Original scientific paper

Timber Truck Payload Management with Different In-Forest Weighing Strategies in Australia

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Abstract

A project was carried out to investigate the impact of four different weighing methods on over/under loading of forestry trucks operating in Forestry Corporation of New South Wales under two types of roads; gazetted (approved for higher legal gross vehicle weight limits) and non-gazetted (standard public road gross vehicle weight limits). For all the technologies tested, it was found that there was a substantial under-loading issue ranging from 5.3 to 6.4 tonnes per load on gazetted roads, while the same technology achieved a much better outcome on non-gazetted roads with a range of 1.4 tonnes under-loaded to 0.1 tonnes over-loaded on average. There was clearly a large under-loading issue on the gazetted routes. As the same operators with the same technology achieved a much more reasonable outcome on the standard access routes, these results suggest that the GVML *available was technically not achievable on the gazetted routes (i.e. not enough volume available to add the weight) or the operators were not aware of or not inclined to load the extra* GVML *available (i.e. not certain what routes were gazetted or not). As the under load was so consistently close to the extra* GVML *allowed, the lack of awareness or inclination seems the most likely reasons of under load. The results point also to a more significant role for policy and methods than the technology used for in-forest weighing in achieving effective payload management in forestry haulage.*

Keywords: forest transport, payload management, on-board scales, loading/transport efficiency

1. Introduction

Trucking is often the most expensive phase of a timber-harvesting operation, accounting for as much as 40 percent to 60 percent of the total harvesting cost (Shaffer and Stuart 1998). As a result, all possibilities for reducing the cost of trucking forest products or improving the efficiency of their transport should be examined (Bolding et al. 2009). Several factors such as payload, trip time and fuel efficiency can impact transport efficiency (Acuna et al. 2012, Ghaffariyan et al. 2013). Trucks should be loaded to their maximum legal weight every time as higher payloads will reduce transportation costs per unit which can lead to increased wood demand (Lukason et al. 2011).

Load variation can be analysed by measuring load weight to determine any over-loading and under-loading during each transportation cycle. Over-loading may cause considerable safety issues and structural impacts on the roads, which can result in heavy fines. Under-loading will reduce transportation efficiency, which can lead to increased transportation costs. A low cost and simple technique to reduce load variability is for the truck driver to frequently communicate with loader operator to effectively estimate load weight, ideally using an on-board weighing device on the loader or truck. The three basic types of on-board weighing devices are on-board truck scales, portable platform scales, and grapple scales. Both on-board and platform scales can provide single axle and tandem weights as well as net payload weight, while grapple scales record the weight of the wood in the grapple and accumulate grapple loads to calculate net payload weight. These scales can help to increase average payload while reducing overweight fines or mill penalties (Bolding et al. 2009, Overboe et al. 1998). In a Canadian study (Dayson 2010), a comparison of the delivery point platform scale and on-board truck scale weights of each truck total payload showed the difference varied from –0.1% to 0.9%. McNeel (1990) evaluated the effect of tractor and trailer log truck scales on truck loads. On average, the mean net load weight increased by 2.07 tons when on-board electronic scales were used. Gallagher et al. (2004) analysed the difference in gross vehicle weight (*GVW*) between trucks that use scales (either in-woods platform scales or electronic on-board scales) and trucks that do not use scales where they found that weighed trucks in wood had higher net payload than other trucks. Variation in payload has negative consequences for both underloading and over-loading. Under-loading increases hauling cost, decreases profit, contributes to mill bottlenecks, and puts more trucks on the highway. Overloading may lead to citations, safety hazards, equipment damage and mill penalties (Bolding 2008). According to a study in the USA, the wood suppliers with the most uniform weights (less weight variations) had a hauling cost savings of 4% to 14% (Hamsley et al. 2007). The moisture content can also impact the payload of trucks and transportation cost, which can be managed to improve truck efficiency (Ghaffariyan et al. 2013). Beardsell (1986) determined using scale house (weighbridge) data and using weighing devices to buffer the problem of *GVW* variability. The method involved the mill setting a target *GVW* range, and sending reports on a systematic basis to suppliers indicating their performance relative to the performance of other mill suppliers, which could create suitable base to compare the performances. Brown (2008) studied the wood transport systems in Australia and indicated the current fleets exhibit a wide range of tare weights within each vehicle configuration indicating there is potential for considerable savings in transport costs by equipment selection and management of tare weights. Management of tare weight it primarily done at the time of vehicle specification and purchase where decisions about what components, materials and design can have significant impacts on the tare weight and hence also on the load the vehicle can transport.

