Department of Transport, Energy and Infrastructure
Transport Information Management Section

Culway Weigh-In-Motion (WIM)
Compensating for 'Calibration Drift'
Preliminary Report

CARL CARUANA
Traffic Registrar

February 2006

Introduction

Since the late 1990's the topic of 'calibration drift' has been the subject of various discussions and written papers. In particular Mr. R.J.Peters (Main Roads WA) has explored and written papers on calibration drift and I am hoping that my research and findings will add value to this topic.

I have worked with the Culway WIM system since 1994 and by 1996 I had formed the opinion that calibration drift existed to some degree or another at all our Culway sites. Over the years we have had to address various problems and issues relating to the continuous improvement of our Culway sites. One of the key issues has always been calibration drift - what causes it, and what can we do to compensate for it?

Methodology

By 1997 I was convinced that most of the effects of calibration drift resulted from temperature variations in the road surface/pavement. Calibration drift can also be influenced by other environmental factors (eg. moisture, wind and cloud cover). However, I believe that at the end of the day it doesn't matter what causes it, as long as you can recognise when it is happening and you have an effective way of dealing with it and/or compensating for it. At the time I did not have a lot of evidence to support this theory but I still proceeded with developing a method to compensate for what ever was causing the drift in calibration.

The method I use is based on the average steer axle weights for class 9 vehicles (Type A123 only). As highlighted by Mr. R.J.Peters the steer weights of type A123 vehicles do not vary much (regardless of the loading condition). Hence, I firstly calculate the average A123 steer axle weight for each of our Culway sites from data collected during calibration exercises and vehicle weighing stations (the average varies slightly from site to site between 5.5 and 5.8 tonnes). These were then used as benchmark weights for monitoring and subsequently 'normalising' our Culway WIM data. I then used spreadsheets to determine where sensitivity factors (CF1) needed to be adjusted to compensate for calibration drift. We have now been using this method of 'normalising' our Culway WIM data for the past 9 years during which time my colleague Roger Bloor has improved the process, by creating new spreadsheets with additional formulas and macros.

The only time that I have experienced calibration drift at a Culway site due to moisture was when we had a temporary drainage problem at one of our sites. Road works had altered the drainage at the site creating a build up of water on the side of the road. This caused the shoulders and road pavement material to become saturated. The problems at this site were immediately apparent from the Culway WIM data (even before the road surface/pavement began to fail). As soon as the drainage problem was rectified and the road repaired, the site was recalibrated and thereafter we did not experience any significant calibration drift at this site. From this I concluded that as long as the moisture content in the base and sub-base material of the road pavement can be maintained at a reasonably constant level then moisture will have very little to do with the drift in calibration.

One could argue about which of the environmental factors contributes most to calibration drift, and even though I believe that temperature is the main factor, the key question is - what is the influence on the strain readings (which is what the calibration factors are applied to)?

The answer is not actually in the temperature or moisture (or any of the other environmental factors) it is in the road surface/pavement. When we talk about 'calibration drift' we should actually be focusing our attention to the 'stiffness' or 'rigidity' of the road surface and pavement. The rigidity of a flexible road surface/pavement changes with temperature and this has a direct impact on the strain readings. That is why sites that have a deep asphalt surface can change dramatically as the temperature changes.

The South East Freeway site near Monarto (SA) is a classic example of this scenario and at this point has been the main focus of this study because we experience our greatest 'calibration drift' at this site.

The Westbound kerb lane has a deep asphalt surface of 150 mm (comprising a 35 mm OG10 wearing course and 115 mm AC14). The base course material is 150 mm deep (20 mm dolomite crushed rock) and the sub base is 150 mm deep (20 mm to 40 mm limestone rubble) giving a total depth of 450 mm of pavement over the culvert.

The following photos are of the AC core sample taken from this site.

The culvert is 2 cells wide (each cell being 3.0 m wide by 2.5 m high) and the legal speed limit at this site is 110 km/h. The site was last calibrated on 6th April 2004 and the following calibration factors were calculated and consistently used for this study of the Monarto Westbound kerb lane:

Sensitivity (CF1) = 0.035869
Power Law (CF2) = 1.001615
Unit Influence Line (CF3) = 3.4
Steer Factor (CF4) = 1.1

In September 2004 we installed a small temperature recorder ('T-TEC 6' Temperature Data Logger) at the Monarto Culway site. Two temperature probes were also installed. The first was installed about 70 mm below the asphalt surface (to give pavement temperature) and the second in the shade near the end of the culvert (to read the ambient temperature).

When it comes to drawing any conclusions and/or making any adjustments to Weigh-In-Motion data based on temperature I believe that the pavement temperature is the key element, and should be used in preference to ambient temperature.

Results

We have collected over twelve months of temperature data from this site and plotted it against the steer axle weights of Class 9 (Type A123) vehicles. Even though there are some gaps in the data (due to battery and equipment failure) we still have sufficient data to show the correlation between temperatures and steer axle weight.

The following chart (Chart 1) shows the correlation of temperature data against the average steer axle weights (at half hour intervals) for the whole period of the study (September 2004 – October 2005).

