PERFORMANCE OF ONBOARD WEIGHING SYSTEMS ON SUGARCANE TRANSPORT VEHICLES

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Abstract

To minimise the cost of transporting sugarcane it is important to optimise the payload. Overloading the vehicle will damage the roads and the vehicle, and compromise safety. There is also the risk of prosecution. Underloading the vehicle will result in lost revenue and increased costs. There are two aspects to loading a vehicle; one is to ensure that the gross mass is correct, and the other is to ensure that the load is correctly distributed between the various axles. These objectives are difficult to achieve with a crop such as sugarcane, where the bulk density of the material varies substantially. Other industries with similar problems, such as the timber industry, have settled on load-cell based 'onboard' weighing systems as the only practical answer to the problem.

One year of data from a sugarcane grower and haulier in the Sezela area has been analysed to assess the suitability of using an onboard weighing system in a sugarcane haulage operation. The results have been compared with a vehicle that has an airbag suspension with a simple weighing mechanism, and a vehicle with spring suspension and no weighing system.

The conclusion is that the onboard weighing system achieves the desired load far more consistently than the airbag system, which in turn is more consistent than the spring suspension. The ablity to consistently achieve maximum payloads means that the cost of the onboard weighing system can be recovered over one or two seasons.

Keywords: sugarcane, transport, onboard weighing, payload, overload, load-cell

Introduction

In order to consistently load a vehicle optimally, it is essential to have an accurate measurement system as an indicator of both the gross vehicle mass of the vehicle and individual axle weights. In this way it may be possible to minimise both overloading (and avoid prosecution) and underloading (and save money). Available systems include:

- portable vehicle scales
- weighbridges
- pressure gauges on airbag suspensions
- onboard weighing systems.

Onboard weighing systems have been successfully implemented in the timber industry and are possibly the most cost-effective and accurate systems presently available in South Africa.

At a 2005 SASTA Workshop, a presentation dealing with onboard weighing systems (Cole, 2005) gave a comparison of gross vehicle mass of 78% of all loads delivered to Sezela mill during the 2004 season. This included data from any vehicle that operated 24 hours a day, six days a week and consistently delivered sugarcane loads to Sezela mill. A comparison was made of the gross vehicle mass of loads achieved by three vehicles, one fitted with an onboard weighing system, one with air suspension and an air pressure gauge and one with spring suspension and no weighing system. It was shown that the onboard weighing system was a cost-effective tool to optimise sugarcane loading.

Data used for this report relates to sugarcane loads carried by three vehicles from two farms during 2005. Two of the vehicles used were fitted with onboard weighing systems supplied by Loadtech (Pty) Ltd, and were used to transport 95% of the loads. The third vehicle, without a weighing system, was used sparingly during the 2005 season (5% of all loads). Data regarding this vehicle has been included, however, since the number of loads transported was very limited, it has been considered separately.

The data used in this report included weighbridge slips from Sezela mill as well as printouts from the Loadtech onboard weighing systems. There were a number of loads where no Loadtech printouts were available. For these loads, it is not certain as to whether or not the weighing system estimations have been used. For this reason, these loads have been considered separately from the loads where weighing system printouts were made. Drivers were instructed to aim at loading between 56 tons and 58.8 tons, without having individual axle overloads.

For all loads analysed, a Bell loader was used at a loading zone to load loose cane onto each vehicle. This ensured that it was possible to evenly spread the load across each axle.

Data analysis

Onboard weighing system used

The effectiveness of the Loadtech onboard weighing system was analysed from two points of view. These were (i) the consistency of gross vehicle masses achieved and (ii) the accuracy of the onboard weighing system estimations. In all cases the weighbridge at the Sezela mill has been regarded as correct and has been used as a reference to determine the accuracy of the weighing system.

The effectiveness of the weighing system was considered in the following categories: (i) all loads carried during 2005, (ii) individual vehicles and (iii) loads from individual growers.

All loads during 2005 season

This section includes all loads from both vehicles during 2005 where weighing system estimations were printed. All of these loads were analysed for consistency of mass of loads delivered and accuracy of the weighing system.

Consistency of mass of all loads delivered

The consistency of gross vehicle mass was viewed as (i) the number of loads per ton (e.g. the gross vehicle mass of 489 loads was within the range of 57-58 tons) and (ii) as a proportion of overloading or underloading.

Figure 1 shows the trend of gross vehicle masses of all loads carried during 2005. The target gross vehicle mass of all loads carried was 58.8 tons.

