The purpose of a weighing system is to calculate the mass of material in a loader's bucket, relay this back to the loader's operator in real-time and record the mass for later use.

ONBOARD WEIGHING SYSTEMS:

IMPROVING THE BOTTOM LINE, REDUCING CO² EMISSIONS

With tough economic times looming and a strong awareness of human impacts on the environment, it is critical to cut costs and minimise environmental impacts. **Jeff Vickers** discusses how Loadrite loader and excavator weighing systems can help to optimise truck loading.

In 2006, Actronic Technologies started a project with the University of Auckland in New Zealand to reduce the environmental impacts of its Loadrite onboard weighing systems. As quarries often install weighing systems to improve productivity, a sub-project was set up to compare the environmental impacts of the products themselves to the savings achieved by using them.

For a New Zealand quarry that uses Loadrite weighing systems to optimise road truck loading, it was estimated that 700,000 MJ of non-renewable energy consumption and 52 tonnes of CO^2-equivalent greenhouse gas emissions were avoided for each loader that had a weighing system installed. The potential impacts caused by manufacturing, distributing, using and disposing of that same weighing system were 144 and 154 times smaller respectively. While the improvement achieved will vary from quarry to quarry, such a large difference should not come as much of a surprise - an onboard weighing system uses much less energy than a wheel loader, yet it can significantly improve the operating efficiency of that wheel loader.

While the environmental impacts of the weighing system itself have been assessed quite accurately, much more data is needed on productivity improvement. If you are interested in how a Loadrite weighing system could improve the productivity of your quarry, there is an opportunity to participate in this study at the end of this article (see page 21).

THE LOADRITE WEIGHING SYSTEM

A basic Loadrite weighing system, as installed on a wheel loader, is shown in Figure 1. Its purpose is to calculate the mass of material in a loader's bucket, relay this back to the loader's operator in real-time and record the mass for later use. In practice, a microprocessor uses pressure and angle readings to determine the mass.

The basic system consists of:

1. An indicator unit, which includes a microprocessor, keypad and screen.

2. A trigger, which monitors the position of the boom.

3. Two pressure transducers connected into one of the boom's hydraulic cylinders, one transducer on the lift side, the other on the return side.

4. Hydraulic fittings, hydraulic hoses and electrical cables.

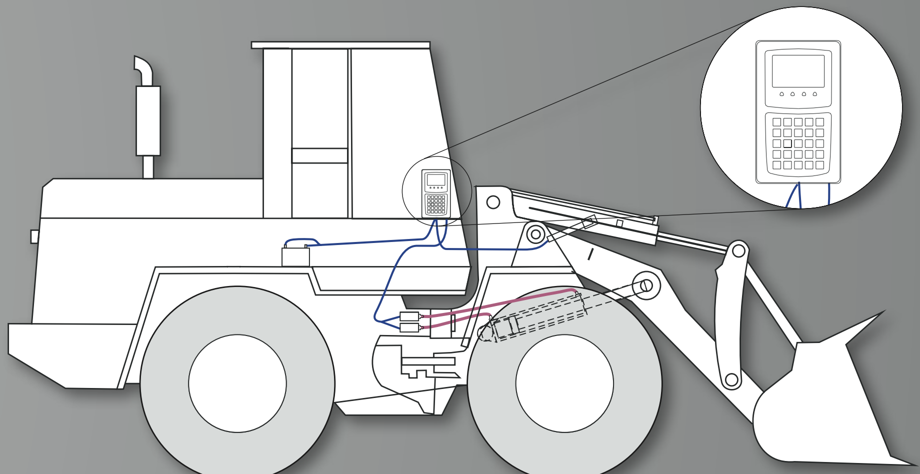


Figure 1: A Loadrite weighing system installed on a wheel loader.

"A basic Loadrite weighing system calculates the mass of material in a loader's bucket, relays this back to the operator in real time and records the mass for later use."

