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Improving Timber Trucking Performance by Reducing Variability of Log Truck Weights*

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Abstract

We evaluated weight data from 79,760 truckloads delivered to 24 southern forest products mills in fall 2005 to assess opportunities for improving trucking efficiency by reducing the variability of gross, tare, and net weights. We compared the mean gross vehicle weight (GVW) at each mill to the federal weight limit of 40 tons and to any stated mill overweight policy. A benchmark group of suppliers was identified at each mill by selecting the five with the lowest coefficient of variation (CV) on their gross vehicle weights (GVW) to compare to the other suppliers at each mill. All mills had mean GVW significantly different from the federal limit of 40 tons at the 90% confidence level or stronger. A strong majority of loads delivered to each mill (77-100%) complied with the mill GVW policy. At most mills, the benchmark group had lower GVW variability as well as higher mean GVW and mean net weights. We observed that decreased GVW variability led to higher payloads—a 1% decrease in GVW variability yielded a 0.22 to 0.73 ton increase in payload weight. At 8 mills we observed that reducing the variability of tare weights helped reduce the variability of GVW—each 1% reduction in the CV of tare weight correlated to a 0.22-0.72% reduction in the CV of GVW. Only five mills showed any relationship between tare weight and payload variability. However, mean tare weight and mean net weight demonstrated an approximate 1:1 relationship at 15 mills. The BM groups at 14 of the 24 mills had significantly larger payloads and we project had 4 to 14% lower per ton hauling costs than other suppliers at the mills. Operating at the reduced variability level of the benchmark groups across the 221 million tons of roundwood annually consumed in the U.S. South suggests that $100 million of savings are potentially available.

1. INTRODUCTION

Transportation is not only the most public aspect of log extraction from the woods, but it is also the most expensive—and often limiting—step for the logging contractor. This project focused on the potential efficiency gains of fully loading trucks more consistently. Legal and corporate mill restrictions confine the weights that raw material transporters can haul. Hauling the maximum legal load every trip is the most cost efficient method of transporting raw materials.

2. LITERATURE REVIEW

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Previous studies have examined the relationship between haul truck weights and productivity. Beardsell (1986) determined that there could be a substantial net gain in average payload by eliminating both overloading and underloading. He estimated the potential savings to two mills, using an approximate haul rate of $2.30 per loaded mile, as if all haul trucks arrived at the maximum legal gross vehicle weight (GVW) and no tare weights exceeded 27,000 pounds. The gross annual savings were $153,000 for the first mill and $431,000 for the second mill. Stuart (1995) also estimated the advantage of hauling fully loaded log trucks. If trucks average 77,500 pounds GVW, and the operation averages 15 loads per day assuming 175 days worked per year, the operation could increase its productivity 5% without making any changes in workers or machines. Assuming a $12 per ton cut and haul rate, hauling fully loaded would give a margin increase of approximately $27,000 per year in profit. A $16 per ton cut and haul rate would give a margin increase of approximately $37,500 per year.

Several studies have evaluated the benefits of in-woods weighing. McNeel (1990) evaluated the effect of modified tractor and trailer log truck weights 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) analyzed the difference in GVW between trucks that use scales and trucks that do not use scales (either in-woods platform scales or electronic on-board scales). In general, they found that trucks weighed in the woods had higher net payloads than those that were not weighed. In addition, trucks that utilized scales had higher average GVW than those without scales, and they had reduced variation of GVW. Shaffer *et al.* (1987) examined the use of on-board log truck scales using case studies of a Georgia logger and a Virginia logger. The use of scales by the Georgia logger decreased the standard deviation of net payload by 0.52 tons and decreased overweight fines but had no effect on mean net payload weight. The projected cost savings yielded an internal rate of return of 24.3% on the scale investment for the Georgia logger. The Virginia study found the scales were 98-99% accurate when compared to mill weights.

Mill policies also affect truck weights. Rayonier adopted a new truck weight policy at Georgia mills in January 2002 to discourage excessive truck overloading. As a result of the policy, the percentage of trucks with a GVW in excess of 44 tons decreased (Conradie *et al.* 2004). The percentage of underloaded trucks also decreased while the percentage of loads within 10% of the legal limit increased. The average GVW increased, as did the average payload. These increases in average values were the result of decreased variability of truck weights as demonstrated by the reduced coefficient of variation (CV).