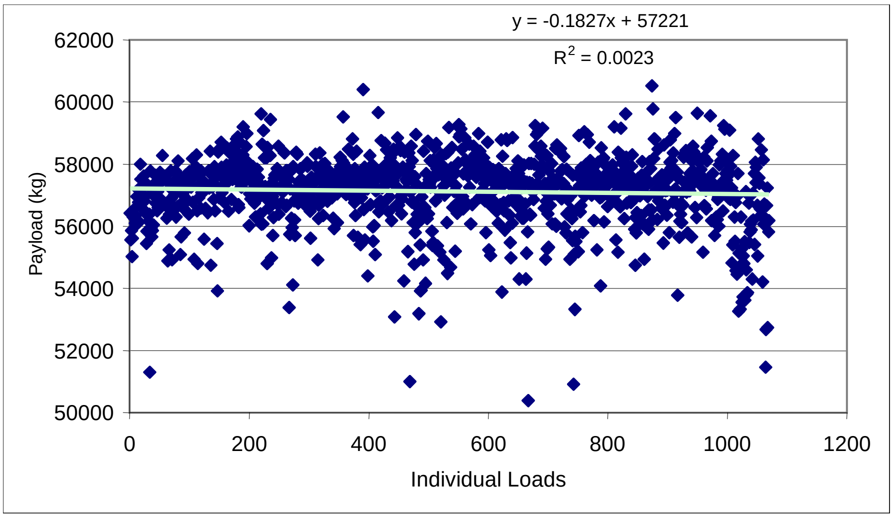

Figure 1. Gross vehicle mass for loads delivered to Sezela mill during 2005 season (weighbridge).

Figure 2 shows the distribution of gross vehicle mass of loads delivered during 2005. This indicates that the gross vehicle mass of a very large proportion of loads delivered were in the range of 57-58 tons.

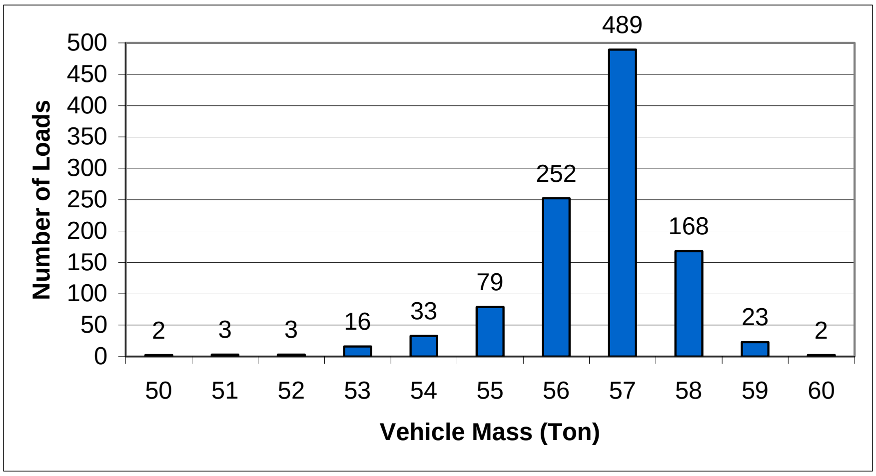

Figure 2. Gross vehicle mass for all loads during 2005.

Table 1 shows the distribution of gross vehicle mass for all loads in terms of overloading and underloading in relation to a maximum gross vehicle mass of 56 tons. Fifty-six tons is the maximum legal gross vehicle mass; however, fines for overloading are only charged for loads where the gross vehicle mass is above 58.8 tons. For this reason the target gross vehicle mass for all loads was 58.8 tons.

Table1. Gross vehicle mass for all loads.

Loading		No.	%	
Overloaded:	> 5%	43	4.0	Above 58.8 t
Overloaded:	2 - 5%	579	54.1	57.1 - 58.8 t
Overloaded:	0 - 2%	310	29.0	56 - 57.1 t
Underloaded:	0 - 2%	91	8.5	54.9 - 56 t
Underloaded:	2 - 4%	30	2.8	53.8 - 54.9 t
Underloaded:	4 - 6%	12	1.1	52.5 - 53.8 t
Underloaded:	6 - 8%	1	0.1	51.3 - 52.5 t
Underloaded:	> 6%	4	0.4	Below 52.5 t

It is important to note that:

- the gross vehicle mass of 83.1 % of all loads was within the range of 56-58.8 tons, but
- the gross vehicle mass of only 4 % of all loads was above the target mass of 58.8 tons.

The statistics regarding gross vehicle mass of all loads, loads carried by each vehicle and loads carried from each farm are given in Table 2.

Table 2. Gross vehicle mass statistics.

	Total	Vehicle 1	Vehicle 2	Dungay	Cranbrook
Number of loads	1070	667	403	760	310
Average gross vehicle mass (t)	57.12	57.32	56.81	57.29	56.72
Max load (t)	60.52	60.52	60.40	60.52	59.62
Min load (t)	50.38	51.00	50.38	50.38	51.30
Standard deviation (t)	1.17	1.05	1.30	1.08	1.29
Tons carried	61 122	38 229	22 893	43 538	17 584
Extra loads due to underloading	30.5	16.9	13.7	19.6	11.0
Proportion of total loads carried (%)	2.85	2.53	3.39	2.57	3.53

Comments regarding Table 2:

- The drivers of vehicle 2 were new to the weighing system and the drivers of vehicle 1 had a year's experience.
- In most cases, vehicle 1 carried loads from Dungay Trust and vehicle 2 carried loads from Cranbrook Farms.
- The loading zones at Dungay Trust are generally flatter and more level than those at Cranbrook Farms.

