THE USE OF PORTABLE IN MOTION WEIGHT CONTROL TECHNOLOGIES AT LANDFILL SITES

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ABSTRACT

Verifiable data on the quantities of waste generated and disposed of in South Africa is important for informed planning and decision-making by all three spheres of government. However, pilot projects conducted by the Department of Environmental Affairs and Tourism as part of the South African waste information system project, highlighted that many medium and large general waste landfill sites in South Africa currently operate without weighbridges, although required to under the Minimum Requirements for landfilling.

As an alternative, in-motion weighing technology currently available in South Africa, was investigated to assess its suitability as a 'portable landfill weighbridge'. These technologies are used traditionally by trucking companies to ensure that vehicles are not overloaded, or unevenly loaded when leaving the trucking yard. These systems, which use load, cell weight sensors to determine axel weights had only been used on a limited and intermittent basis for the purposes of weighing waste at landfills. It was therefore not known if these systems could be appropriately adapted to function as portable weighbridges. To assess the suitability of the technology, four tests were undertaken at various landfill sites within the Gauteng Province. Aspects considered during these tests included: accuracy of the technology given the varied truck types and loads, the durability of the system, the ease of use, and the infrastructure required to utilise the system effectively. In terms of accuracy, the results obtained from the final test indicated a 99% confidence that the measurements recorded using the in-motion weighing technology are within 5% of that recorded on a calibrated, on-site weighbridge.

The experience gained through testing the portable weighpad technology has indicated that the technology can be used successfully to weigh waste loads within a landfill environment and to verify data collected through density-volume estimation methods. This technology is not however considered a long-term option for medium and large landfill sites and should not be seen as a replacement for permanent weighbridges. The intention is that this technology, in the absence of an on-site weighbridge, be used to periodically verify estimated data.

KEYWORDS

Portable, in-motion weight control technologies, weighpad, data collection, SAWIS, landfill site

INTRODUCTION

At present in South Africa there is no comprehensive, up-to-date source of information on the waste streams generated in the country or on how they are managed. This lack of waste data severely impacts on the Department of Environmental Affairs and Tourism's (DEAT) ability to develop long term policies and plans for waste management which in turn impacts on the plans of other government structures. At a provincial level, one of the most apparent implications of the information gap is the impact that this has on the ability to make effective decisions regarding Environmental Impact Assessment authorisations undertaken on new developments including new disposal sites and treatment facilities. At an institutional level, one of the most apparent implications of the information gap is this lack of data to support the day to day management of waste disposal and treatment facilities.

The information gap was identified and highlighted through the development of the National Waste Management Strategy (NWMS) and is being addressed by DEAT through the development and implementation of the South African Waste Information System (SAWIS). The framework document which supports the development of the SAWIS targeted certain facilities for the first phase of data collection, which included among others landfill sites classified as large general (GLB), medium general (GMB) and hazardous (H:H, H:h) in terms of the Minimum Requirements for Waste Disposal by Landfill (DWAF, 1998). These landfills were prioritised for reporting to the SAWIS as they are required, through the Minimum Requirements, to operate weighbridges, thereby 'ensuring' the immediate availability of waste data.

In order to test the first version of the SAWIS, pilot projects were initiated in the Eastern Cape and the Mpumalanga provinces. Through the implementation of these pilot projects it was realised that the assumption that all GMB and GLB landfills operate weighbridges was incorrect for many of the municipal landfills within these provinces. Further enquiries into the weighbridge status at landfills within other provinces revealed the same findings. To determine the scale of the problem country wide, the number of landfills in the Gauteng province operating without a weighbridge was determined and a percentage calculated. By applying this percentage to the number of GMB, GLB and H landfill sites in the country as identified by the Baseline Studies (DWAF, 1997) it is estimated that ~50% of these landfill sites operate without weighbridges.

In the absence of weighbridges, some landfill sites use density-volume estimation methods to generate landfill data, however the accuracy of estimation methods is highly variable and as a result, the confidence in the waste data being provided to the SAWIS is questionable.