Deckard *et al.* (2001) measured roundwood delivery turn times in the southeastern United States and estimated potential efficiency gains. They gathered data for 9,476 loads delivered to eight mills in the Southeast and separated the top 25% mills with the shortest median turn times and named this sample subset the benchmark group. They determined that if the remaining 75% of the sample mills (ROS=rest of sample) reduced their median turn times to those of the benchmark group, it would save $12.39 per load in direct marginal system costs. They placed the potential impact on the southern US wood supply chain at between $44.1 million and $87.1 million in 2001.

Beardsell (1986) determined two ways to buffer the problem of GVW variability: using scalehouse data and using weighing devices. The first method involves 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. Overboe *et al.* (1988) discovered that providing load weight information to loader operators led to slightly decreased weight variability and greater profits.

Our study also examined variability of gross, tare, and net weights to determine if more uniform weights were associated with higher payloads and lower costs. We looked at GVW variability through comparisons of load frequency distributions and the performance of benchmark suppliers compared to the other suppliers to a mill. Relationships involving gross, tare, and net weights were also tested.

3. METHODS

To analyze haul truck weights, we gathered data from forest products mills across the Southeast operated by forest products companies that are members of the Wood Supply Research Institute (WSRI). The data consisted of haul truck weight information for all trucks delivering raw forest products (roundwood or chips) during four consecutive weeks. Specifically the data included date, truck weight in, truck weight out, contractor/supplier code, species and product code, state where the mill is located, and general information about any overweight policy of the mill. Trucks with tare weights less than 12 tons were removed from the data to exclude the small percentage of loads delivered by short-bed trucks or other non-traditional hauling vehicles. In addition, suppliers that delivered fewer than 10 loads in the four-week period were removed to assure that the suppliers in the analysis were suppliers that regularly delivered wood to each mill. Mills were grouped into two categories—saw/ply mills and pulp/OSB mills—based on the products delivered at each mill. The data analysis consisted of two parts:

- evaluating the means and variability of current gross vehicle, tare, and payload weights of trucks hauling to forest product mills across the southeastern United States, and
- estimating the potential cost savings associated with increasing gross vehicle or payload weights, and/or reducing the variability of the above measures.

One way to increase the efficiency of the wood supply system is to fully load trucks to the legal limit. To measure this we determined the average GVW of trucks hauling to a mill and compared it to the federal weight limit of 40 tons. We also examined frequency distributions of loads delivered to each mill to determine compliance with any mill overweight policies.

Without making structural or equipment changes to the current system, the potential performance of the system is reflected by the abilities of its top performers. We used methods for this data analysis that were similar to the methods used by Deckard *et al.* (2004) to compare turn times. The five suppliers at each mill with the lowest coefficient of variation of gross weight served as a benchmark (BM) group, and the remaining suppliers comprised the rest of sample (RS) group. We then determined if the mean GVW of the BM group was significantly different from the mean GVW of the RS group. Another way to potentially increase efficiency is to reduce variability of GVW, which should also help increase the number of fully loaded haul trucks. We compared the CV of GVW for the BM group to the CV of GVW for the RS group.

A second question examined the effect of GVW variability on net weight. We hypothesized that suppliers with more uniform GVW showed more control of how they load their trucks. We examined the statistical correlation of the CV of GVW with mean net weight, viewed plots of these values, and attempted to regress mean net weight with the CV of GVW where correlations and plots suggested that a relationship existed.

A third question investigated the effect of tare weight on payload. The first test determined if a more uniform truck fleet was related to a more uniform gross vehicle weight by examining the relationship between CV of tare weight and CV of GVW with regression. A second test to determine the effect of tare weight on payload strived to answer the question: do suppliers with smaller tare weights have higher control of net payloads? Regression analysis was used to test this hypothesis by evaluating the relationship between mean tare weight and CV of mean payload. A third test to examine the effect of tare weight on payload directly evaluated the relationship between tare weight and net payload. Because the two contributors to gross vehicle weight are tare weight and net payload, theoretically lower tare weights should correspond to higher net payloads. Again to test this hypothesis, we used regression analysis.