If the average gross vehicle mass of loads carried by vehicle 1 (NX7789) from Dungay Trust are compared with loads carried by vehicle 2 (NX4084) from Cranbrook Farms, it can be seen that the standard deviation is lower and the average gross vehicle mass is higher for loads carried by vehicle 1. This suggests that in the limited cases where vehicle 1 was used to carry loads from Cranbrook Farms, the consistency of loading was better than when vehicle 1 carried loads from Dungay Trust, despite the fact that the loading zones at Cranbrook Farms are usually of lesser quality than the zones at Dungay Trust. It has been suggested that the level of experience of the vehicle drivers had a greater effect on the effectiveness of the weighing system than the quality of the loading zones.

Accuracy of Loadtech weighing system

To determine the accuracy of the Loadtech weighing system, the differences between the values of gross vehicle mass, the weighbridge measurements and the weighing system estimates when loading, have been compared. Figure 3 is a graphical representation of this difference for all loads carried during 2005 where weighing system printouts were printed. Table 3 gives errors in estimation made by the weighing system when loading.

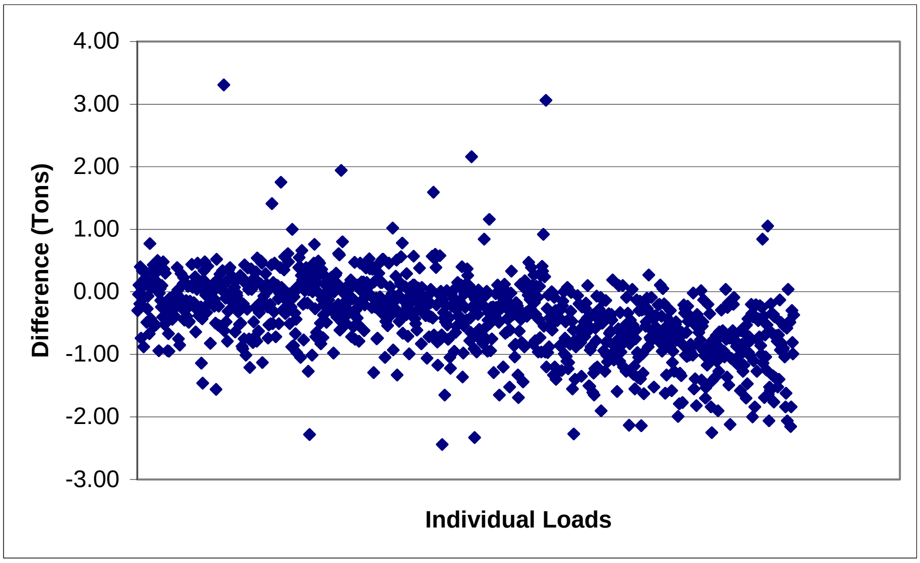

Figure 3. Difference between Loadtech and weighbridge measurements of gross vehicle mass.

Table 3. Weighing system estimation errors when loading.

	Total	Vehicle 2	Vehicle 1	Dungay	Cranbrook
Average Error (Ton)	-0.40	-0.3374	-0.4297	-0.40	-0.39
Max Error (Ton)	3.31	2.16	3.31	3.06	3.31
Number of Loads	1033	385	648	735	298
Standard Deviation (Ton)	0.607	0.592	0.610	0.610	0.603

Comments:

- Apart from 16 loads, the weighing system estimations have always been within 2 tons of the weighbridge measurement.
- 89.8% of all load estimations had an error less than 1.2 tons (1.2 tons = 2% of the maximum legal gross vehicle mass of 58.8 tons).
- The majority of loads carried by vehicle 1 were taken from Dungay Trust.

Consistency of Loadtech estimations: At zone vs at weighbridge

The error of the estimations of gross vehicle mass by the weighing system for each load when loading (at a zone) and when unloading (at the weighbridge/mill) were compared. Both Table 4 and Figure 4 show that the accuracy of estimates made when loading and when at the weighbridge are very similar. It seems that the accuracy of the weighing systems have been consistently similar.

Table 4. Loadtech error when loading and unloading.