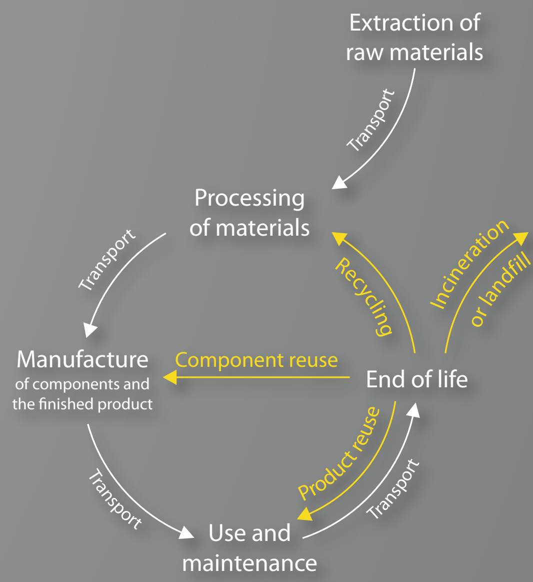
This system can be extended by adding a printer, remote buttons, additional sensors, etc, but only the core system is shown in Figure 1.

LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is a technique used to assess the environmental impacts of a product throughout its life. An LCA is typically carried out from "cradle to grave," which means that all phases of a product's life cycle are considered: extraction and processing of raw materials, manufacture of components and the finished product, packaging, distribution, the use of the product and, finally, processing (reuse, recycling, incineration or landfill) at the end of the product's useful life.

A complete LCA would estimate the potential environmental impacts of all inputs taken from the environment (resources and energy) and all outputs to the environment (waste). In practice, however, only certain impacts on the environment can be assessed as the natural environment is complex and difficult to model.

There are many LCA software tools available.[1] For this assessment, eVerdEE was chosen over other tools[2] because:



Typical phases in the life cycle of a product

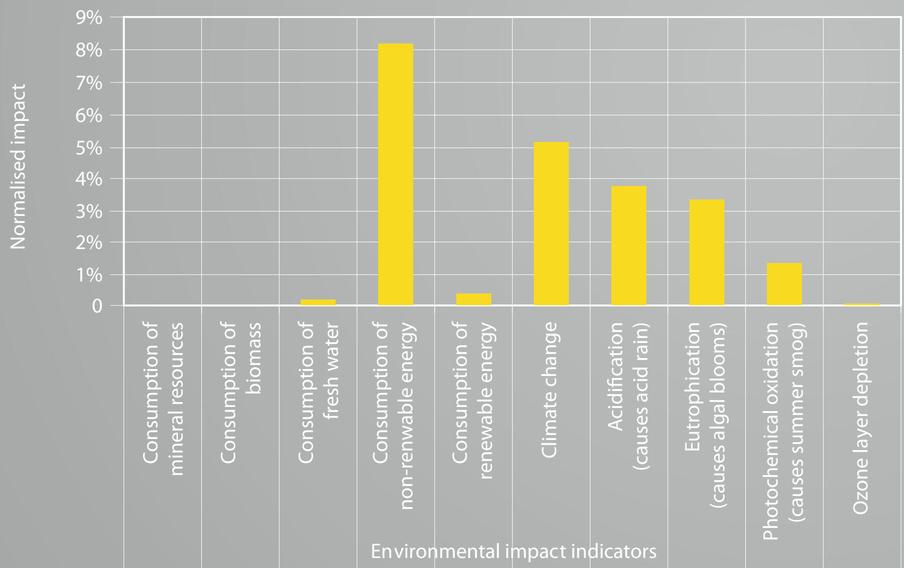
- Its methodology is based on the international standard for LCA, ISO 14040.
- Its database of materials, components and processes was well suited to an industrial electronic product.
- It assesses a number of useful environmental impacts, such as non-renewable energy consumption, global warming potential and acidification potential.
- It is free to use.