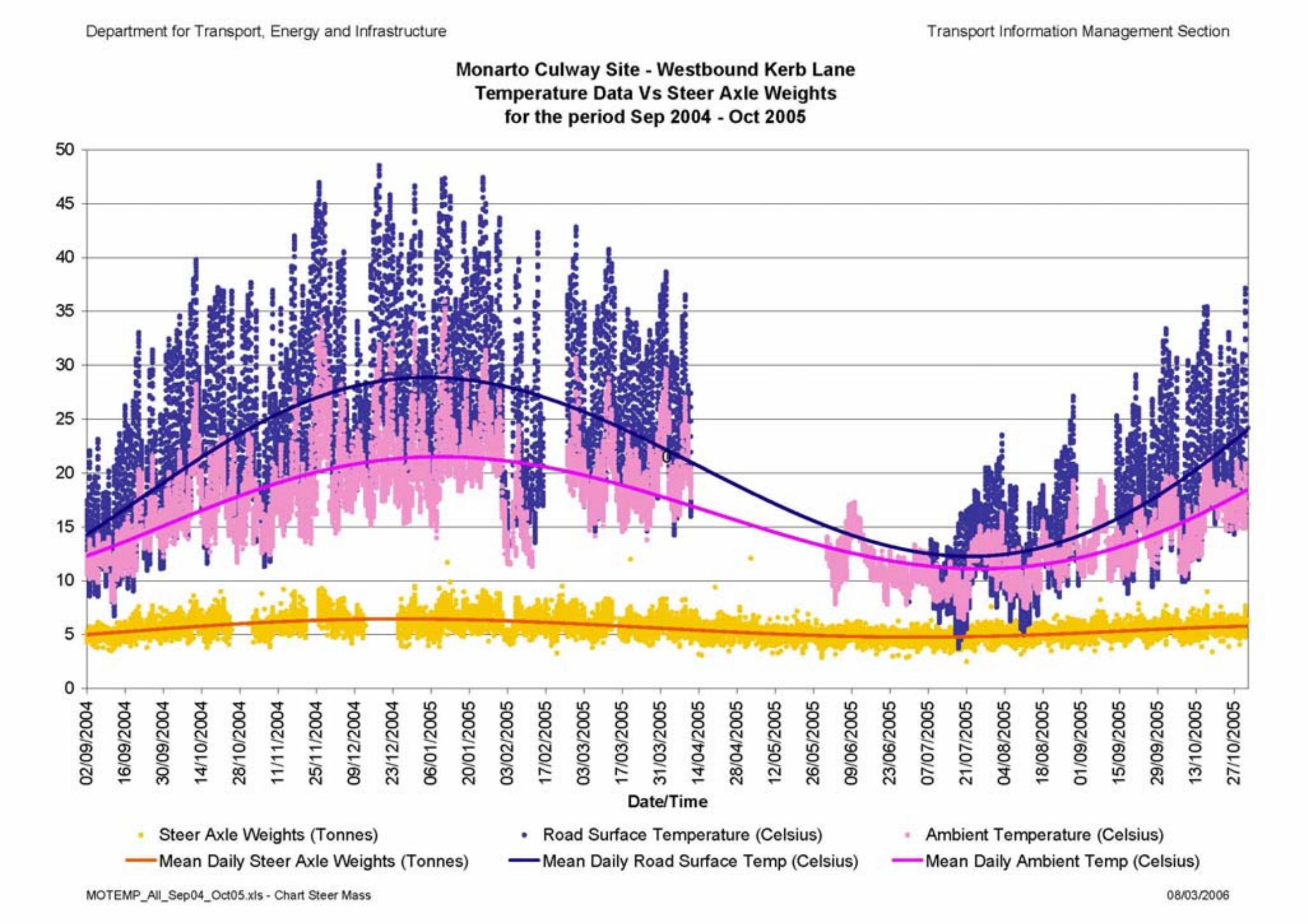

Chart 1 – Annual Temperature Vs Steer Axle Weights

Note that the vertical scales of the charts in this report are not labelled but the legend describes the units that correspond/apply to weight (Tonnes) and temperature (Celsius).

Chart 1 demonstrates that there are basically two distinct cycles (the 12-month annual temperature cycle and the 24-hour daily temperature cycle). However, it does not give enough detail to compare specific steer axle weights to the corresponding pavement temperature and ambient temperature.

The next two charts (Chart 2 and Chart 3) zoom into a typical summer week in January 2005 and a typical winter week in July 2005. This provides sufficient detail to be able to clearly see that the rise and fall in steer axle weights directly corresponds to the rise and fall in temperature. It also demonstrates the difference between pavement temperature and ambient temperature, where changes in pavement temperature lag behind changes in ambient temperature. I put this down to all the other environmental factors (eg. wind, rain and cloud cover) that have an almost instant effect on the atmosphere but may take some time to have the same effect on the pavement. Chart 2 clearly demonstrates the variations that can occur within the same week. The day-to-night variations are also very evident. However, Chart 3 shows that for a typical winter week (July 2005) the temperatures are relatively stable and therefore the steer axle weights are far more consistent.