Maximum payload and allowable axle load can also be impacted by the quality of the roads. Improving road standards (forest roads and highways) can also reduce road user costs in areas line fuel consumption, vehicle maintenance, road maintenance, travel speed and overall productivity (load size), which can contribute to the sustainability of the forest industry and increase the total amount of fibre that can be economically harvested. As an example, the Minister's Council on Forest Sector Competitiveness recommended subsidies to the forest industry for maintaining primary forest roads in Ontario, Canada (Hajek et al. 2008). Gazetting of a road is a process of assessing designated routes to determine if they can physically and safely carry a higher load than the standard classification. If all water crossings, road geometry, other users, etc. are found to be within defined safety and technical limits, which vary between locations and road types to suit the situation, the route is identified as gazetted. For this study, the exact criteria required for a road to qualify as gazetted were not provided, only what routes were gazetted and their legal *GVML*. Truck configuration in this study was 7-axle b-double tractor trailers. These heavy vehicles, covered in this study, are allowed an extra 5500 to 6000 kg on their gross vehicle mass limit (*GVML*) depending on the vehicle configuration and contractor status on gazetted roads. Non-gazetted roads have the standard *GVML* restrictions of 50,000 to 51,500 kg for 7-axle b-doubles depending on their configuration and contractor status.

There is little information available on the effect of the weighing method or road type on the over/under loads of the forestry trucks in Australia. Thus, this project was carried out to investigate the impact of four different weighing methods on over/under load of forestry trucks operating under contract to the Forestry Corporation of New South Wales (*FCNSW*) on two types of roads; gazetted (approved for higher legal gross vehicle weight limits (*GVML*)) and non-gazetted (standard public road *GVML*). While in-forest on-board weight systems are very common in Australian forest transportation, not all operations use them but in the case of this study all loads were weighed upon loading in the forest.

2. Material and methods

2.1 Data collection

Data was collected from existing log-haul operations in New South Wales without any prior notice to the operations to help ensure normal operations were observed. Fig. 1 shows the log truck loaded by a grapple loader with pine logs. The trees were felled and processed mechanically by harvesters. Then the logs were extracted to the road side forwarder. The logs were stacked by forwarder into piles along the road side to be loaded later by grapple loader.

Using data collected and maintained for commercial purposes by the mills receiving the logs, a 12 month dataset was extracted to ensure a sufficient range of

Fig. 1 Log truck loaded by pine logs at the forest road side being prepared to travel to mill

Table 1 Descriptive statistics of recorded parameters for each truck load for gazetted roads

	N	Mean	Standard deviation
Gross weight, t	13 050	50.37	2.23
Tare, t	13 050	18.60	1.40
Volume, m^3	13 050	31.88	2.52
Nett weight, t	13 050	31.78	2.57

Table 2 Descriptive statistics of recorded parameters for each truck load for non-gazetted roads

	N	Mean	Standard deviation
Gross weight, t	40 704	49.53	1.45
Tare, t	40 704	18.67	1.45
Volume, m^3	40 704	30.95	2.02
Nett weight, t	40 704	30.86	2.04

data was obtained. The dataset included records for just over 17,700 deliveries by just over 50 individual trucks including 7-axle b-double configurations, operated by 4 contractors. Gross weights, tare weights, load volume and net weights were recorded at each mill using weighbridges certified as legal for trade. The descriptive statistics of these parameters are presented in Table 1 and Table 2 for both types of road.

The forest manager also provided:

⇒ The gross vehicle mass limit (*GVML*) for each vehicle *ID* for both gazetted and non-gazetted routes,

⇒ The in-forest weighing system (*s*) used by each truck *ID*,

⇒ Status of the driver for each truck *ID* (hired driver or owner/operator),

⇒ Which routes between wood sources and mill destinations included in the data base were gazetted and non-gazetted. If any portion of the route between the logging coupe and the delivery destination was non-gazetted, the load was treated as non-gazetted. As gazetting of the route is typically targeted at operational routes, in most cases the entire route was either gazetted or not, mixed routes were very uncommon.

