certification Australia Ltd. (2007). Annual Report. from <http://www.tca.gov.au/SiteMedia/w3svc051/Uploads/Documents/FINAL%20-%20TCA-A24-%202006-2007%20Annual%20Report-1.pdf>

United States Government Department of Health and Human Services. (2007). *Code of federal regulations title 45 public welfare Part 46 Protection of human subjects* (Vol. 46.102(f)). USA: US Government.