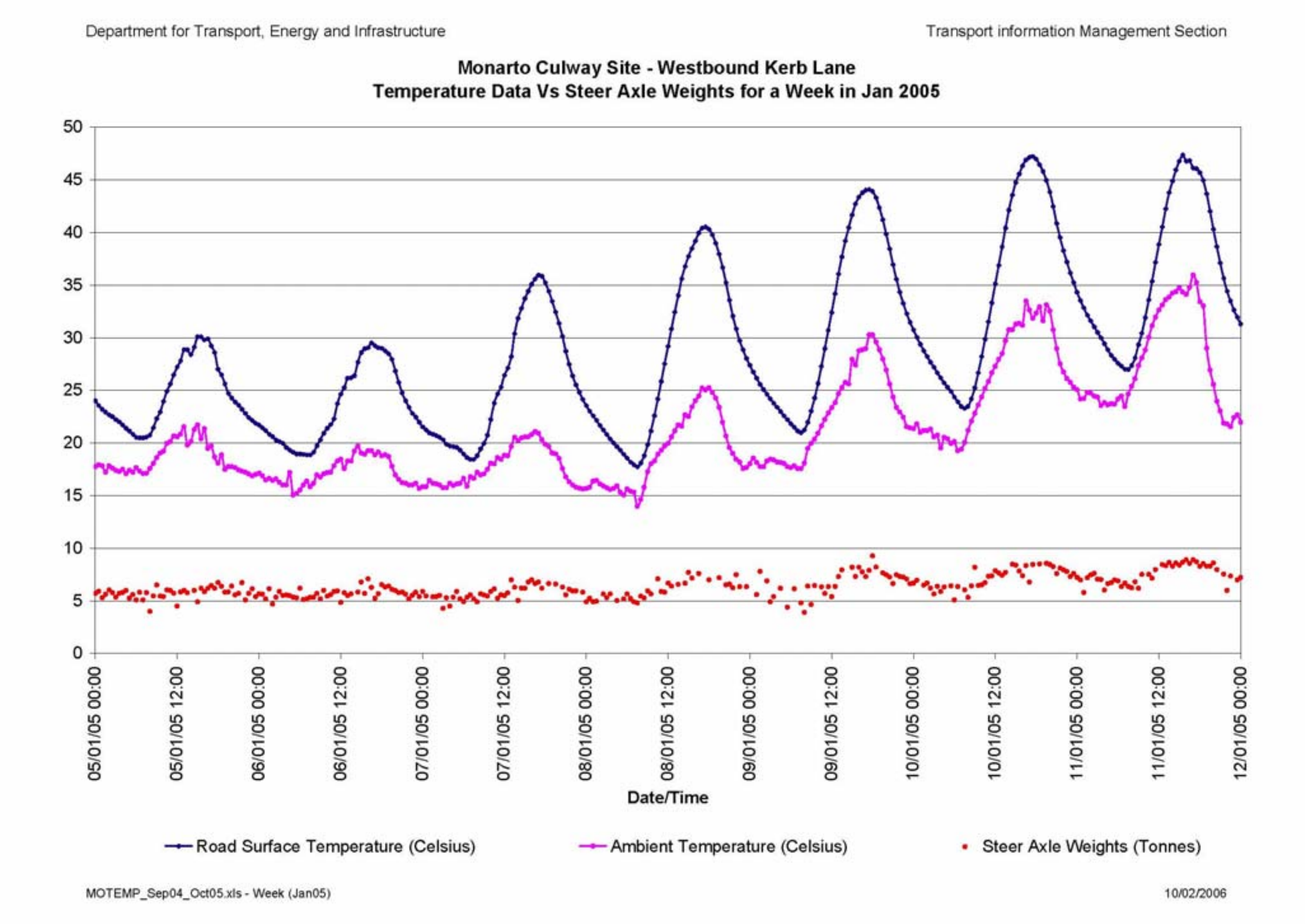

Chart 2 – Typical Summer Week

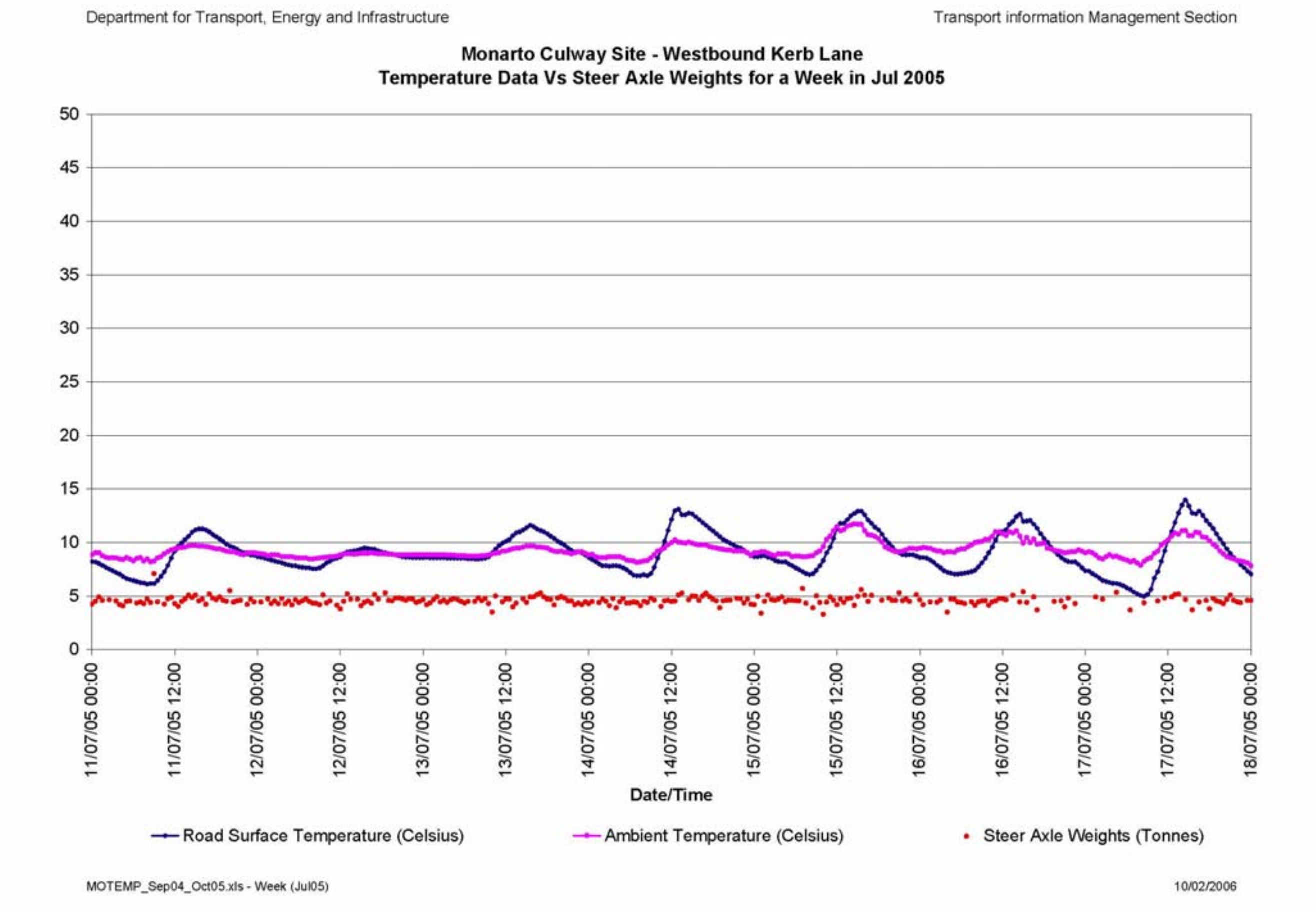

Chart 3 – Typical Winter Week

The next two charts provide even more detail. Chart 4 zooms in on a typical day in summer (January 2005) followed by Chart 5 showing a typical day in winter (July 2005).