	Loading	Unloading
Average error (t)	-0.41	-0.38
Max error (t)	3.31	3.32
Standard deviation (t)	0.617	0.667

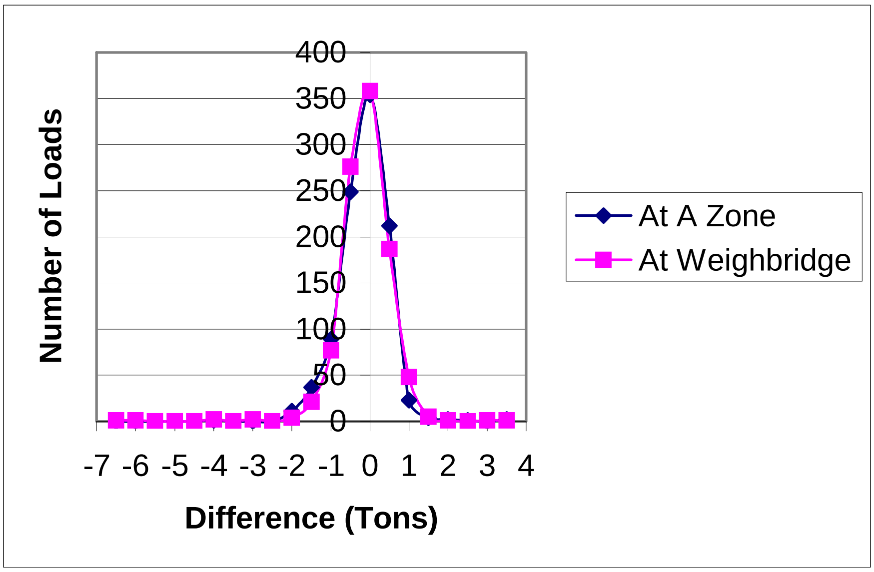

Figure 4. Difference between Loadtech estimates when at a zone (loading) and at the weighbridge (unloading).

Estimated savings from use of onboard weighing system

Savings during 2005 from the use of onboard weighing systems have been estimated, based on the assumption that the average payload should have increased by at least 2 tons when compared with loads carried before any weighing system was used. From Table 5 it can been seen that, if the average payload increased by 2 tons from the use of the weighing systems, approximately R86 000 was saved during 2005.

Table 5. Estimation of savings made during 2005 from use of weighing system.

	Vehicle 1	Vehicle 2	Saved During 2005
Average Tare	24.04	23.91	
Max permissible Payload	34.76	34.89	
Average Payload	33.15	32.98	
Mass Below Optimum (Ton)	1.61	1.91	
Average Gross Vehicle Mass	57.253	56.892	
Money Lost from Left Behind	R44,791.48	R30,576.70	-
If average payload had been 2 tons lower:			
Average Payload	31.15	30.98	
Money Lost from Left Behind	R99,084	R62,763	
	R54,292.70	R32,186.00	R86,478.70
If average payload had been 3 tons lower:			
Average Payload	30.15	29.98	
Money Lost from Left Behind	R126,231	R78,856	
	R71,937.83	R46,669.70	R118,607.53
If average payload had been 30 tons (5 tons below optimum)			
Money Lost from Left Behind	R130,302	R78,856	
	R85,511.00	R48,279.00	R133,790.00

Comments

The current cost of a Loadtech onboard weighing system fitted to an interlink is approximately R78 000 per vehicle, excl VAT.

If the number of loads carried was constant and the average payload was increased by 3 tons per load because of the use of the weighing system, it would take two seasons to cover the capital cost of the weighing systems for both vehicles.

Grower/Farm

It is likely that the conditions at all of grower A's loading zones are similar, but different from the loading zones of grower B. Thus it is important to consider sugarcane transported from each grower individually.

All sugarcane loads included in this data analysis have been taken from either Cranbrook Farms or Dungay Trust. A large proportion of loads carried during 2005 were taken from Dungay Trust farm. In most cases, loads from Dungay Trust were transported by vehicle 1, and loads from Cranbrook Farms were carried by vehicle 2. For this reason, the comparisons between growers and vehicles may be similar.

Consistency of mass of loads delivered during 2005

Figure 5 shows the distribution of gross vehicle mass of loads carried from each farm. The gross vehicle mass of loads carried from Dungay Trust had a slightly better distribution than the loads carried from Cranbrook Farms.