LCA OF LOADRITE

There are four stages to an LCA:

1. Goal and scope definition.
2. Inventory analysis.
3. Impact assessment.
4. Interpretation.[3]

As the LCA of a Loadrite weighing system was intended for product designers, its goals were to:



Impact	0.217	0.686	0.791	4860	33.3	340	1.73	0.310	0.149	4.16
Units	g Sb eq.	kg	m^3	MJ	MJ	kg CO_2 eq.	kg SO_2 eq.	kg PO_4 eq.	kg C_2H_4 eq.	mg CFC-11
Normalised	0.011%	~ 0	0.21%	8.2%	0.36%	5.2%	3.7%	3.3%	1.3%	0.033%

Figure 2: Results of the life cycle impact assessment of a Loadrite weighing system.

"If trucks are loaded to their rated capacity first time this will reduce the number of trucks that must be reloaded by wheel loaders and reduce the average time a truck spends in the quarry."

a) Identify "hot spots" of environmental impact across the product's life cycle so that these can be minimised in future product design.

b) Approximate the size of these impacts relative to the size of avoided impacts due to the use of the product.

To allow different LCAs to be compared, a functional unit should be defined. As a product may have many functions, the functional unit defines the function of interest. For example, a refrigerator might have two functions: (1) to keep food and drink at a desired temperature; and (2) to display fridge magnets and notes. Assuming that the function of interest is cooling, the functional unit might be "maintaining a volume of 400 L at 4ºC for 100,000 hours".

For this study, the functional unit was based on the typical use of a Loadrite weighing system and was defined as "a system that records and displays (in real-time) the mass carried by one hydraulic lifting machine functioning an average of 56 hours per week, every week of the year for 8.5 years". The amount of product required to fulfil this function was one Loadrite system and typical spare parts required over its life.

As a full LCA can take several months, or even years, the process is often streamlined. Two parts of this study that were streamlined were data collection - as life cycle inventory data can be difficult to obtain from suppliers, much data was taken from life cycle inventory databases - and the end of life phase, which considered disposal only.

The results of the life cycle impact assessment are shown in Figure 2. In order to plot many different environmental impact indicators on the same axes, the results have been normalised. These normalised impacts are a ratio of the impact in a given category to the annual impact caused by one "average" global citizen; that is, the sum of all human interventions in the environment in one year divided by the number of people in the world. So, for example, over its useful life (including raw material extraction, manufacture, distribution, 8.5 years' use and disposal) a Loadrite weighing system requires 8.2 per cent of the non-renewable energy that one "average" person uses in a year.

As normalised impacts share the same frame of reference, they can be used to determine the relative significance of each impact. Based on Figure 2, the impact categories most significant to the Loadrite system are:

- Consumption of non-renewable energy.
- Climate change.
- Acidification.
- Eutrophication.
- Photochemical oxidation.[4]

Normalisation does have its limits, particularly as the current level of human impact on the environment is unlikely to be the same as a sustainable level. To work around this, LCA allows each impact category to be weighted. However, as there is no widely accepted set of weightings, all impacts were assumed to have equal importance.

CASE STUDY

A typical quarry, as shown in Figure 3, operates in the following way: as a truck enters the site it drives over an incoming weighbridge to determine its tare weight. It then drives to a stockpile where it is filled by a wheel loader. Once the truck is loaded it drives to the outgoing weighbridge. If it is overweight it must drive to a waste pile or back to the main stockpile and tip off excess material before returning to the outgoing weighbridge. If it is significantly underweight, it will instead return to the stockpile to be reloaded before it can return to the outgoing weighbridge. Once the truck is loaded to approximately the correct weight, it leaves the site.

The benefits of loading trucks to their rated capacity first time include the reduction of:

- The number of trucks that must be reloaded by wheel loaders.
- The average time a truck spends in the quarry as fewer trucks must tip-off excess product or be topped up if they are underweight.
- The number of trucks that leave the site underweight, thereby reducing the number of truck trips needed to move a

certain amount of product.