The in-forest weighing methods were then grouped into four categories (scaling methods):

⇒ Loader scale – weight measured using a load cell system incorporated in the grapple of the loader,

⇒ Truck scale (driver) – truck based scale using either load cells or air pressure sensors integrated into the truck and trailer suspension and fifth-wheel; operated by a hired driver,

⇒ Truck scale (owner/operator) – truck based scale using either load cells or air pressure sensors integrated into the truck and trailer suspension and fifth-wheel; operated by the owner of the truck,

⇒ Loader and truck scale – both loader and truck scales being used.

While the technology between air sensors, strain gauges and load cells for truck scale systems is very different, the results achieved from properly used commercial systems are very similar. Past operational observations had indicated that care and attention to use are critical to getting good performance from truck scales and that an owner-operator, being more directly motivated to get the best load performance (maximum load put more profit right in his pocket and overload fines go directly to him), tend to use the scales differently and get significantly different outcomes so the owner-operators using truck scales were examines as a different group.

The datasets were then examined and outliers and corrupted entries (weight recorded was less than 60% of the *GVML* – i.e. half loads, vehicles having made less than 5 deliveries in the 12 month period, missing or unknown vehicle *ID*, missing or unknown harvest block *ID* and missing or unknown product *ID*.) were removed leaving just over 17,700 records for analysis, 13,050 on gazetted roads and 4704 on non-gazetted roads. The collected data for each category on gazetted roads included Loader and truck scale: 2861, Loader scale: 9289, Truck scale (driver): 475 and Truck scale (owner/operator): 425. The number of observations per each category for non-gazetted roads included Loader and truck scale: 1103, Loader scale: 2593, Truck scale (driver): 467 and Truck scale (owner/operator): 541. The datasets were then statistically analysed to explore the relationship between the in-forest weighing method and over or under loading. The log length and product type were plotted versus load variation but these variables did not have any significant correlation with the load variation.

2.2 Statistical evaluation

The over/under load was calculated by subtracting gross weight from *GVML*. A frequency histogram of the over/under load data with a fitted normal curve was prepared by SPSS 21 for each road type. The normality of the data was proved by checking the frequency histograms. Then, an analysis of variance (ANOVA) was applied to test the hypothesis of equality of the average of over/under load per each scaling method. As a post-hoc test, Duncan's multiple range test was applied to derive the homogenous subsets (Zar 1974, Yazdi Samadi et al. 1998) to compare the differences between the pair of treatments. This test could identify what treatment (in this case study means scaling method) was significantly different from the others. There are various post-hoc tests to apply including least significant difference (*LSD*), Student-Newman-Keuls test (*SNK*), Tueky, Dunnett and Duncan multiple range test. *SNK* method seems to be more powerful test than other methods such as least significant difference (*LSD*). For *LSD* method, in independent comparison within pairwise comparison of the treatments, for some of them the probability level (α) would be larger than determined probability.

With larger number of treatments, the error will be higher. Duncan and Tukey methods do not have this disadvantage of the *LSD* but the disadvantage of Tukey is that it shows less significant differences as it applies largest range for the multiple range tests. However, *SNK* method does not have such a disadvantage (Yazdi Samadi et al. 1998). In this case study, Duncan results were double checked with Tukey and *SNK* outcome and the statistical significance level of 5% (α=0.05) was applied in the data analysis. The null hypothesis could be expressed as follows:

H_0: Average under/over load of loader and truck scale = Average under/over load of loader scale = Average under/over load of truck scale (driver) = Average under/over load of truck scale (owner/operator)

3. Results

3.1 Over/under load in transportation on gazetted roads

The descriptive statistics of the over/under load of each scaling method have been presented in Table 3. The highest standard error (0.09 t) occurred for the over/under load data of truck scales (driver or owner/operator types), while the lowest standard error belonged to under/over load of loader scale (0.03 t). The frequency histogram is shown is Fig. 2, which indicates the data follows a normal distribution. The skewness and kurtosis values of this data set were 0.095 and 0.438, respectively, while the mean value for over/under load was –5.66 t with a standard deviation of 2.46 t.