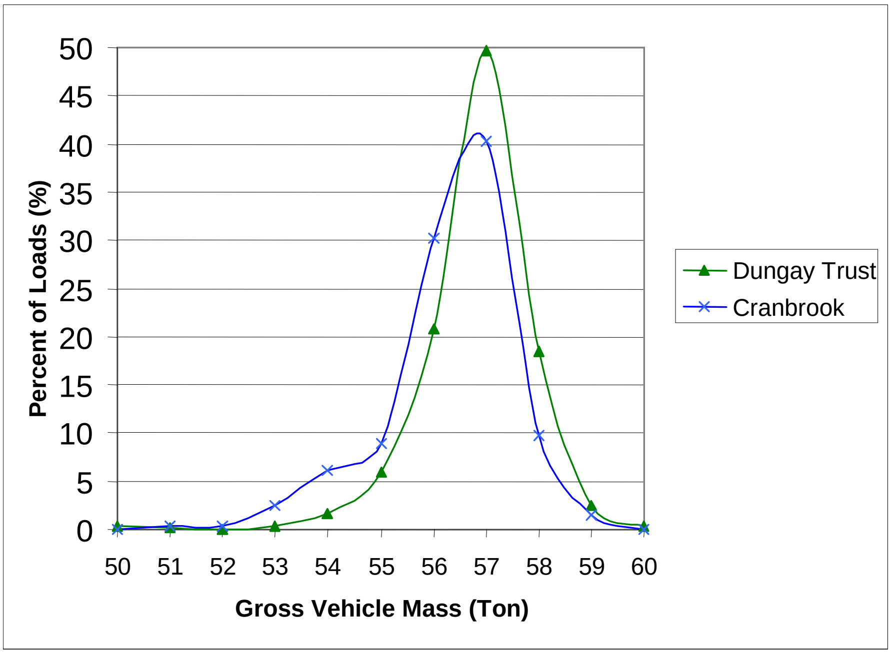

Figure 5. Gross vehicle mass of loads from individual growers.

Accuracy of Loadtech onboard weighing system

The accuracy of the Loadtech estimations of gross vehicle mass have been compared for all loads from each farm. This was to determine whether changing conditions at each zone had an effect on the accuracy/effectiveness of the weighing system. In figure 6, the proportion of loads from each farm for different degrees of accuracy have been compared.

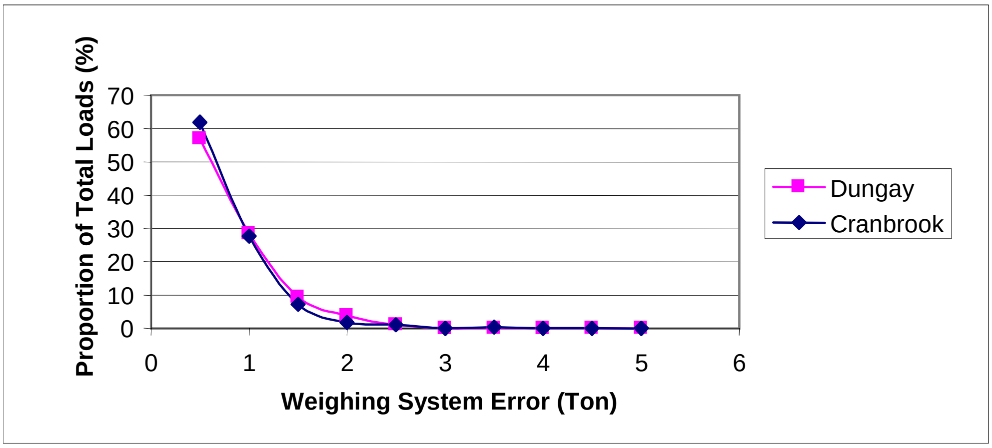

Figure 6. Weighing system errors at each farm when loading.

Loading zones at Cranbrook Farms

A number of loading zones both at Dungay Trust and Cranbrook Farms that were used during 2005; however, individual loading zones are not specified on the weighbridge slips for loads from Dungay Trust. For this reason, only loads from Cranbrook Farms have been used in the comparison below (Table 6). Table 6 shows the standard deviation of gross vehicle mass of loads from each loading zone used on Cranbrook Farms during 2005.

Table 6. Standard deviations at each loading zone on Cranbrook Farms.

Parameter	Zone number									
	5270	5271	5272	5273	5274	5275	5276	5277	5278	5279
Gross vehicle mass (Std dev)	1.01	1.10	1.86	1.42	1.56	0.13	1.03	1.91	1.92	0.15
Loadtech errors (Std dev)	0.44	0.37	0.33	0.75	1.12	0.250	0.625	0.45	0.48	0.83

Comments

- The loading zones at Dungay Trust are flatter and more even than the loading zones at Cranbrook Farms.
- A slightly larger proportion of loads from Dungay Trust reached the preferable gross vehicle mass range of approximately 57-59 tons, but the accuracy of the weighing system at each farm seems to be similar.
- The standard deviation of gross vehicle mass for loads from Dungay Trust is slightly lower than for loads from Cranbrook Farms.
- The conditions at each loading zone had an effect on both the consistency of gross vehicle mass and the accuracy of the weighing system.

Vehicle

The gross vehicle mass and accuracy of the onboard weighing system were analysed for loads carried by each vehicle during 2005. Figure 7 and Table 7 illustrate these relationships.

Consistency of mass of loads delivered

The proportions of loads delivered by each vehicle, in each range of gross vehicle mass, are shown in Figure 7. It may be seen that the proportion of loads carried by vehicle 1 was higher than the proportion of loads carried by vehicle 2 only for the range of gross vehicle mass of 57-59 tons.