Collecting verifiable data is essential for the successful operation of the SAWIS. Based on the fact that many landfill sites do not (i) collect any waste data, and (ii) collect waste data only through estimation methods, DEAT initiated a study to investigate:

- the relative accuracy of waste estimation methods;
- explore different technologies that are presently available on the South African market that could be used to periodically test tonnage estimation results; and
- explore the possibility of supporting the landfill tonnage estimation systems with periodic data collected using portable weighpad technology.

This paper describes the technologies, reviews the process followed and documents the findings of the study.

THE RELATIVE ACCURACY OF WASTE ESTIMATION METHODS

Several attempts have been made by various municipalities in South Africa to estimate the mass of waste entering their landfill sites. In some municipalities these estimations are used for billing purposes e.g. Buffalo City Municipality, however usually these estimation exercises are implemented for once off purposes, which could include:

- Statistics generation for the development of Integrated Waste Management plans (IWMPs);
- statistics generation for the development of a new landfill site in the area; and
- a general update of waste statistics for the municipality.

Waste mass estimation methods are calculated using the following formula:

$$\textit{Waste mass [kg]} = (\textit{truck volume } [m^3]) \times (\textit{loading factor}) \times (\textit{waste density } [kg/m^3])$$

Densities can be found in literature or calculated by weighing certain waste types over the weighbridge and using these densities as a standard. Variations in calculation methods include; weighing specific vehicles and their typical loads once and using these figures as a standard; another method involves determining the maximum payload per vehicle from the design specifications of the vehicle, this figure is then used together with a density for the waste type transported. Due to the number of variables used and the assumptions made to support each variable, the results obtained using estimations could vary significantly.

To determine the relative accuracy of the waste mass estimation method, the mass calculated using an estimation method was compared to the mass recorded on a weighbridge for the same waste load. In order to do this an exercise was undertaken at three different landfill sites in Gauteng through which the mass of a total of 57 sample waste loads were estimated and then weighed on a weighbridge.

