Metsäteho

Crane scale accuracy: A case study on timber truck and forwarder crane scale measurement

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Crane scale measurement in Finland

- Crane scale measuring became an official measuring method within Finland in 2009 established through the Ministry of Agriculture and Forestry Acts in 2008 and updated in 2010, providing guidelines on measuring procedures and utilization of fresh and semi-fresh weight to volume conversion factors for pulpwood and logwood timber assortments (Ministry of Agriculture and Forestry, 2008, 2010).
- Energy wood measurement by crane scales are currently conducted by agreement among forest and energy industry stakeholders, however, will be implemented as an official measurement method by the end of December, 2013.
- Improved reliability, efficiency, and cost effectiveness in measurement and logistics have been identified in crane scale measurement (Melkas, T. and Hämäläinen, J. 2012).

Crane scale measurement in Finland

- Approximately 1,500 trucks and 600 forwarders currently operate with crane scale measuring systems.

- Crane scale measurement accounted for ~12.4 % of privately owned forest delivery sales in Finland in 2012 equalling 0.7 million m^3 and has shown a rapid increase in use, increasing its percentage share from 1 % to ~12.4 % since 2009 (Melkas, T. 2013).

Accuracy and Calibration$_I$

- Crane scale measuring must adhere to established guidelines when operating, including measuring methods, conversion factors, and minimum accuracy requirements to ensure system reliability (Ministry of Agriculture and Forestry, 2008).

- As of 2012, crane scale measuring are required to meet accuracy limits of ± 4 %. Contractors are responsible for accuracy of the measurement system, while operators must ensure the measuring system and use of the crane scale adhere to manufacturers guidelines prior to use (Ministry of Agriculture and Forestry, 2008).

- In 2013, new timber measurement legislation is expected to change accuracy requirements by measured weight (kg) from ± 8 % with measured crane scale weights of 10,000 – 30,000 kg to ± 4 % with measured weights greater than 100,000 kg (Ministry of Agriculture and Forestry, 2013).

Accuracy and Calibration$_{II}$

- Calibration of crane scales are currently conducted by three methods depending on crane scale utilized.
- Accuracy monitoring methods determine acheived accuracies, while recommended guidelines suggest when crane scale should be calibrated.
- Calibration methods include:
  - 1) Accuracy monitoring of operative timber truck crane scales with weight bridge.
  - 2) Accuracy monitoring with controlled test weights of forwarder scales.
  - 3) Accuracy monitoring with controlled test weights and random sampling.
- Within the timber Truck and Trailer and Forwarder crane scale study, accuracy monitoring of timber truck crane scales (with weight bridge) and controlled test weightings of forwarder scales were examined.

Accuracy and calibration$_{III}$

- Timber truck crane scale recommended calibration guidelines and accuracy calculations include:
  - Guidelines established by Metsäteho Ltd, which determine when crane scales are to be calibrated and include:
    - ≤ ± 2%, calibration not required.
    - > ± 2%, occuring 3 times in same direction, calibration required by manufacturer instructions.
    - > ± 4%, occuring 2 times in same direction, calibration required by manufacturer instructions.
    - > ± 7%, scale is calibrated by manufacturer instructions (Metsäteho, 2011).
    - Contractor responsible, if not automated, to record and compare information for calibration on a weekly basis.
    - Testing of accuracy to be made on a weekly basis by comparing load (control) weight with weight bridge to the scaled weight.

- Accuracy monitoring calculation method:
  - $Timber\ truck\ average\ difference, \% = \frac{(loader\ scale, kg - weigh\ bridge, kg)}{weigh\ bridge, kg} \times 100$

Accuracy and calibration$_{IV}$

- Forwarder crane scale accuracy tests (with testing weight) following recommended guidelines of Metsäteho Ltd. and accuracy calculataion methods include:
  - Testing of accuracy to be made on a weekly basis by comparing control weight with test lifts (20 lifts) to the scaled weight.
    - ≤ ± 2%, calibration not required.
    - > ± 2%, calibration and renewed accuracy testing occurs by manufacturer instructions.
    - > ± 7%, scale is calibrated by manufacturer instructions (Metsäteho, 2011).

- Accuracy monitoring calculation method:
  - $$Forwarder\ average\ difference, \% = \frac{(loader\ scale, kg - (control\ weight, kg \times 20\ lifts))}{control\ weight, kg \times\ 20\ lifts} \times 100$$

Timber truck and forwarder crane scale study$_{I}$

- In 2012, a study on the accuracy of crane scales utilized in timber procurement operations within partners of the Finnish Forest Industry Federation was conducted by Metsäteho Ltd.
- Operative data from timber truck and trailer crane scale measurements and controlled calibration tests of forwarder crane scale measurements were analyzed.
- Accuracy results were determined by:
  - Weight classifications of measured timber (kg).
  - Time periods (measured in quarters).
  - Scale manufacturers and models (represented by assigned letter).
  - Measuring principle in use.
  - Timber assortment being measured (Truck and Trailer study).
  - Contractors identified within the studies.
- The two studies, 1). Operative Truck and Trailer, and 2). Forwarder identified reliability and performance through mean accuracies and standard deviations from recorded observations.