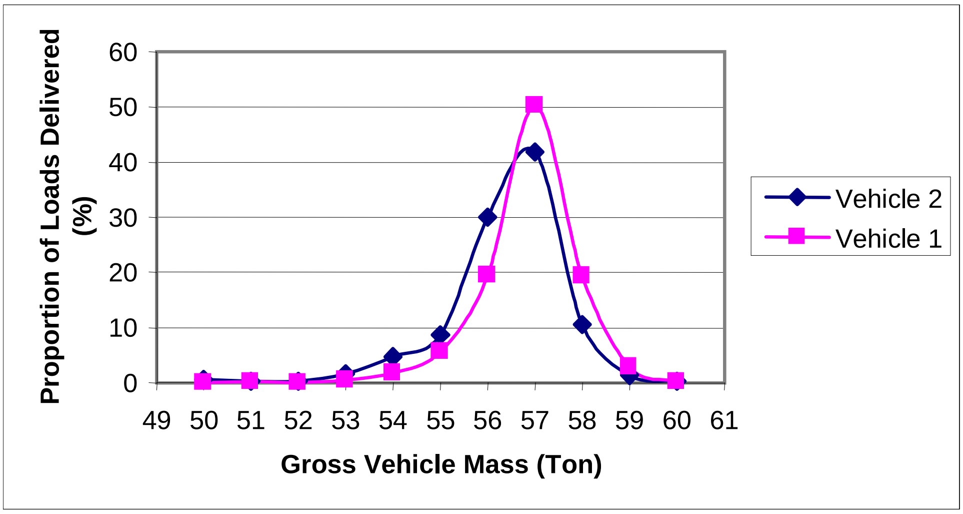

Figure 7. Gross vehicle mass of all loads delivered by each vehicle.

Table 7. Gross vehicle masses for each vehicle.

GVM (t)	Dungay	%	Cranbrook	%
50	2	0.3	0	0.0
51	1	0.1	1	0.4
52	0	0.0	1	0.4
53	2	0.3	7	2.5
54	12	1.6	17	6.1
55	44	5.9	25	9.0
56	155	20.9	84	30.2
57	369	49.66	112	40.3
58	137	18.4	27	9.7
59	19	2.6	4	1.4
60	2	0.3	0	0.00
Total	743	100	278	100

Accuracy of Loadtech onboard weighing system

It may be seen from Figure 8 that the accuracy of the Loadtech onboard weighing system has been consistent for loads carried by each vehicle.

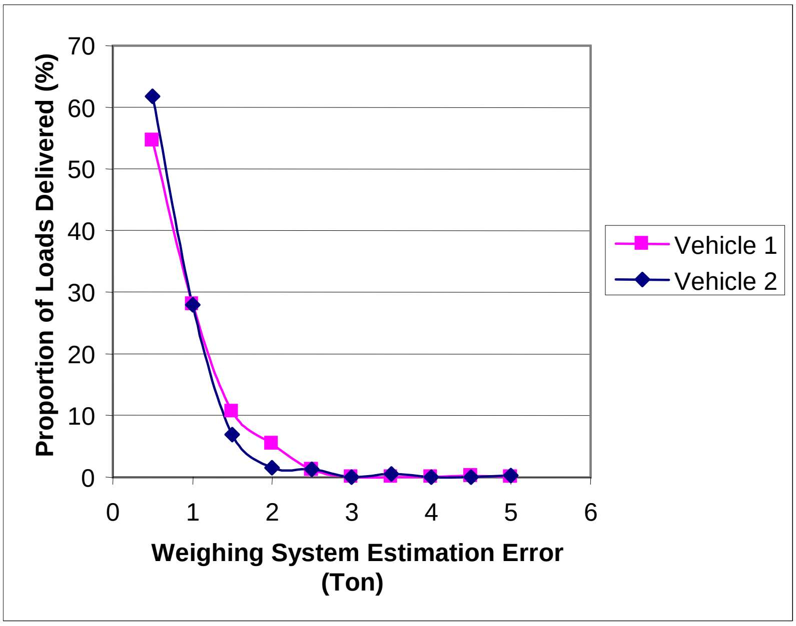

Figure 8. Weighing system estimation errors on each vehicle when loading.

Comments

The slight difference in trend between gross vehicle mass for each vehicle and each grower is most likely to be because of the difference in conditions between the loading zones at Dungay Trust and Cranbrook Farms rather than due to the difference in experience of the drivers of each vehicle.

Loads where weighing system data was missing

This section includes only loads where a Loadtech weighing system had been fitted to the vehicle but no weighing system printout was made. This may have been because the driver did not use the weighing system at all (e.g. system down); or the weighing system was used but the estimations were never printed (e.g., out of printing paper).