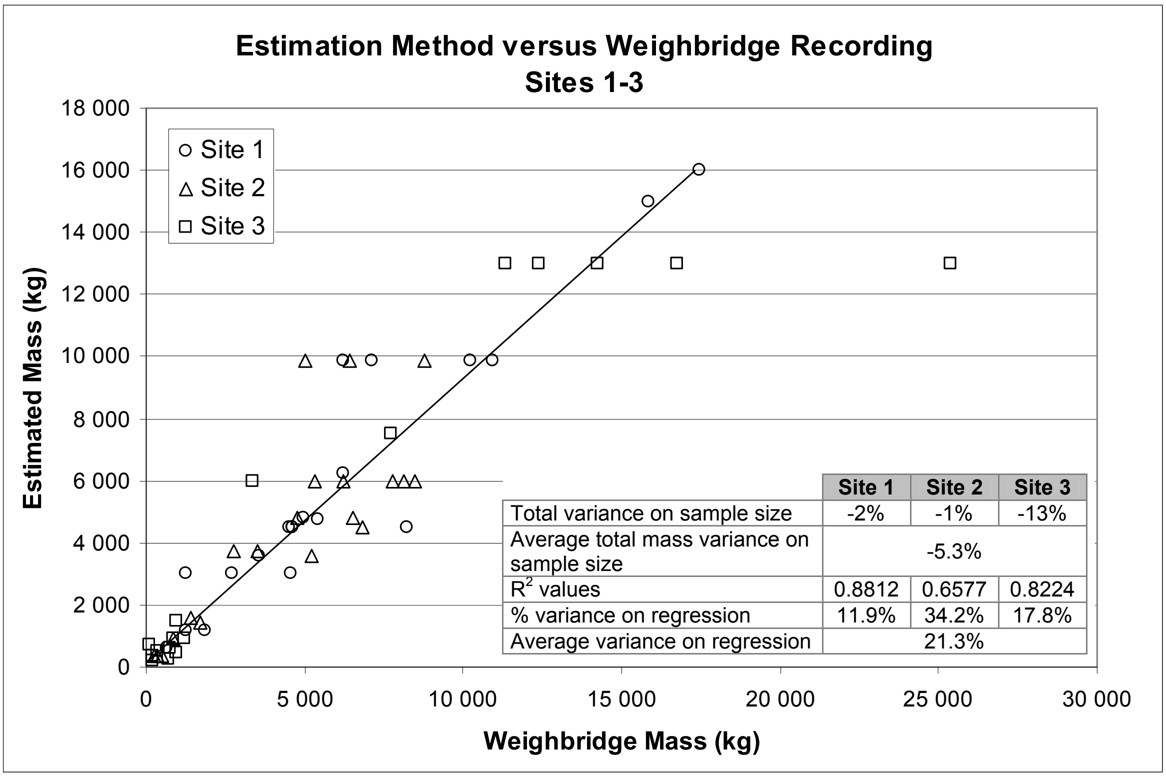
Methodology

The mass of the waste loads entering the site were estimated using the following methodology:

- the disposal cab of selected vehicles entering the site were measured and the disposal volume of the vehicles determined and recorded;
- the loading of the vehicle was determined through a visual inspection and recorded;
- the type of waste was inspected and recorded;
- a pre-determined density for the specific waste type was taken from available literature and recorded as a standard;
- The information was then entered into the waste mass formula and the load mass determined;
- The vehicle was then weighed on a weighbridge and the mass of the load recorded;
- The results of the two methods were compared and plotted on a graph.

Results

The variation between the total estimated mass of all selected vehicles and the total weighed mass of all selected vehicles was on average 5.3% with the estimated mass generally being less that the weighbridge mass. However the regression figures, which compare each individual measurement and not the total, varied by an average of 21.3% (Figure 1), which indicates that the individual errors in estimation evened out over the sample size.



	Site 1	Site 2	Site 3
Total variance on sample size	-2%	-1%	-13%
Average total mass variance on sample size		-5.3%	
R^2 values	0.8812	0.6577	0.8224
% variance on regression	11.9%	34.2%	17.8%
Average variance on regression		21.3%	

Figure 1: Results of the variance between the estimated mass verses the measured mass over the weighbridge

The results demonstrate a relatively acceptable overall level of accuracy, however, it should be noted that the sample size(1) was small in relation to the number of trucks entering the landfill site daily (on average 19 vehicles weighed of a possible 300)(2). A second factor to consider is that the densities were amended with respect to the mix of waste entering the site, so as to ensure the highest level of accuracy. With the limited capacity, i.e. gate control experienced at many landfill sites in South Africa, it is expected that when implementing estimation methods on a daily basis at landfill sites, higher variances may be experienced.

THE RELATIVE ACCURACY OF PORTABLE WEIGHPAD TECHNOLOGY

The project team was aware that a portable weighpad had been used on a once-off basis at rural landfills within the Ekhuruleni Metropolitan Municipality and at the Rustenburg landfill site. The results of these once-off weighing exercises were used to support strategic waste planning in Ekurhuleni and to assist with the development of an IWMP in Rustenburg.

The intention of investigating portable weighpad technology was not to propose the substitution of weighbridges at landfill sites, but rather to determine if portable weighpad technology could be used to verify data collected through estimation methods to increase the confidence in the statistics generated. This possible use is seen as a temporary intervention to allow for the required information to be collected and reported to the SAWIS until weighbridges are installed as required at all GMB, GLB and H landfill sites in the country.

Portable in-motion weighing technologies guaranteed to have a maximum variance of 5% (when used under ideal operating conditions) are currently available on the South African market.

(1) Site 1 – 20 samples, Site 2 – 20 samples, Site 3 – 17 samples
(2) average number based on approximately 9000 vehicles visiting the site monthly

These systems are generally referred to as “low speed in motion axel scales” or “weigh pads”, and are traditionally used by long-haul trucking companies to screen vehicle loads to prevent overloading or uneven loading. The systems, which determine axel loads by weighing vehicles in motion using load cell weight sensors, are compact and portable and can therefore act as ‘portable weighbridges’.