The null hypothesis was rejected because there were significant differences among the means of over/under loads for different scaling methods, for data collected on gazetted roads (Table 4). There was no significant difference between the means of the over/under loads between loader and truck scale vs. truck scale (driver). However, both these groups were significantly different from loader scale and truck scale (owner/operator) in terms of the means of the over/under loads (Table 5). Application of Tukey and Stu-

Table 3 Descriptive statistics for under/over load (t) for gazetted roads

Scaling method	*N*	Mean	Std. deviation	Std. error	95% confidence interval for mean	
					Lower bound	Upper bound
Loader and truck scale	2861	–5.31	2.25	0.04	–5.40	–5.23
Loader scale	9289	–5.74	2.56	0.03	–5.79	–5.69
Truck scale, driver	475	–5.48	1.97	0.09	–5.66	–5.31
Truck scale, owner/operator	425	–6.44	1.84	0.09	–6.62	–6.27
Total	13,050	–5.66	2.46	0.02	–5.70	–5.62

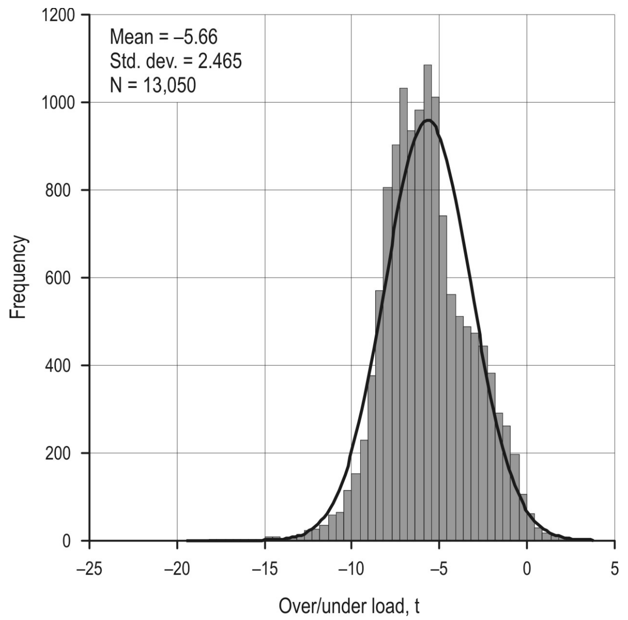

Fig. 2 Frequency histogram for data on gazetted roads

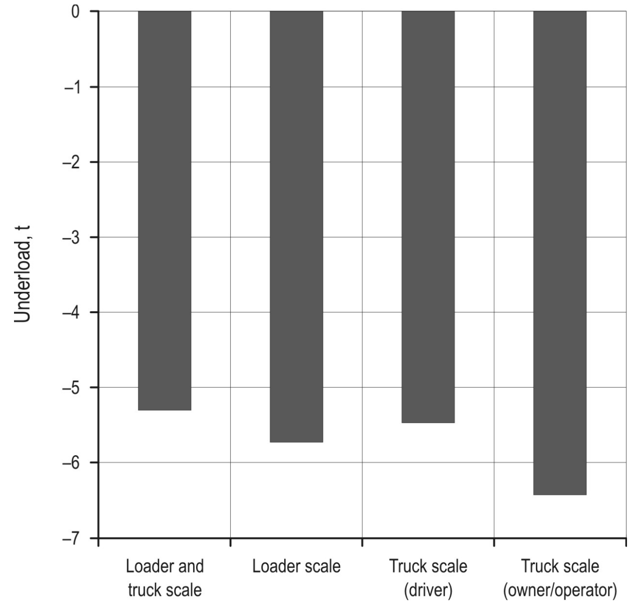

Fig. 3 Means of under-loads for four types of scaling methods on gazetted roads

Table 4 Analysis of variance for gazetted roads

	Sum of squares	df	Mean square	*F*	Sig.
Between groups	676.85	3	225.62	37.43	0.00
Within groups	78636.48	13046	6.03	–	–
Total	79313.34	13049	–	–	–

Table 5 Homogeneous Subsets obtained by Duncan method for gazetted roads

	N	Subset for alpha = 0.05		
		1	2	3
Truck scale, owner/operator	425	–6.44	–	–
Loader scale	9289	–	–5.74	–
Truck scale	475	–	–	–5.48
Loader and truck scale	2861	–	–	–5.31
Sig.	–	1.00	1.00	0.16

dent-Newman-Keuls approaches offered similar results to the Duncan. Loader and truck scale had the lowest mean under load (–5.31 t), while truck scale (owner/operator) usage resulted in the largest mean under load (–6.44 t) (Fig. 3).