Loads carried during the 2005 season

Consistency of mass of loads delivered

The proportion of loads carried which lie in each range of gross vehicle mass have been compared (Figure 9) in order to illustrate the consistency of mass of loads delivered for all loads where the weighing system data was missing.

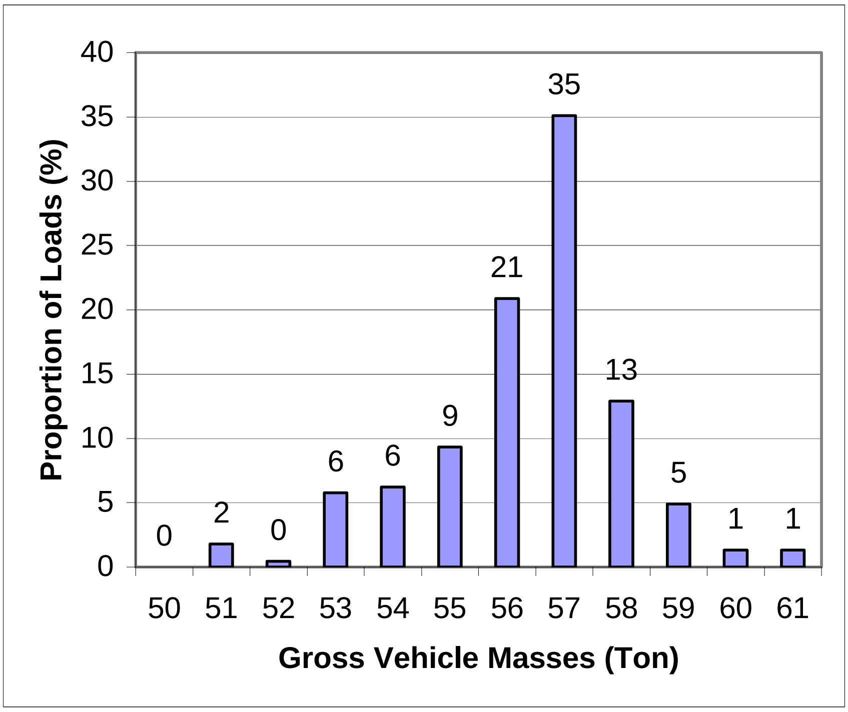

Figure 9. Gross vehicle masses of loads where Loadtech data was missing.

A particularly low proportion of loads had a gross vehicle mass above 59 tons; however, the distribution of gross vehicle mass was not found to be much larger than the distribution for loads where a weighing system had been used. Table 8 shows that a large proportion of loads in this category (where Loadtech data was missing) were carried by vehicle 2. This was due to the trailer being out of service for 15 days for repairs, and a trailer with airbag suspension being used, and the time before the new drivers used the printer of the onboard weighing system correctly when loading.

Table 8. Statistics.

	Vehicle 1	Vehicle 2	Overall
Number of loads	111	116	227
Percentage of all loads	14.27	22.14	17.43
Minimum (t)	52.12	51.14	51.14
Maximum (t)	61.96	60.36	61.96
Average (t)	57.20	56.53	56.87
Total (t)	6349	6557	12906
Standard deviation	1.64	1.92	1.81
Extra loads due to underloading	3.0	4.5	7.5
Proportion of total loads (%)	2.7	3.9	3.3

Comments

- Where the onboard weighing system data was not available, approximately 15 % less of all loads were in the range of gross vehicle masses of 57-59 tons.
- The standard deviations of gross vehicle mass are considerably higher (approximately 0.6 tons) where the Loadtech data was not printed/available.
- However, the gross vehicle masses are not as varied as would be expected if the weighing system had been ignored in all cases.

No weighing system available - Vehicle 3 (NX8814)

Loads during 2005 season

This includes data related to loads carried by vehicle 3 during 2005. This vehicle had no weighing system at all and was used to transport only a small number of loads.

Consistency of gross vehicle mass of loads

Figure 10 and Table 9 have been used to show the distribution of gross vehicle mass of loads carried vehicle 3 during 2005. Figure 10 shows that the gross vehicle mass of loads was fairly inconsistent.

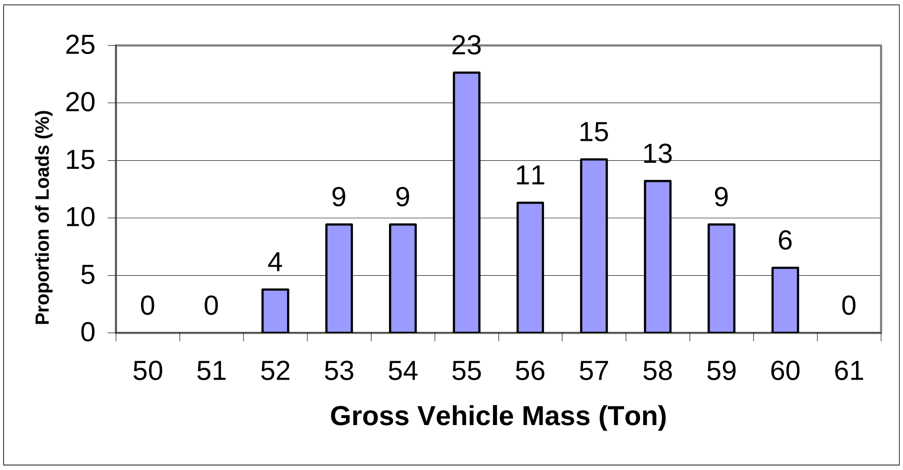

Figure 10. Gross vehicle masses where no weighing system used

Table 9. Loads carried by vehicle 3.