The second part of the study examined the potential cost savings if the suppliers to a mill had the same average payloads as the top suppliers. To quantify the savings, we compared the mean payload of the benchmark group to the mean payload of the rest of sample group at each mill. Next, we calculated haul cost per ton for the BM and RS groups at each mill using cost information from Mendell *et al.* (2006). Using their daily cost of $550 to own and operate a haul truck, a 50 mile one-way haul, and production of 3 loads a day with a 25.5 ton payload, the cost per ton-mile becomes $0.14, which is comparable to present haul costs (Gallagher *et al.*, 2004).

Lastly, we calculated the estimated savings for the South if all suppliers produced at the level of the average BM group. We assumed that 5% of loggers are currently managing for variability. We used U.S. Forest Service measurements of the volume of roundwood products harvested in the United States in 2001 to estimate the annual tonnage hauled in the South (Smith *et al.*, 2002). We assumed that all of the roundwood harvested was delivered by truck, and calculated the average per ton savings value for decreasing variability. This value was multiplied by the tons hauled per year in the South and multiplied by the percentage of loggers assumed to not currently manage variability to estimate the annual savings.

4. RESULTS AND DISCUSSION

The mills included 13 pulp/OSB mills and 11 saw/ply mills (Table 1). Products were both pine and hardwood. Loads received during the 4 week period at each mill ranged from 791 to 8,111, with a total of 79,760 in the sample. Tons purchased ranged from 21,376 to 207,742, with a total of 2,105,441 in the sample.

Mills were ranked based on CV of GVW. The lowest CV pulp/OSB mill had a CV of GVW of 4.10% while the highest CV pulp/OSB mill had a CV of GVW of 7.77%. The lowest CV saw/ply mill had a CV of GVW of 2.90% while the highest CV saw/ply mill had a CV of GVW of 6.62%.

All of the mills analyzed had mean GVW that were significantly different from the federal limit of 40 tons at the 90% confidence level. All mills except two pulp/OSB mills had mean GVW that were higher than 40 tons. A majority of the loads delivered to each mill complied with the mill policy; the percentages ranged from 77% to 100%. The BM group had a significantly higher mean GVW than the RS group at 16 of the 24 mills (Table 2). The BM group for all 24 mills had significantly lower CV than the RS group.

The BM group of 14 of the 24 mills had significantly larger payloads than the RS group. Assuming a haul cost of $550 per day and a production of 3 loads per day, the BM groups at each mill had 4 to 14% lower per ton hauling costs than the RS group.

Table 1. Gross weight, tare weight, and net weight statistics for the mills analyzed.