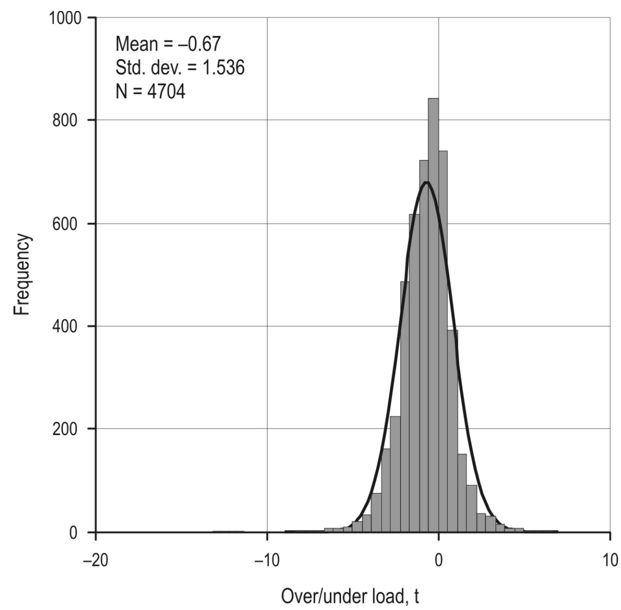

Fig. 4 Frequency histogram for data on non-gazetted roads

3.2 Over/under load in transportation on non-gazetted roads

Table 6 includes descriptive statistics of over/under load for each scaling method in transportation on non-gazetted roads. Over/under loads from using loader scale and truck scale (owner/operator) had the lowest standard error (0.03 t), while the largest standard error

Table 6 Descriptive statistics for over/under load (t) for non-gazetted roads

Scaling method	*N*	Mean	Std. deviation	Std. error	95% confidence interval for mean	
					Lower bound	Upper bound
Loader and truck scale	1103	–1.43	1.68	0.05	–1.53	–1.33
Loader scale	2593	–0.53	1.50	0.03	–0.59	–0.47
Truck scale, driver	467	–0.54	1.39	0.06	–0.66	–0.41
Truck scale, owner/operator	541	0.09	0.59	0.03	0.04	0.14
Total	4704	–0.67	1.53	0.02	–0.72	–0.63

Table 7 Analysis of variance for non-gazetted roads

	Sum of squares	*df*	Mean square	*F*	Sig.
Between groups	1008.73	3	336.24	156.69	0.00
Within groups	10,085.46	4700	2.15	–	–
Total	11,094.19	4703	–	–	–

Table 8 Homogeneous subsets obtained by Duncan method for non-gazetted roads

	N	Subset for alpha = 0.05		
		1	2	3
Loader and truck scale	1103	–1.43	–	–
Truck scale, driver	467	–	–0.54	–
Loader scale	2593	–	–0.53	–
Truck scale, owner/operator	541	–	–	0.09
Sig.	–	1.00	0.96	1.00

occurred in the case of truck scale (driver) application, which was about 0.06 t. The frequency histogram of the data is shown in Fig. 4. The skewness and kurtosis values of this data set were –1.64 and 20.58, while the mean value for over/under load was –0.67 t with a standard deviation of 1.53 t.

For operations on non-gazetted roads, there was a significant difference between the means of over/under loads for different scaling methods (Table 7). There was no significant difference between means of over/under load for using loader scale and truck scale (driver). However, both groups were different from loader and truck scale (driver) and truck scale (owner/operator) in terms of load variation (Table 8) (similar results were achieved by Tukey and Student-Newman-Keuls methods). The loader and truck scale had the largest mean under load (–1.43 t), while the truck scale (owner/operator) resulted in a small mean over load (+0.09 t) (Fig. 5).