- The queues at the outgoing weighbridge.
- The overload fines.

To determine the improvement due to a Loadrite weighing system, measurements would need to be taken both before and after a system was installed. However, as most medium to large scale quarries in Australasia already have weighing systems on their wheel loaders, it is difficult to find a suitable site. Instead, fuel consumption data have been gathered from a quarry that already uses Loadrite products. This fuel use represents the scope remaining for further efficiency improvements in new product development and it can also be used to estimate how much fuel might be used in a quarry that does not use onboard weighing systems.

The data collected from the case study quarry is shown in Table 1. Unless otherwise specified, all data are averages over the 2007 calendar year. In June 2008, this quarry used the following wheel loaders: two Caterpillar 980-G series I, two Caterpillar 980-G series II and one Caterpillar 980-H. The number of loaders operating at any one time depends on the number of trucks on-site; however, it is typical for four loaders to operate simultaneously. Over the quarry's 61.5 hour working week, 1600 trucks are loaded on average. Each week, it is estimated that 25 to 35 trucks must either reload or tip-off and of these approximately half are reloads and half are tip-offs. Using the lower estimate, each loader causes approximately three reloads and three tip-offs per week, or 1300 of each over the 8.5 year life of the Loadrite system.

Rather than have truck drivers return to the main stockpiles to be topped up or tip off excess material, the quarry has smaller stockpiles of common products near its outgoing weighbridge. There is also a waste pile of mixed product if a truck needs to tip-off but is not carrying one of the common products. If a truck needs to be topped up and is not carrying a common product, the driver will typically leave the site slightly underweight rather than return to the main stockpile for that product. To simplify the calculations, it will be (conservatively) assumed that no drivers return to the main stockpiles. To estimate total fuel use:

- *Fuel consumption per reload,* F_{RL} *= fuel use by truck* $(d_{RL} \times f_{TD} + [t_{DT} + t_{RL} + t_{WB}] \times f_{TI})$ *+ fuel use by loader* $([t_{DT} + t_{RL}] \times fL)$ *= 2 L*
- *Fuel consumption per tip-off,* F_{TO} *= fuel use by truck* $(d_{TO} \times f_{TD} + t_{WB} \times f_{TI} + f_{TO})$ *= 0.3 L*

Total fuel consumption caused by improper loading over the life of the Loadrite weighing system ($n_{RL} \times F_{RL} + n_{TO} \times F_{TO}$) is estimated as 3000 L of diesel fuel on average. Data on spared truck trips have been omitted in this study due to a lack of data, so this figure is likely to