						Gross wt			*Tare wt*		*Net wt*					
	Mill	**State**	**Contractors**	**Loads**	**Tons**	**Mean**	**CV**	**p-value**	**Mean**	**CV**	**Mean**	**CV**	**Overweight Policy (OP)**	**≤ 40 tons**	**> 40 tons & ≤ OP**	**> OP**
				n		**tons**	**%**		**tons**	**%**	**tons**	**%**	**tons**		**% of loads**	
Pulp/OSB Mills	A	OK	50	5159	139,428	41.45	4.10	<0.01	14.43	7.05	27.03	7.02	42.5	17	73	10
	B	TX	100	3926	107,960	42.06	4.80	<0.01	14.56	7.21	27.50	7.59	N/A	19	N/A	81
	C	GA	25	5240	137,395	40.34	5.64	<0.01	14.12	4.6	26.22	8.95	44	49	48	3
	D	VA	62	5165	130,027	40.35	5.82	<0.01	15.18	7.05	25.17	10.15	46	49	51	0
	E	GA	100	8111	207,742	40.41	6.14	<0.01	14.80	5.34	25.61	9.53	N/A	49	N/A	51
	F	SC	29	5187	136,882	40.97	6.28	<0.01	14.58	8.46	26.39	9.80	N/A	39	N/A	61
	G	AL	30	5591	149,119	41.77	6.60	<0.01	15.10	6.27	26.67	11.12	44	29	58	12
	H	GA	35	1923	49,401	40.12	6.69	0.089	14.43	4.53	25.69	10.14	44	56	39	5
	I	AL	26	3333	89,057	41.93	6.71	<0.01	15.21	6.74	26.72	10.54	44	27	59	13
	J	AL	31	2345	61,215	40.97	6.93	<0.01	14.86	4.40	26.10	10.40	44	41	51	9
	K	VA	33	1515	36,892	39.66	7.34	<0.01	15.31	7.61	24.35	12.84	46	57	43	0
	L	VA	43	5284	128,389	39.26	7.42	<0.01	14.97	4.11	24.30	11.91	46	65	35	0
	M	TX	30	2359	61,953	40.83	7.77	<0.01	14.57	11.33	26.26	13.70	45	45	50	5
Saw/Ply Mills	N	OK	16	1386	38,725	41.86	2.90	<0.01	13.92	8.73	27.94	6.04	42.5	7	80	14
	O	NC	27	4082	106,393	40.50	3.13	<0.01	14.43	5.49	26.06	5.49	42	43	55	2
	P	AR	16	1962	54,515	41.94	3.44	<0.01	14.16	7.90	27.79	6.56	42.5	11	66	23
	Q	MS	19	2497	66,570	41.49	3.51	<0.01	14.83	6.34	26.66	6.19	42	14	75	11
	R	AR	40	3511	98,075	41.79	3.63	<0.01	13.85	6.74	27.93	6.48	42.5	14	66	20
	S	TX	27	2003	57,640	42.60	4.09	<0.01	13.82	6.83	28.78	6.95	N/A	12	N/A	88
	T	AL	27	2994	84,706	43.28	4.23	<0.01	14.96	7.06	28.29	7.39	44	7	77	16
	U	GA	14	796	21,376	41.68	5.77	<0.01	14.83	4.55	26.85	8.90	N/A	28	N/A	72
	V	GA	53	1787	47,801	41.41	6.17	<0.01	14.66	5.05	26.75	9.37	N/A	35	N/A	65
	W	AL	21	791	21,421	42.13	6.49	<0.01	15.05	7.31	27.08	10.75	44	23	63	14
	X	SC	30	2813	72,759	40.52	6.62	<0.01	14.66	4.99	25.87	10.48	N/A	47	N/A	53
			Totals	**79,760**	**2,105,441**											

Table 2. Comparison of benchmark and rest of sample groups' gross vehicle weights, coefficient of variations of gross vehicle weights, mean payload weights, and hauling cost per ton assuming production of 3 loads per day.

	GVW tons			CV of GVW %			Mean Payload tons			Hauling Cost $/ton			
Mill	**BM**	**RS**	**Difference**	**BM**	**RS**	**Difference**	**BM**	**RS**	**Difference**	**BM**	**RS**	**Difference**	**% Change**
Pulp/OSB													
A	42.30	41.26	1.04**	0.50	3.93	3.43**	28.01	27.05	0.96*	$6.55	$6.78	$0.23*	3.55%
B	42.85	41.67	1.18*	2.25	4.40	2.15**	28.35	27.29	1.06**	$6.47	$6.72	$0.25**	3.87%
C	41.25	40.07	1.18**	2.73	5.51	2.78**	27.08	26.07	1.02*	$6.77	$7.03	$0.26*	3.91%
D	42.87	40.03	2.84**	2.00	5.14	3.14**	27.94	24.86	3.08**	$6.56	$7.38	$0.81**	12.39%
E	41.28	40.35	0.94	2.24	5.08	2.84**	26.49	25.60	0.89	$6.92	$7.16	$0.24	3.47%
F	41.77	39.54	2.23**	1.95	5.75	3.80**	27.66	24.37	3.29**	$6.63	$7.52	$0.89**	13.49%
G	43.26	41.37	1.90**	2.13	6.00	3.88**	27.98	26.14	1.83**	$6.55	$7.01	$0.46**	7.01%
H	40.42	40.04	0.38	4.07	6.44	2.37**	25.93	25.64	0.29	$7.07	$7.15	$0.08	1.14%
I	42.74	41.41	1.33**	4.19	6.71	2.52**	27.44	26.28	1.16**	$6.68	$6.98	$0.29**	4.41%
J	40.20	40.95	-0.74	3.10	6.35	3.25**	25.37	26.10	-0.72	$7.23	$7.03	-$0.20	-2.77%
K	41.42	38.87	2.55**	2.91	6.24	3.34**	26.52	23.26	3.26**	$6.91	$7.88	$0.97**	14.03%
L	40.46	38.85	1.61**	2.86	6.00	3.14**	25.74	23.98	1.76*	$7.12	$7.64	$0.52*	7.33%
M	41.70	40.37	1.34	4.37	7.20	2.83**	27.74	25.89	1.85**	$6.61	$7.08	$0.47**	7.15%
Saw/Ply													
N	42.10	41.72	0.38**	0.84	2.73	1.89**	28.27	27.99	0.28	$6.48	$6.55	$0.06	1.00%
O	40.92	39.90	1.02**	1.34	4.04	2.70**	26.24	25.45	0.79	$6.99	$7.20	$0.22	3.10%
P	42.23	41.01	1.22**	1.53	4.79	3.27**	28.14	26.57	1.57**	$6.52	$6.90	$0.38**	5.89%
Q	41.56	41.23	0.33	1.58	4.35	2.77**	26.93	26.34	0.58	$6.81	$6.96	$0.15	2.22%
R	42.26	41.53	0.73**	0.56	3.42	2.86**	28.84	27.76	1.08**	$6.36	$6.60	$0.25**	3.88%
S	43.27	42.07	1.20**	2.16	4.51	2.36**	27.40	27.74	-0.33	$6.69	$6.61	-$0.08	-1.20%
T	43.70	42.88	0.82*	1.76	4.51	2.75**	29.41	27.56	1.85**	$6.23	$6.65	$0.42**	6.71%
U	41.31	41.00	0.31	3.40	6.63	3.23**	26.58	26.19	0.38	$6.90	$7.00	$0.10	1.46%
V	40.26	41.39	-1.14	2.34	5.44	3.10**	26.07	26.74	-0.68	$7.03	$6.86	-$0.18	-2.54%
W	42.01	42.17	-0.16	3.48	7.27	3.80**	27.32	26.91	0.41	$6.71	$6.81	$0.10	1.52%
X	41.77	40.07	1.71**	3.70	6.73	3.02**	27.30	25.50	1.81**	$6.72	$7.19	$0.48**	7.08%