Two different portable weighpad systems were identified – the Vehicle Load Monitor (VLM) supplied by IRENCO (Pty) Ltd and a portable Low Speed Weigh in Motion Program supplied by Mikros Systems (Pty) Ltd. The Mikros system had been used on a limited scale for the purposes of weighing waste at landfill sites, with limited verification of the accuracy of the information generated in landfill applications. It was therefore decided to test the products supplied by both equipment suppliers within a landfill environment, with the specific view to determine if the technology could be appropriately adapted to function as a ‘portable landfill weighbridge’. The aspects considered important to test included:

- The accuracy of the technology given the varied truck types and loads,
- the durability of the system;
- the ease of use;
- the resources (personnel and other) required to operate the system;
- the flexibility of the system given the varying wheel bases of different waste vehicles;
- required skill level of the operator(s); and
- the infrastructure required to utilise the system effectively.

Initial portable weighpad tests – Sites 1 to 3

Both the Irenco and Mikros systems were tested at two different landfill sites in Gauteng. A third test using the wider sensor Mikros system (the 0.95m wide sensors were replaced with 1.5m wide sensors) was conducted at a third landfill site. For each of the three tests the portable weighpads were set up at the entrance to the landfill site. Vehicles were directed over the portable weighpad, weighed and then weighed on the on-site weighbridge. Vehicles retuning from the tip face were weighed again on the on-site weighbridge and the portable weighpad on their outbound route. The ‘in’ and ‘out’ weights from the portable weighpad were recorded on a strip printer and the vehicle registration number was recorded on each strip to ensure that the ‘in’ and ‘out’ weights for each vehicle could be correlated. Results were then transferred to a spreadsheet that enabled analysis and comparison with the on-site weighbridge results.

Set up

The following observations were made with regard to setting up the portable weighpad systems:

- The systems are compact and are easily transportable in a sedan vehicle. A custom designed trailer is available for transporting the Mikros system if required;
- the 1.5m wide weigh sensors require two people to carry them with ease;
- the systems can be set up within half an hour;
- the systems can operate on rechargeable batteries, it is however advised to use 110 - 220v AC mains electricity if available;
- both systems require that the sensors be set up on a smooth, hard and level surface. Although a concrete or tarred surface is preferred, tests were successfully carried out on a paved surface;
- it was found that an approach distance of approximately 20 meters was ideal;
- it is advisable to provide a portable structure of some kind to protect the operators and equipment from rain, dust and sun (Figure 2);
- the set up of the systems does not require a high level of skill and the process can be easily learnt.

Standard 0.95m wide weigh pads

Larger 1.5m wide weigh pads

Figure 2: The portable weighpad systems in operation

Operation

Details of the operation of the in motion weighing systems are captured in a report to DEAT (DEAT, 2006). The following observations were however made with respect to the operation of the portable weighpad systems tested:

- It was important to explain to the driver what was expected prior to the first pass;
- maintaining the correct intervals between measurements was crucial to ensure that the vehicle identification was recorded;
- the wider 1.5m-weigh sensors were better suited to the landfill situation as drivers were more easily able to manipulate trucks over the wider sensor;
- two people were required to successfully manage the weighing process. One person was required to ensure the correct speed and direction of the vehicle to be weighed and one person was required to record the vehicle identification on the print out;
- the recording system requires a fair amount of data capture to successfully calculate tonnages and create usable information. The double handling of data is resource intensive and increases the possibility for errors; and
- a competent database manager is required to set up the data capture systems and support the data capture personnel, as required.

Results of the initial portable weighpad tests

The results obtained from the first three portable weighpad tests (Figure 1) were disappointing. The results indicated a relatively low level of accuracy between the portable weighpad systems and the on-site weighbridges. On average, the percentage variance between the total daily mass recorded by the portable weighpad and the on-site weighbridge was 10.6%. When comparing the average total mass variance result achieved in the estimation method test (Figure 1) and the portable weighpad test (Figure 3) over the same sample size, the estimation method test results appear at first glance to be more accurate. However the regression figures indicate that the portable weighpad is in fact more accurate than the mass estimation method. The regression variance over the sample size was 21.3% for the estimation method and for the portable weighpad technology 18.3% (Table 1). The regression figures provide a more accurate understanding of the relative accuracies of each individual measurement as opposed to the daily total mass.