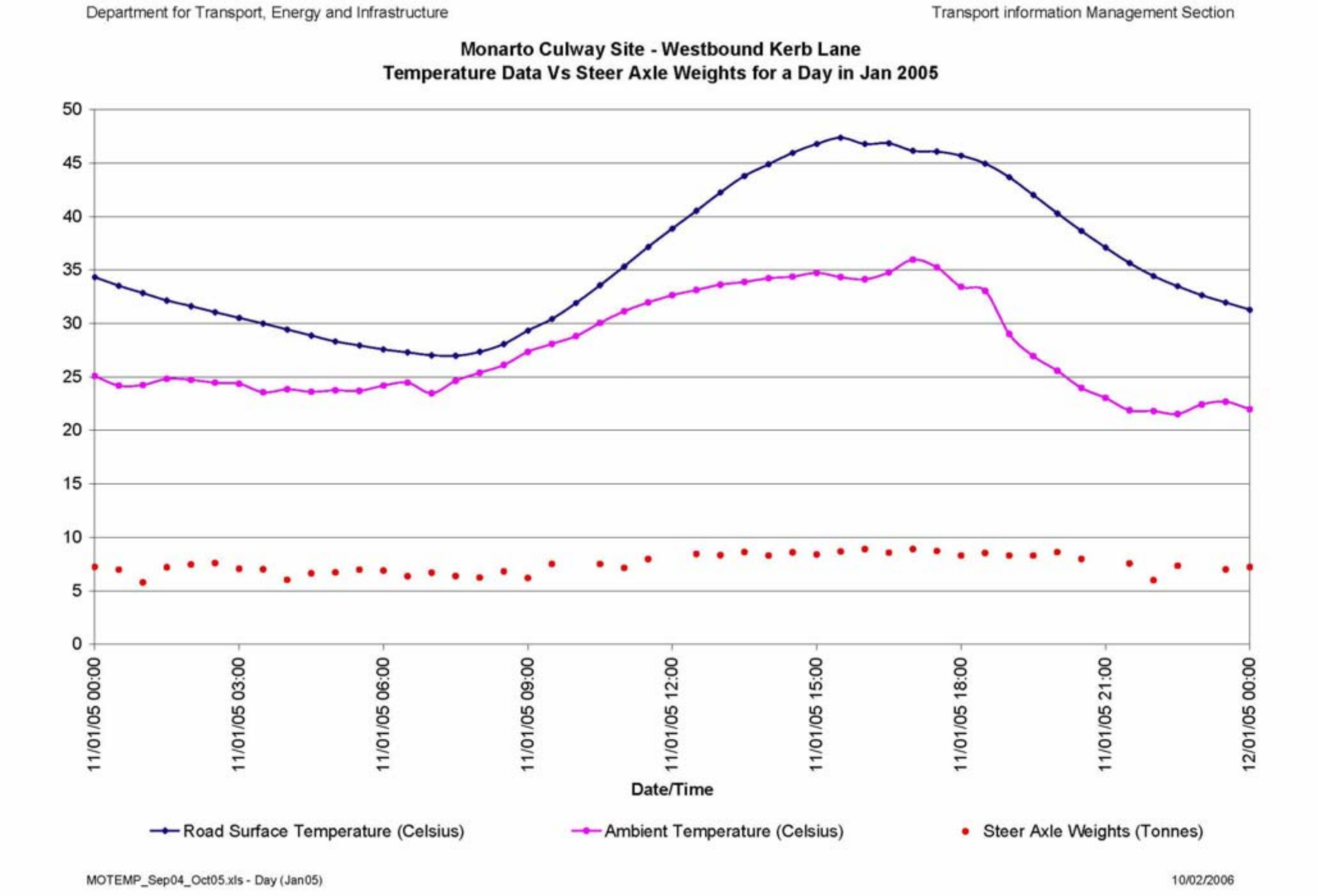

Chart 4 – Typical Summer Day

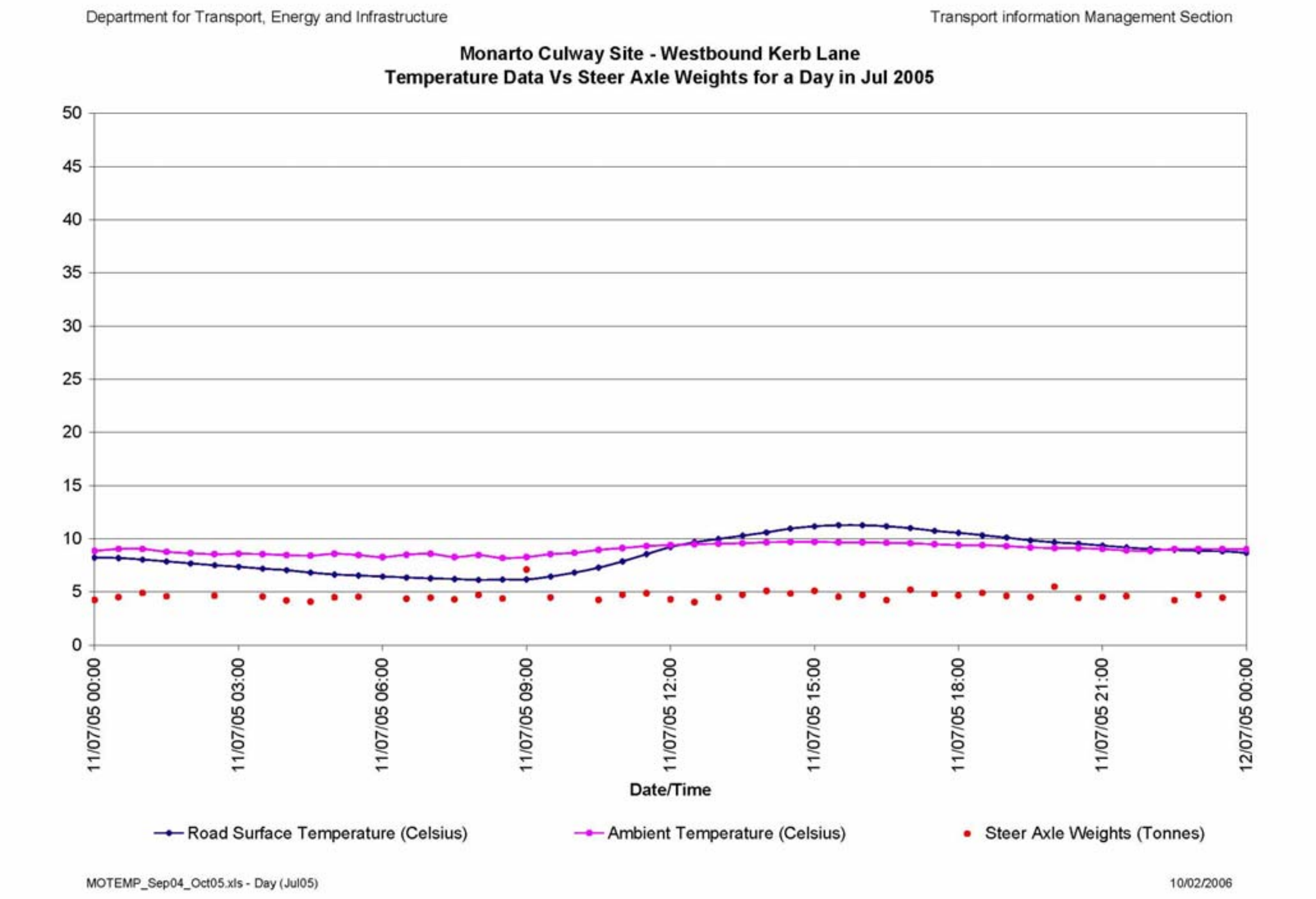

Chart 5 – Typical Winter Day

Chart 5 clearly shows that the steer axle weights are far more consistent during a winter's day than a summer's day (Chart 4). This is because the daily temperature variations are smaller during winter. As the variation in temperature increases so does the variation in steer axle weights. More importantly, the variations are consistent. It is also important to note that even though the weights are more consistent on a winter's day they may still need to be 'normalised' to bring them up to the standard benchmark weight for the site. This is necessary because the calibration factors for each site are based on information that was collected on a specific day where the temperature may have been quite different on that day. This is why we generally try to undertake our calibrations during spring or autumn (more neutral conditions, where hopefully the daily temperature will not vary much during the course of the day).