**Significant at alpha 0.05   *Significant at alpha 0.10

Approximately 221 million tons of roundwood were hauled in the U.S. South in 2001 (U.S. Forest Service, 2002). Using this tonnage, and assuming 5% of loggers already manage variability, the U.S. South wood supply chain could save approximately $100 million by reducing variation of payload.

Reducing GVW variability was associated with higher mean net payloads at 19 of 24 mills. We saw a significant inverse relationship between the CV of GVW and mean payload. A 1% decrease in GVW variability yielded a 0.22 to 0.73 ton increase in payload at individual mills. When the data from eleven significant pulp/OSB mills and data from the eight significant saw/ply mills was combined, the general trend remained the same (Figure 1). The sawtimber loads generally have higher payloads than pulpwood loads because sawtimber is a more consistent product that is easier to load to maximum GVW than pulpwood.

More uniform tare weights were associated with more uniform gross vehicle weights at 8 of 24 mills. We found no relationship at 16 of the 24 mills. A 1% reduction in variability of tare weight resulted in a 0.22 to 0.72% reduction in GVW variability at individual mills. When the data from the five significant pulp/OSB mills and the three significant saw/ply mills was combined, the relationship between CV of tare weight and CV of GVW was only significant for the pulp/OSB mills (Figure 2).

Lower tare weights were not correlated with more uniform payloads at 19 of the 24 mills. Five of the 24 mills showed a significant direct relationship between mean tare weight and payload variability. At these mills a 1 ton reduction in tare weight led to a 0.08 to 4% reduction in payload variability. Because only five mills had a significant relationship between tare weight and payload variability, the relationship between these two factors is difficult to quantify as payload variability is likely linked to several elements other than tare weight. Although the exact relationship is elusive, there is at least some benefit of lower variability as tare weight is reduced.

Higher payloads were associated with lower tare weights at 15 of the 24 mills. We saw a significant inverse relationship between mean tare weight and mean net weight at those mills. A 1 ton reduction in tare weight approximately correlated to a 1 ton increase in net payload (Figure 3). Lower tare weights are clearly correlated to higher payloads.