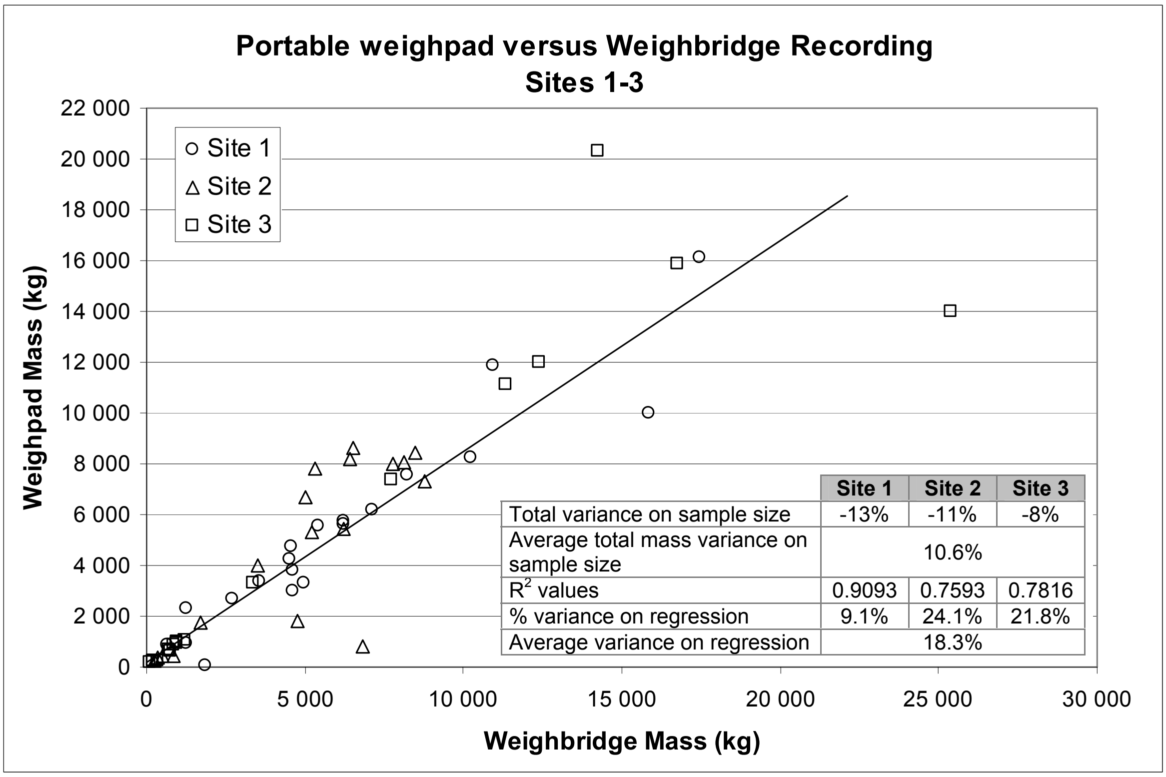


Figure 3: Variance between the results from the portable weighpad and the fixed weighbridges

The results indicated that there was only a 3% improvement in the data collected using the portable weighpad system as opposed to the waste estimation (density-volume) method. When considering that the portable weighpad technology was tested to determine the ability of this technology to verify waste data generated through estimation methods, a 3% improvement in the accuracy of the data may not be considered significant enough to motivate the expense of purchasing the portable weighpad technology. However, it must be reiterated that the estimation tests were undertaken with extreme care to ensure accuracy, something which is unlikely to be achieved on a daily basis at a landfill site.