4. Discussion and conclusions

The results of this study indicated that the mean under loading varied from 0.5 t to 6.4 t for both types of roads and the mean over loading occurred only in one case (0.1 t). These results contrast with those of an American case study (McNeel 1990), where an increase of 2.1 t mean load weight was achieved through using on-board electronic scales. Although in our case

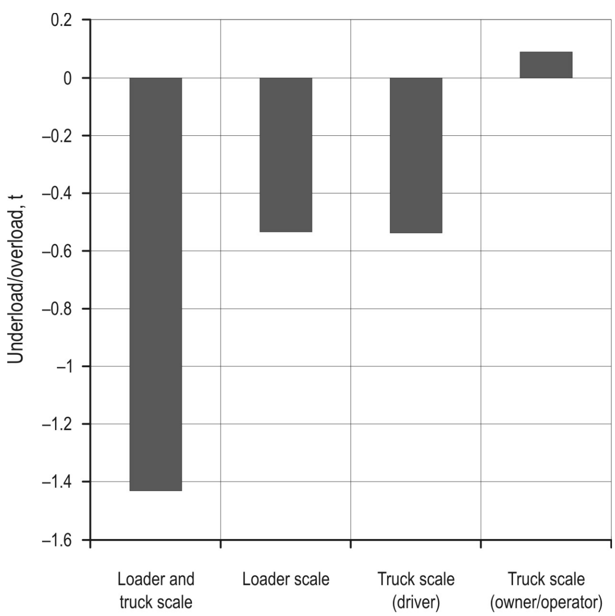

Fig. 5 Means of under/over loads for four types of scaling methods on non-gazetted roads

study it is not clear whether introduction of on-board scales increased mean load weights, it is clear that maximum payloads have not been reached in most cases. In our case study, if the under loading of the trucks could be eliminated, then the potential saving for the company could be between $3 million and $7 million ($0.60/m^3 – $1.20/m^3). Significant savings can be achieved through eliminating load variation. Beardsell (1986) found gross annual savings were $153,000 and $431,000 for two different mills, and Deckard et al. 2011 predicted the potential impact on the southern United States wood supply chain at between $44.1 million and $87.1 million.

In comparing the study results for the two types of roads, there is clearly a substantial under loading issue on the gazetted roads as compared to the non-gazetted roads. As the same operators with the same technology achieved a much better outcome on the non-gazetted roads, these results suggest that the *GVML* available was technically not achievable on the gazetted roads (i.e. not enough truck volume capacity available to add the extra weight) or the operators were not aware of or not inclined to load the extra *GVML* available (i.e. not certain what routes were gazetted or not). The log length and product type did not have any significant correlation with the load variation, which can explain these factors did not influence the under and over loads in this case study. As the data were collected post-operations without any direct observations of the operations, not much insight can be given on the reason, but since the under load is so consistently close to the extra *GVML* allowed on gazetted roads, the lack of awareness or inclination seems the most likely. Post study discussions with the operations managers revealed that the rate system at the time of the study had no incentive for the operators to load the higher weights on gazetted roads (same 4/t-km rate for both route types so revenue targets are met with non-gazetted loads on both route types), which is an issue that has been addressed with new contract arrangements. A follow-up study is being considered to explore the influence of this new contract arrangement. To remove any load variation, the transport management should consider applying an accurate weighing method at the loading areas before departing the trucks to mills. Distributing the responsibility of weigh measurement over two operators (such as loader and truck operator in this case study) should be avoided, since the study showed the shared responsibility gave poorer results (one assuming the other is looking after it). Where routes have been identified to allow higher loads, operations need to ensure information is readily available to drivers, vehicles assigned to the route are able to take advantage of the potential productivity gain of the higher load and contract arrangements are in place so all stakeholders are appropriately motivated to take advantage of the potential productivity gain through increased payloads.

Looking at the three results together, it appears the benefit of using the loader scale and truck scale in combination is not necessarily realised in practice with the non-gazetted roads, showing a considerably poorer outcome than when the technologies are used separately. This suggests work methods and techniques can play as great a role, if not greater, than the technology itself, and should be explored in future research.

Further research on the performance of the different weighing technologies, under different policy frameworks and methods of usage, need to be explored to better understand how best to achieve efficient payload management in Australian forest haulage operations.

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Received: November 12, 2014
Accepted: February 5, 2015

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