The next issue in this study is to prove that there is a similar relationship between temperature and the Gross Vehicle Mass (GVM). However, this may not be as obvious due to the wide range of loads that are possible with Class 9 vehicles (from empty, at about 17 tonnes to fully loaded at 45.5 tonnes for vehicles fitted with road friendly suspension). Despite the assumed difficulty in being able to demonstrate this, the next chart (Chart 6) does suggest that the GVM has the same relationship with temperature as the steer axle weights. This provides further evidence that <u>axle weights</u> (strain readings) are proportional to the temperature within the road surface/pavement (the degree of influence depends on the composition of the road pavement, which varies from site to site).

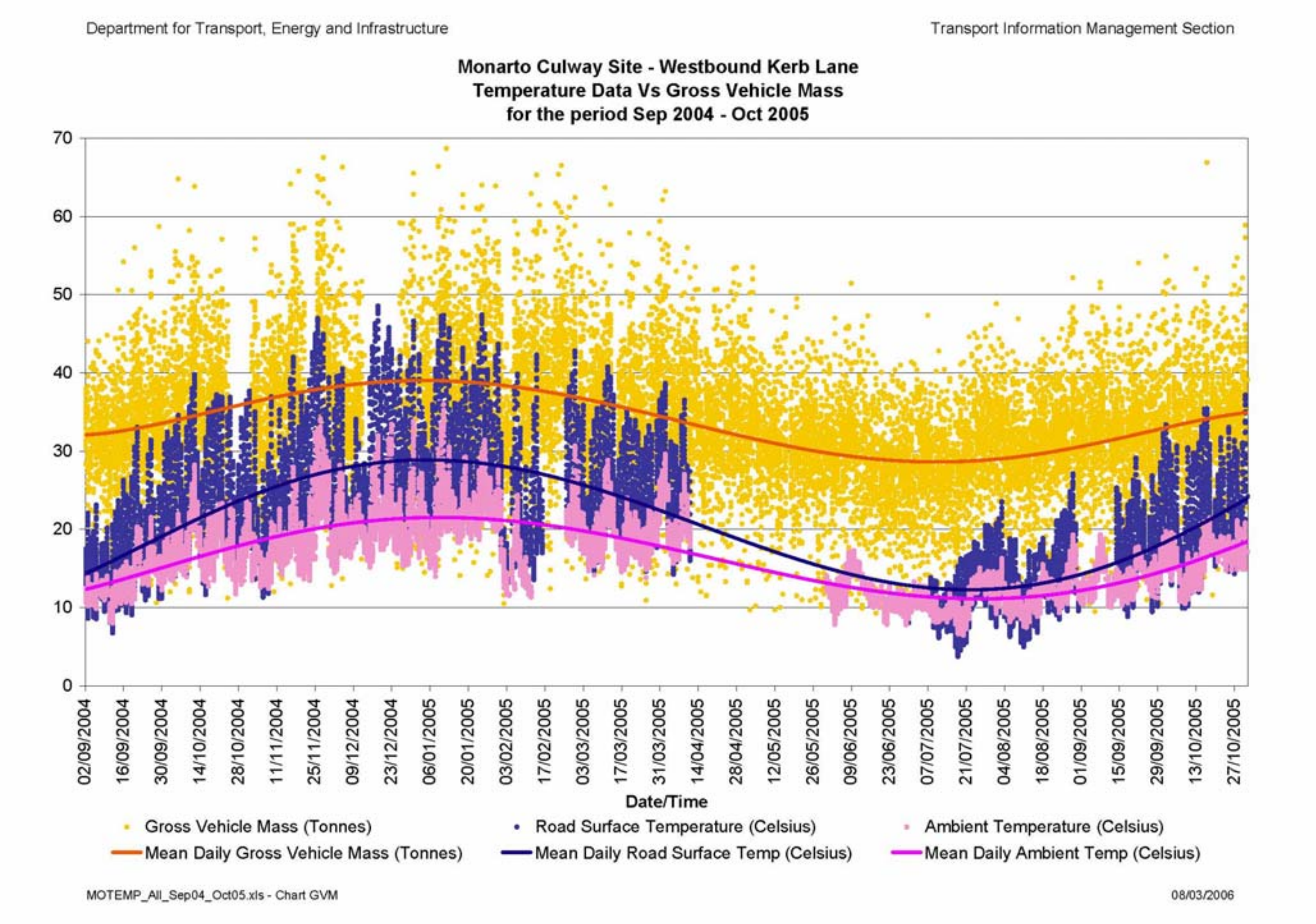

Chart 6 – Annual Temperature Vs Gross Vehicle Mass

The scatter of GVM beyond what is normally expected for Class 9 (A123 type) vehicles demonstrates how necessary it is for us to 'normalise' the data from this site. At this stage it would be reasonable to assume that all vehicles weighed at this site are producing results that are also influenced by temperature. It should also be noted that our normalisation procedure does not compensate for variations in the daily temperature (over a 24 hour period). Compensating for daily/hourly variations in temperature is more difficult to achieve. This would require a much more sophisticated method of normalising the data. At the time this report was written we only had 'normalised' data for 2004. Hence, Charts 7 and 8 will show how (for the 2004 dataset) the mean steer axle weight and mean gross vehicle mass have been flattened (to compensate for the seasonal variation between the summer and winter months).