Table 1: Comparison between the results of the estimation method and the portable weighpad technology

Test	Estimation method		Portable weighpad technology	
	Total mass variance	Regression variance	Total mass variance	Regression variance
Site 1	-2%	11.9%	-13%	9.1%
Site 2	-1%	34.2%	-11%	24.1%
Site 3	-13%	17.8%	-8%	21.8%
Average variance	-5.3%	21.3%	-10.6%	18.3%

A careful review of the results indicated that there might have been a number of reasons for the poorer than expected results obtained from the portable weighpad technology. These included:

- The assumed accuracy of the weighbridge as a point of reference for both the estimation and in motion technology measurements. The assumption may have been incorrect. In fact, careful review of the weighbridge data indicated obvious errors, e.g. inconsistencies between tare weights of a specific vehicle on two different weighing events and some weighbridge data which had a negative figure as the nett weight;

- some discrepancies in the vehicle identification during the portable weighing exercise, resulting in incorrect weights being recorded for some vehicles;
- the small sample size did not provide adequate information to make reasonable assumptions; and

Fourth portable weighpad test

Considering the immense potential the portable weighpad systems could have in verifying estimated waste data at landfill sites, the project team and the management of the Mikros Systems decided that a fourth exercise be undertaken in an attempt to minimise the possible reasons for the poor results obtained and to improve the confidence in the results obtained. Improvements to the system were discussed and the following changes were made:

- The exercise was based on a statistically determined sample size that would provide a 99% confidence rate in the results obtained. To obtain this confidence rate a minimum of 601 vehicles were to be weighed 'in' and 'out' (1202 measurements) (pers comm., Jenny Holloway);
- software modifications were made to an existing data capture system used by Mikros, which allowed the information to be captured directly onto a laptop computer. This improvement removed the errors experienced using the strip printer, eliminated the two minute delay between vehicle measurements and the recording of the data, and made the capture and analysis of data easier;
- two portable cameras were set up which could photograph the vehicles inbound and outbound. These images could be used to check vehicle registrations;
- a vehicle identification system was devised which would clearly identify vehicles that had weighed 'in' and needed to be weighed 'out'. Brightly coloured identification markers were temporarily affixed to the windshield of the vehicle on the 'in' measurement, and removed on the 'out' measurement;
- the weighbridge at the landfill chosen for the final test had been calibrated within the past six months, improving the confidence in the point of reference: and
- dedicated personnel were identified and assigned to execute the exercise.

The exercise was undertaken over a period of 9 days. This extended time period was necessary due to poor weather conditions (excessive rainfall) and unexpected power failures that occurred regularly during the exercise period.

Observations made during the fourth test:

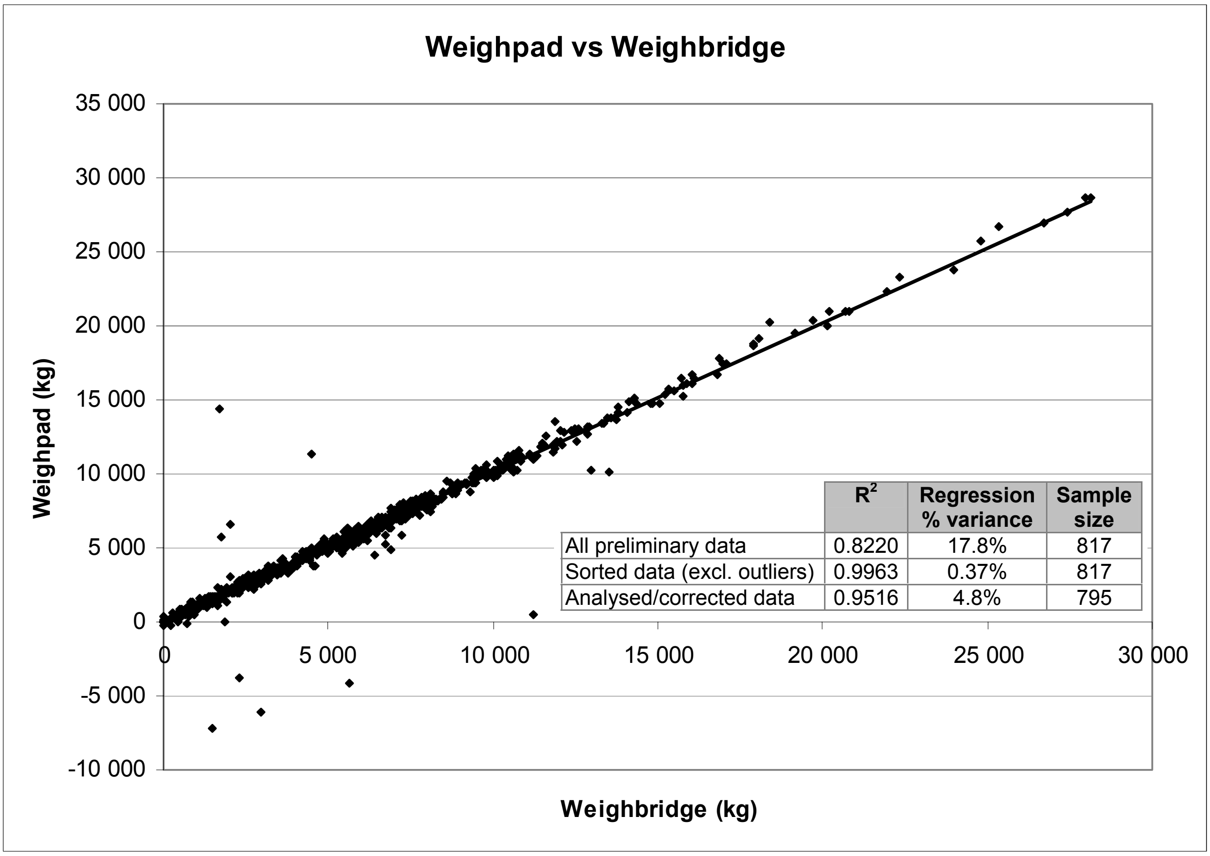
The following observations were made during the fourth test:

- The set up of the system including the laptop and cameras was achieved with ease within half an hour;
- capturing the data required in the capture fields programmed was easily achieved, and it was possible to successfully weigh 60 vehicles per hour on the system, reducing the vehicle measurement time from 2 minutes to 1 minute;
- the weigh sensors could be operated in rainy weather, however, the computer needed to be protected against poor weather conditions;
- a store room where the equipment could be stored on site overnight would be ideal, however when the purpose built trailer is used this is not necessary;
- a 20m approach from both the incoming and outgoing entrances would be advisable for easy access;
- data capture was more accurate as the vehicle registration was captured and stored in the computer at each measurement;
- the system was durable, in excess of 800 vehicles were weighed 'in' and 'out' in the 9 days;

- both the site weighbridge and the portable weighpad record the weighing time. This allows for cross correlation between weighing events which was helpful to check individual truck weights;
- by using dedicated staff a high level of efficiency can be achieved; and
- it is important to have an operator working on the system that can do basic trouble shooting and repairs to minor breakdowns of the system.

Results of the fourth portable weighpad test

The initial analysis of the data indicated that of the 817 vehicles weighed over the weighpad sensors during the exercise, 763 (93.4%) were accurate to within 10kg of the on-site weighbridge mass. This is seen as an extremely good correlation. However in total there were 54 measurements that had variances in excess of one ton between the portable weighpad and the on-site weighbridge results. Twenty-seven of the variances reflected weighbridge results exceeding the portable weighpad weight, and 27 variances reflected the portable weighpad results exceeding the site weighbridge results. Figure 3 displays the initial results in a tabular format.



	R^2	Regression % variance	Sample size
All preliminary data	0.8220	17.8%	817
Sorted data (excl. outliers)	0.9963	0.37%	817
Analysed/corrected data	0.9516	4.8%	795

Figure 3: Initial results of the fourth portable weighpad exercise

Reviewing the results (Figure 3) it is evident that although 763 of the portable weighpad measurements were within 10kg of the weighbridge results the percentage regression variance on all the data was 17.8% which was disappointing. When removing the 54 outliers the percentage regression variance was excellent at 0.37%.