Number of loads	53
Average gross load (ton)	56.559
Maximum load (ton)	60.520
Minimum load (ton)	52.420
Standard deviation (ton)	2.07
Tons carried	2998
Extra loads	3.02
Percentage	5.70

Comments

Compared to loads where an onboard weighing system was used, it may be seen that:

- The standard deviation for these loads was significantly higher;
- A larger proportion of these loads were overloaded (above 58.8 tons) and
- The largest proportion of loads was in the range of 55 tons rather than 57 tons.

Comparison between no weighing system used and where Loadtech data was missing

The distribution of gross vehicle mass for loads carried by the vehicle with no weighing system (Vehicle 3) have been compared with loads carried by the other two vehicles where the onboard weighing system data was not printed.

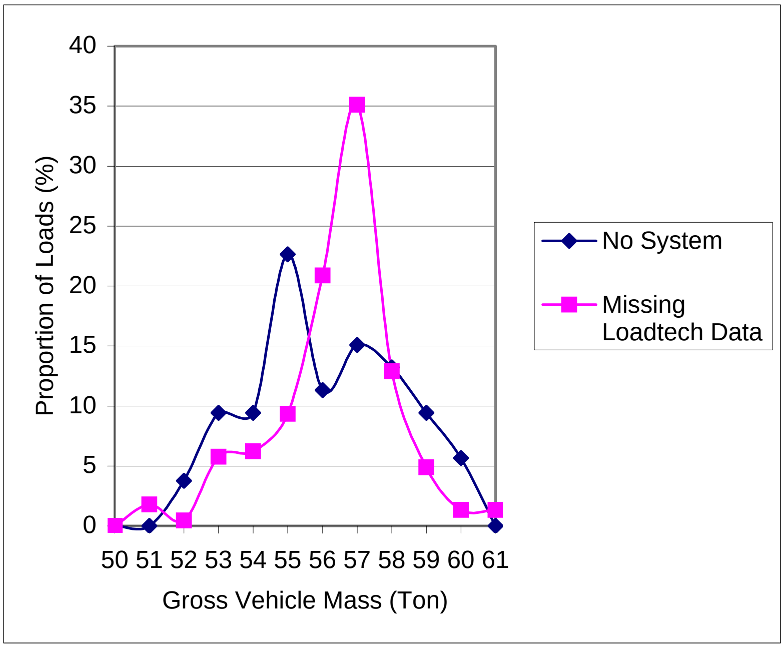

Figure 11. Gross vehicle mass for loads where no weighing system was used and loadtech data was missing

Comment

The gross vehicle mass of loads where there was no weighing system seem to be more inconsistent than loads where the weighing system data was not printed. This suggests that the weighing system was used for a proportion of loads where the data was missing.

Discussion

The data contains only loads that have been loaded at a loading zone. The ground conditions at each zone had an affect on the accuracy of the weighing system, and thus it is likely that the accuracy of weighing system estimations may drop considerably if used when loading sugarcane in-field.

A Bell loader was used for all loading to allow for loose sugarcane to be loaded rather than bundled. The effectiveness of a weighing system would be limited in an operation where sugarcane is loaded in bundles, unless there were small bundles of 0.5-1 ton each as well as large bundles.

If a weighing system were to be considered for an operation where bundled sugarcane is loaded, either the consistency of the loads would be limited by the mass of bundles loaded; or a Bell loader (or crane modifications) may be required to improve effectiveness of the weighing systems.

The primary use of the weighing systems during 2005 has been to minimise overloading beyond the target gross vehicle mass; however, economic estimations have been regarding money saved from minimised underloading. This suggests that the value of onboard weighing systems may be particularly evident where the laws against overloading are implemented.

Conclusion

- Onboard weighing systems have been used effectively to improve consistency of vehicle loading during 2005.
- Considering only the effect of the weighing system on underloading, if the average payload were increased by three tons because of this system, then the money saved would cover the cost of one system in one season.
- Operating the weighing system is easy and requires minimal instruction to drivers.
- Zone quality definitely has an effect on the accuracy of the scales, as the driver needs to release the handbrake when zeroing the scales. This cannot be done on a zone which is not level.

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