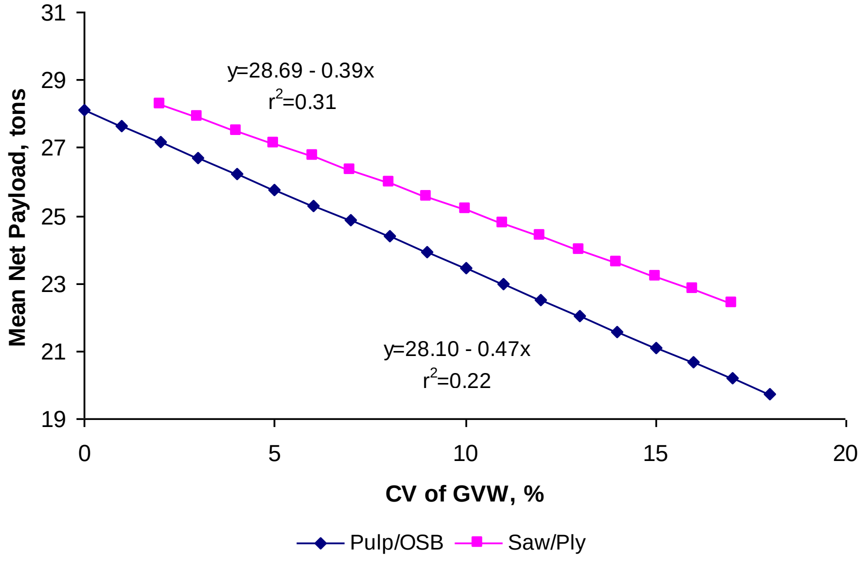

Figure 1. Relationship of CV of GVW to net payload.

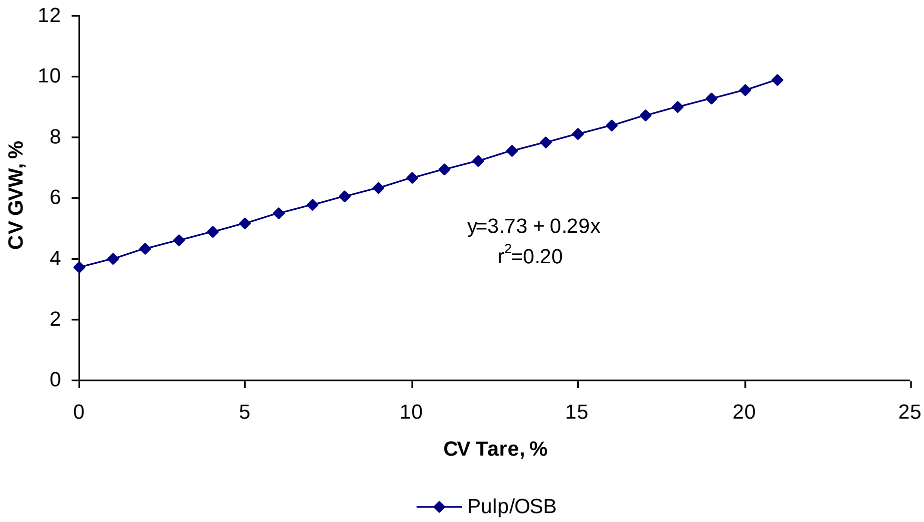

Figure. 2. Relationship of CV of tare weight to CV of GVW.

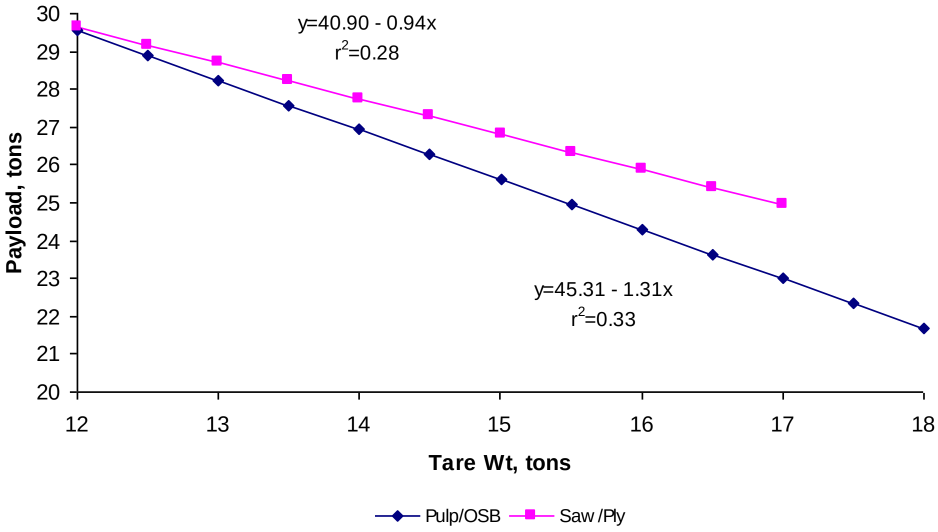

Figure 3. Relationship of tare weight to net weight.