The outlier figures were carefully analysed and the following modification were made:

- The tare weights of some vehicles recorded by the weighbridge were corrected against an average tare (for the same vehicle) recorded over the period;
- entries reflecting a difference in number of axels weighed 'in' and 'out' were removed;
- documented recordings where 'in' results were recorded as 'out' and visa versa were corrected; and
- where weighbridge data reflected a negative result, the measurement was excluded.

These corrections improved the regression average to 4.8% which is regarded as being more reflective of the true figure. This variance is within the 5% variance indicated by the manufactures, proving that the technology could successfully be used to verify results obtained using the estimation method thereby improving the confidence in the data generated.

Observations from weighbridge data

In addition to fulfilling the intended purpose of the investigation, the exercise also highlighted the need to make certain improvements to the general operation of on-site landfill weighbridges so as to improve the accuracy of weighbridge data. Aspects to consider include:

- At least one month's weighbridge data should be annually audited through an external auditor, attention should be paid to the following aspects in the audit:
  - Confirmation of calibration;
  - Availability of a maintenance plan and maintenance records;
  - Statement regarding the accuracy of tare weights used;
  - Statement regarding the accuracy of information recorded indicating obvious errors (e.g. zero or negative values on entry);
  - Correct waste type identification and recording;
  - The tare weights for vehicles are to be checked by the owner from time to time and confirmed with the landfill operator, or by the landfill operator; and
  - All vehicles passing over the weighbridge should reflect on the weighbridge report. Any vehicles not recording a load should be grouped each day and notes made identifying the reasons for no weights being registered. The exercise has shown that at peak times municipal trucks are sometimes routed past the weighbridge or trucks carrying free loads e.g. building rubble are not recorded. This interferes with the deposition rate for the landfill and impacts all waste statistics.

COSTS OF PORTABLE WEIGHPAD SYSTEMS

Approximate costs for the portable weighpad systems as supplied by both suppliers are included in the Table 2. The costs do not include the cameras used on the Mikros system or the laptop used in the fourth test to capture data.

Table 2: Approximate costs of the two portable weighpad systems tested

System	Price [R]
Irenco Vehicle load monitor system	R54 250
Mikros Low Speed weighing in motion system (standard)	R61 400
Mikros System using 1.5m wide sensors	R90 600
Mikros System including the purpose made trailer (cones, umbrella and 2 chairs)	R107 200

* Prices quoted at the time of the study
* Prices exclusive of VAT
* Irenco system quoted as including – two WL110 sensors in aluminium case, one EC110 monitor and charger, cables, four levelers, strip printer, case for electronic unit, software & training manual
* Mikros standard system quoted as including - two sensors (0.9m wide), one terminal, four levelers, strip printer, strip printer case, software & training manual

CONCLUSION

In order to meet the objectives of government in improving the management of waste in the country, there is an urgent need to collect accurate and reliable data on tonnages of different waste streams generated, reprocessed, treated and disposed of. In particular in the short-term, in order to support the development and implementation of the first phase of the SAWIS, specific emphasis needs to be placed on collecting information from landfill sites. The pilot projects implemented in the Eastern Cape and Mpumalanga provinces have demonstrated that it is possible to relatively easily collect waste data through waste estimation systems at landfills. This waste data will enable municipalities to improve on the day-to-day management of landfill sites, facilitate long-term planning and support the implementation of the SAWIS by providing the necessary data required. In addition, it is evident from the Eastern Cape pilot that through negotiation with commercial landfill site users information gathered in this manner can provide the basis for billing.

The experience gained through testing the portable weighpad technology has indicated that the technology can be used successfully to weigh waste loads within a landfill environment and to verify data collected through waste estimation methods. This technology is not however considered a long-term option for medium and large landfill sites and should not replace permanent weighbridges. The intention is that this technology be used to verify estimated data on a periodic basis.

Although the collection and verification of waste data can be achieved at a high degree of accuracy, experienced gained through the implementation of the pilot projects has revealed that the collection of data is not a high priority for many municipalities. In addition it is evident that staff and basic infrastructure are not available at many of the facilities to allow for information collection. It is therefore acknowledged that although data collection and verification is possible, certain challenges will be faced in the collection of data in the short-term.

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