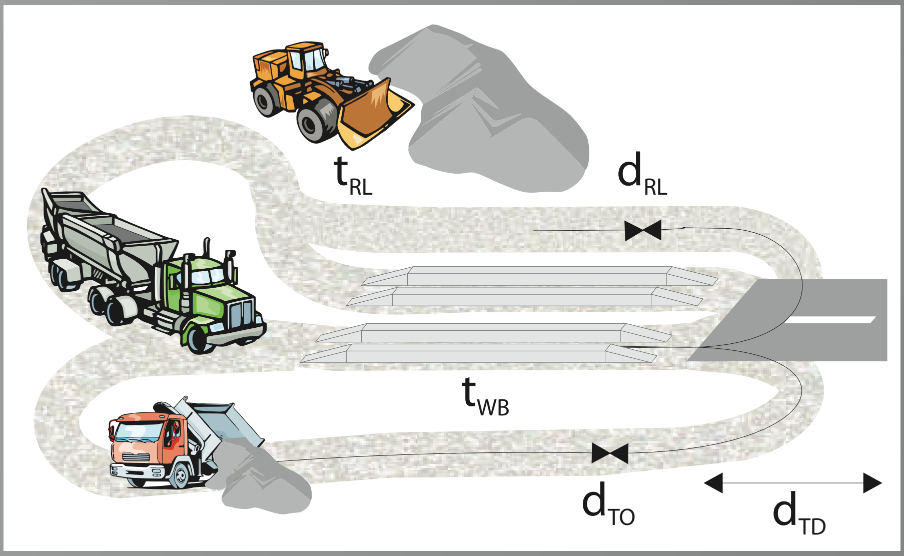
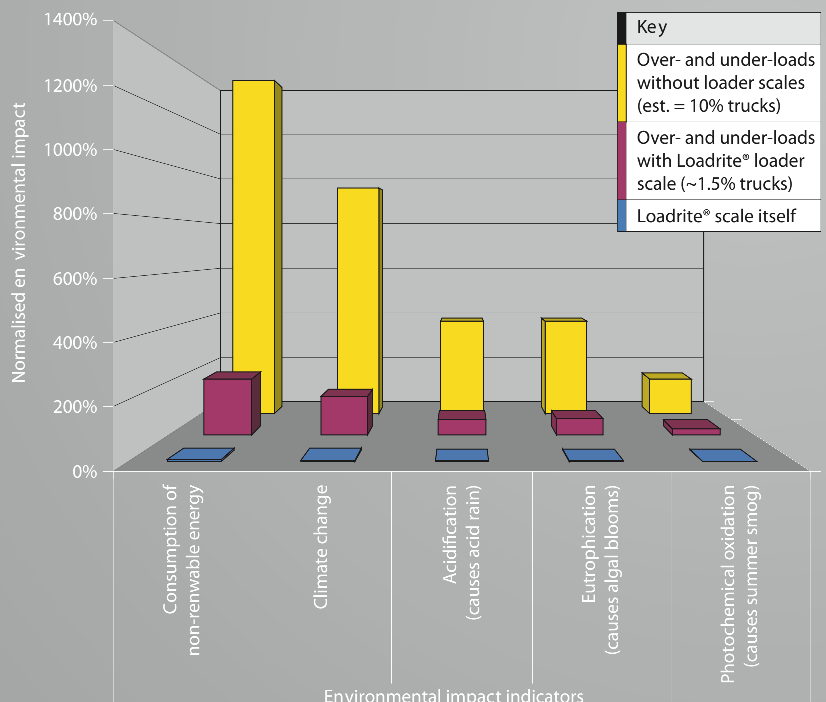


Figure 3: Road trucks being loaded in a typical quarry.

TABLE 1: DATA FROM THE CASE STUDY QUARRY PARAMETER			
Parameter		**Average**	**value**
Number of reloads [A]	n_{RL}	1300	
Number of tip-offs [A]	n_{TO}	1300	
Truck fuel use while driving [B]	f_{TD}	0.55	L/km
Truck fuel use while idling [C]	f_{TI}	3	L/h
Truck fuel use to tip off 2 tonnes [D]	f_{TO}	0.1	L
Loader fuel use	f_L	24	L/h
Return distance to reload [E]	d_{RL}	0.2	km
Return distance to tip off [E]	d_{TO}	0.2	km
Time queuing for and crossing the outgoing weighbridge [E]	t_{WB}	2/60	h
Time for loader to drive to truck [A]	t_{DT}	3/60	h
Time to reload truck [E]	t_{RL}	1/60	h

A Estimate by assistant quarry manager in June 2008.
B Average from a fleet of road trucks using the quarry, mostly 44 tonne (gross) truck-and-trailer units.
C Based on 0.8 gal/h for a large sleeper truck.[5]
D Based on two minutes idling as no data were available.
E Measured in June 2008.



	MJ	Norm.	kg CO_2 eq.	Norm.	kg SO_2 eq.	Norm.	kg PO_4 eq.	Norm.	kg C_2H_4 eq.	Norm.
Over- and under-loads without loader scales	824000	1390%	61600	941%	178	385%	35.7	385%	16.5	147%
Over- and under-loads with Loadrite® loader scale	123000	208%	9240	141%	26.7	57.7%	5.36	57.8%	2.48	22.1%
Loadrite® scale itself	4860	8.20%	340	5.19%	1.73	3.74%	0.310	3.34%	0.149	1.33%

Figure 4: Impacts of the Loadrite weighing system vs impacts of trucks turning around at the weighbridge.

underestimate real consumption considerably.