5. CONCLUSIONS AND RECOMMENDATIONS

Our results show that (1) mills can control their gross vehicle weight distributions by enforcing overweight policies, (2) suppliers can achieve maximum hauling efficiency if they consistently haul fully loaded trucks, and (3) lighter weight trucks correspond to higher payloads.

On a mill-wide scale, mills can control their GVW distributions by enforcing overweight policies. Mill overweight policies did have an effect on average GVW. The percentages of loads in compliance with the mill policies ranged from 77% for Mill P (overweight policy of 42.5 tons) to 100% for Mills D, K, and L (overweight policy of 46 tons). Minimizing load variability will positively affect the entire wood supply system. Mills could set a target variability and GVW range for suppliers, similar to the target system proposed by Beardsell (1986). The target GVW range must be balanced between cost, risk, and liability. If the target range is less than the state limit, then lower payloads and higher cost will cause suppliers to lose money. If the target range is much greater than the state limit, liability and risk will increase as trucks will strive to run overloaded. Suppliers should strive to keep GVW within the target range to ensure maximum payloads, and should strive to maintain a CV within the variability range to ensure consistent payloads. The mills could provide regular progress reports to suppliers showing their variability and GVW in relation to other suppliers and the mill target.

Suppliers that regularly haul fully loaded trucks receive the maximum benefit. There was a group of suppliers at each mill with significantly less variable GVW. For 16 out of the 24 mills the least variable five contractors had a higher average GVW than the rest of the suppliers. Suppliers can increase GVW by hauling more uniform loads. One way suppliers can reduce their load variability is to use scales, on-board (electronic or air) or platform, to measure load weights.

The payloads of the least variable (most consistent) group of suppliers were higher than those of the rest of the suppliers. In the cost analyses, the BM group hauled more wood, at a lower cost, for more revenue than the RS group. For each mill the more uniform suppliers had 4% to 14% hauling cost savings compared to the rest of the suppliers. Reducing variability, through scales or other means, will yield higher revenues and cost savings. The United States southern wood supply chain could potentially save $100 million by reducing payload variability. This estimate of cost savings is conservative as suppliers were compared to the best local benchmark group instead of the best benchmark groups across the region.

There was an inverse relationship between the variability of GVW and mean net payload. The less variable GVW yielded higher net payloads. If suppliers can control their GVW, using whatever method, they can more effectively raise payloads.

We also found that lighter weight trucks contribute to higher payloads. The inverse relationship between average tare weight and average net weight observed at 15 mills supports this conclusion. Each 1 ton reduction in tare weight approximately resulted in a 1 ton increase in payload. Contractors should use lightweight tractor-trailer rigs to increase payloads, and therefore increase revenue. Lighter trucks can be purchased, or existing rigs can be modified to be more lightweight.

Lower tare weights can somewhat contribute to more uniform loads. The direct relationship between average tare weight and payload variability at five of the mills indicates that lower tare weights can contribute to reduced payload variability, although the exact relationship between the two is variable.

Managing uniform truck fleets by itself will only result in small gains in payload; load weights must be measured to further control variability. There was a direct relationship between tare weight variability and GVW variability at 8 of 24 observed mills. Less variable tare weights resulted in less variable GVW, although a 10% reduction in tare weight variability only yielded about a 2 to 7% gain in payload. Suppliers can control tare weight variability by maintaining uniform truck fleets. When purchasing new trucks, trucks should be purchased with similar—preferably lower—tare weights. This will aid in controlling GVW, which will in turn increase payloads.

This analysis did not separate loads or suppliers by product. The product hauled may have affected the variability of some of the suppliers. Accounting for this source of variability may also affect the projected savings. Additional analyses are underway to evaluate these issues.

6. LITERATURE CITED

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