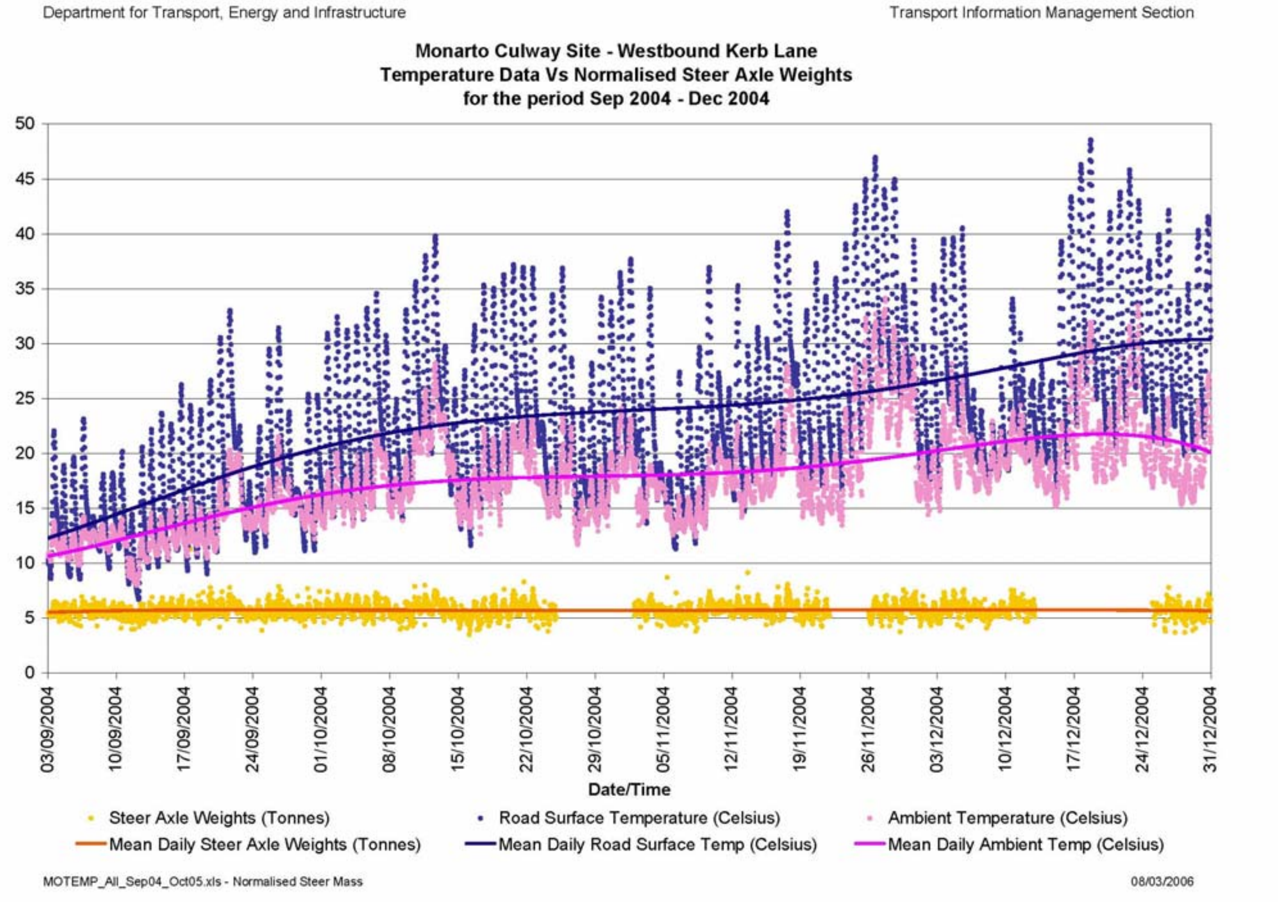

Chart 7 – Temperature Vs Normalised Steer Axle Weights

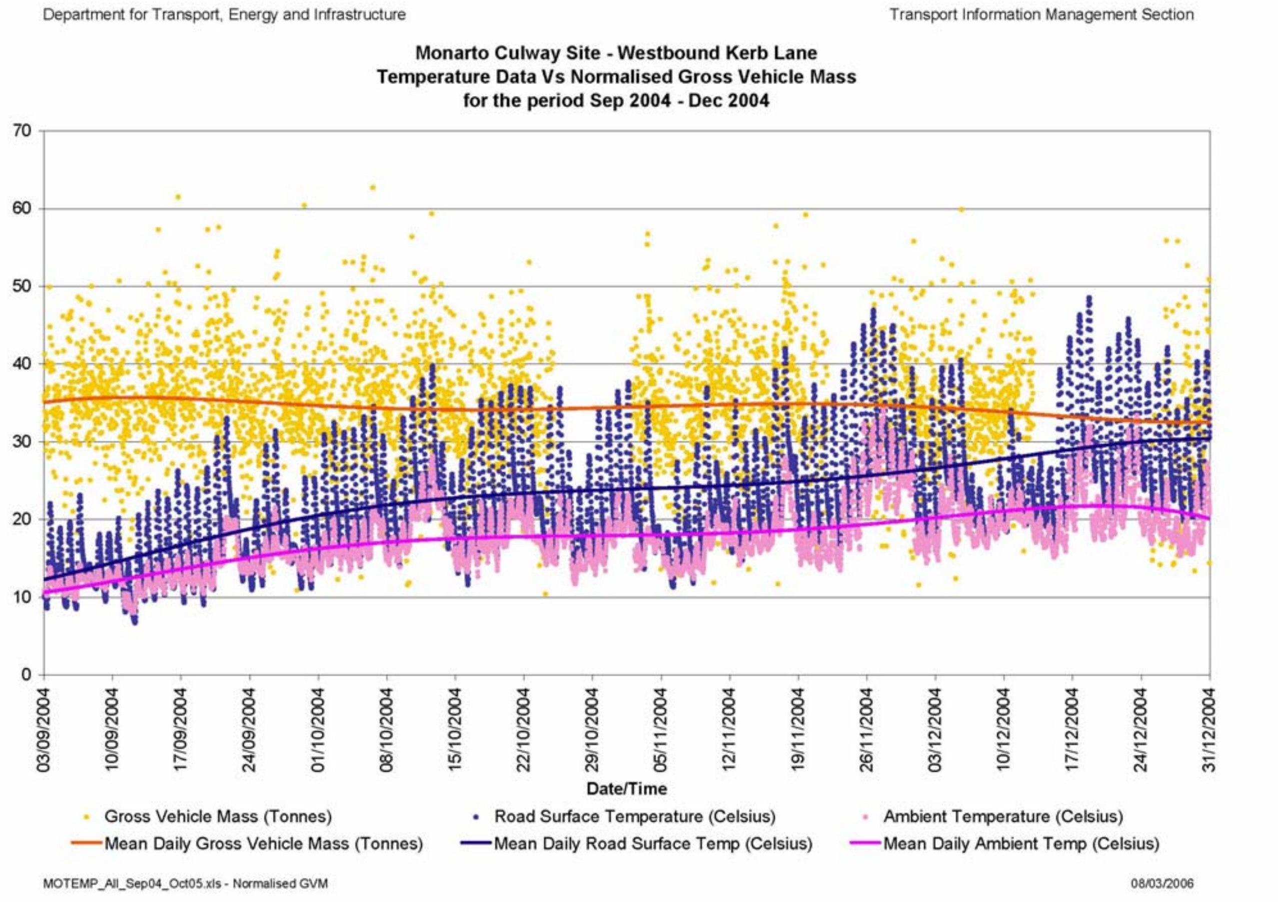

Chart 8 – Temperature Vs Normalised Gross Vehicle Mass

Where to from here?

I am proposing to undertake further temperature studies of some of our other (more typical) Culway sites. I will need to do this in order to see how sensitive to temperature they are in comparison to the Monarto site. This will probably include two more sites, one with deep asphalt (similar to Monarto) and the other having a simple spray seal (chip seal). We have recently started to improve the road surface quality at some of our Culway sites by having asphaltic concrete laid over our sites. This not only improves the road surface but also improves the reliability and quality of piezo installations. I will be paying particular attention to these sites to see how much influence the 75 – 100 mm AC has had on the 'calibration drift' at these sites (I would expect that calibration drift may increase at these sites).

I have partially developed a program that will read raw Culway data (*.CRD files) and the corresponding temperature data files, with the aim of correlating each weighed vehicle to temperature readings at half hourly intervals. The next step would be to prepare a table containing 'temperature compensation factors' and/or establish an empirical relationship, which could be produced from the temperature information collected, and correlating it to the steer weights of Class 9 vehicles.

As you may imagine this is tedious, and it takes a long time to gather and correlate all the necessary data for each site. So this is not necessarily the best way to apply vehicle-by-vehicle temperature compensation factors. My main objective is to show that there is a need to improve the quality of Culway WIM information and to demonstrate that a method to compensate for temperature can be developed. However, (if my findings are justified and supported by other State Road Authorities) the ultimate solution would be to incorporate temperature sensors as part of the Culway WIM system. This would allow temperature data to be logged against each vehicle weighed. The calibration and analysis programs could then be modified/upgraded to use temperature data by locating and applying a suitable factor from a predefined 'temperature compensation factor table' and/or applying an empirical relationship.

I may be dreaming!

But you'll never, never know! …… If you never, never have a go! ☺