In the case study quarry, the proportion of trucks that had to either tip off excess load or be reloaded was approximately 1.5 per cent. When an onboard weighing system is not installed, the number of tip-offs and reloads depends on a number of factors: the level of experience of the loader operator, whether or not the weighbridge radios back the weight of trucks leaving the quarry, etc. However, informal estimates suggest that in quarries without onboard weighing systems, approximately 10 per cent of all trucks will need to tip-off or reload. By scaling up the case study, a quarry without onboard weighing systems would use approximately 20,000 L. If onboard weighing systems were then installed, the saving achieved would be 17,000 L for each loader.

Figure 4 compares the life cycle impacts of a Loadrite weighing system to the impacts of fuel consumption in the quarry, assuming 1.5 per cent or 10 per cent of trucks leaving the site must either tip-off or reload. Impacts were calculated in eVerdEE assuming an energy density of diesel of 35.8 MJ/L and class 8B diesel truck emission factors.[5] Only the top-five indicators from Figure 2 are shown; however, it is very clear that the impacts of the Loadrite weighing system itself are insignificant when compared to the impacts offset by improving productivity.

Jeff Vickers is a PhD fellow in the Department of Civil and Environmental Engineering at the University of Auckland in New Zealand. He has been working with Actronic Technologies since March 2006.

This article is based on the following conference paper:

Vickers JJ, Boireau L, Boyle CA. Streamlined Life Cycle Assessment of an efficiency improving embedded electronic device. In: Reichl H, Nissen NF, Müller J, Deubzer O, (ed). Joint International Congress and Exhibition. "Electronics Goes Green 2008+"; 2008 Sep 8-10; Berlin, Germany. Stuttgart: Fraunhofer IRB Verlag; 2008; p. 511-516.

ENDNOTES

1. For a comprehensive list of tools, please see the list provided by the European Platform on LCA at http://lca.jrc.ec.europa.eu/lcainfohub/toolList.vm
2. eVerdEE can be accessed at http://www.ecosmes.net/everdee/. You must subscribe before using the tool, but subscription is free. For more information on eVerdEE, please refer to the user manual at http://www.ecosmes.net/everdee/downloads/methodTutorialEN.pdf
3. International Organisation for Standardisation (ISO). ISO 14040:2006, Environmental management - Life cycle assessment - Principles and framework. 2nd ed. Geneva: ISO; 2006.
4. Consumption of mineral resources is likely to be more significant, but does not appear so due to an error in the eVerdEE database. This error will be corrected in the next version of the tool. (Patrizia Buttol, personal communication, 30 June 2008).
5. Argonne National Laboratory (ANL). The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, v. 1.8b [Online]; 1999 [updated 2008 May 8; cited 2008 Aug 8]. Available from: http://www.transportation.anl.gov/modeling_simulation/GREET. •

CALL FOR PARTICIPANTS

This study is ongoing so if you think a Loadrite weighing system could help improve your quarry or mine's productivity, **contact Jeff Vickers on +64 9 820 7720 (ext 796) or email jeff.vickers@actronictechnologies.com**

Selected quarries and mines will receive a no obligation 30 day trial of a Loadrite weighing system. At the end of this period, you will receive a breakdown of the economic and environmental savings you have achieved and be given the option to either purchase the weighing system or have it removed free of charge. With your permission, your data will be combined with data from other sites and published as part of this study. No information that could identify your site will be published without your consent.

This project currently focuses on road truck loading in quarries (as discussed in the article) and off-highway haul truck loading at the blast face of quarries and mines (pictured on page 19); however, other processes may also be considered on request.