Timber truck and forwarder crane scale study$_{II}$

- Truck and Trailer crane scale study:
  - Operative crane scale measurement data from approximately 65,131 observations were utilized to analyze accuracy by predefined variables.
  - Accuracy measurements were filtered through a 99% confidence interval, limiting observations to 64,479.
  - The average load size utilized by truck and trailers was 26,891 kg.
  - Average weight at weigh bridge was 26,910 kg.
  - 322 contractors were identified with an average of 46 timber deliveries per contractor.
  - Timber assortments of pulpwood and logwood were assigned by species, timber classification, and delivery destination.
  - Five scale manufacturers and two models of the same manufacturer were utilized within the study: TB Construction, Tamtron, Loadmaster 2000, Loadmaster Multi, LoadOptimizer, and Epec.
  - Measuring principle utilized were identified by scale manufacturer.

Timber truck and forwarder crane scale study$_{III}$

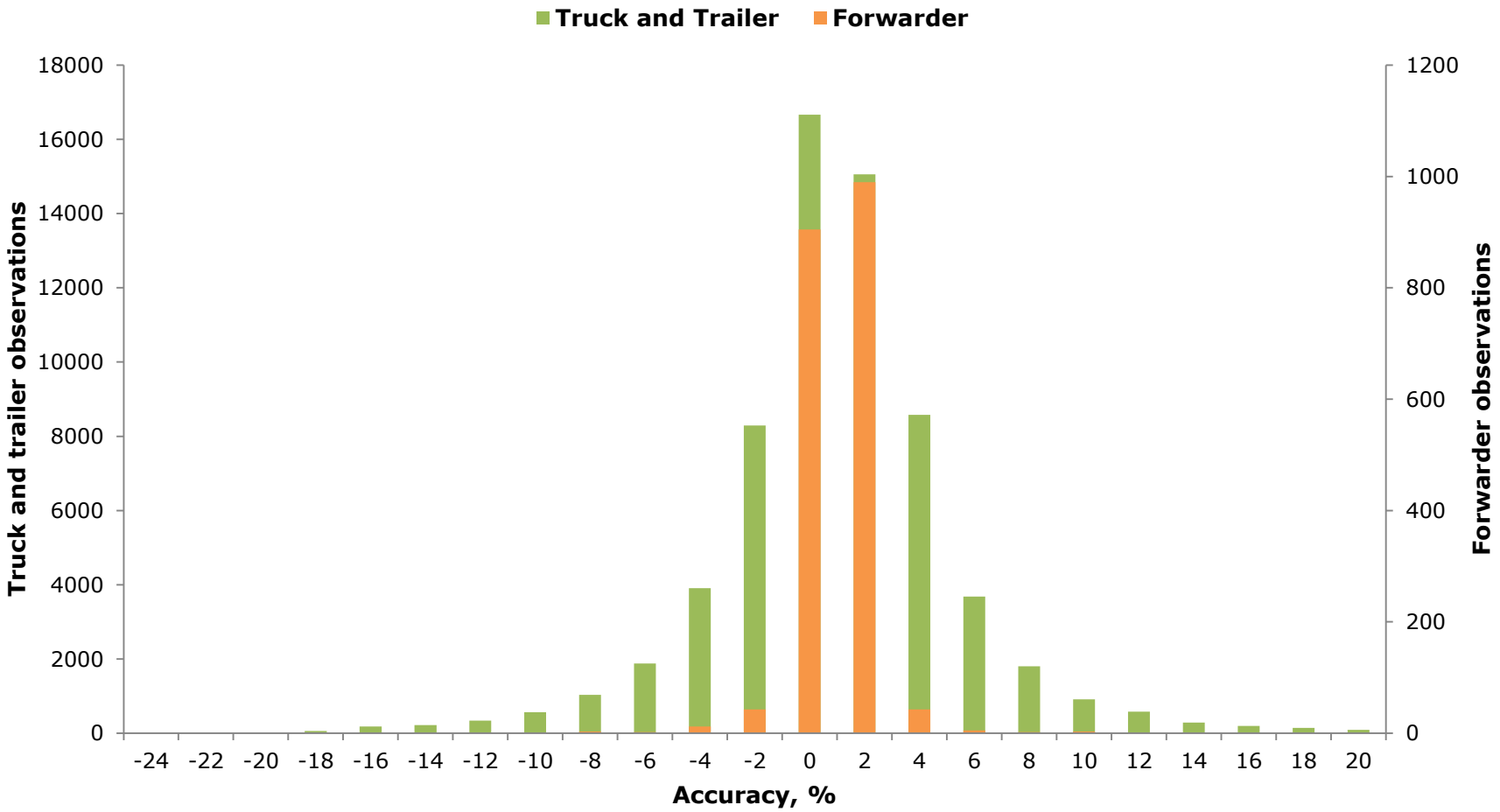
- Forwarder crane scale study:
  - Approximately 2,990 observations conducted during calibration tests were collected from January, 2011 to June, 2012 from members of the Finnish Forest Industries.
  - 2,010 accuracy observations remained after filtering of duplicate information from transfering of PRL files and observations deviating from recommend calibration testing.
  - Control weight mass varied between 242-840 kg, with an average weight of 453 kg. Control weight tests were all conducted with 20 lifts of the control weight.
  - The average testing weight within the study was 9,052 kg.
  - Average crane scale weight was 9,054 kg.
  - 158 contractors were identified with an average of 12.7 test weighting performed.
  - Six crane scale manufacturers were included within the study: Tamtron, Ponsse, Mecanil, Loadmaster, Komatsu, and John Deere.

Results

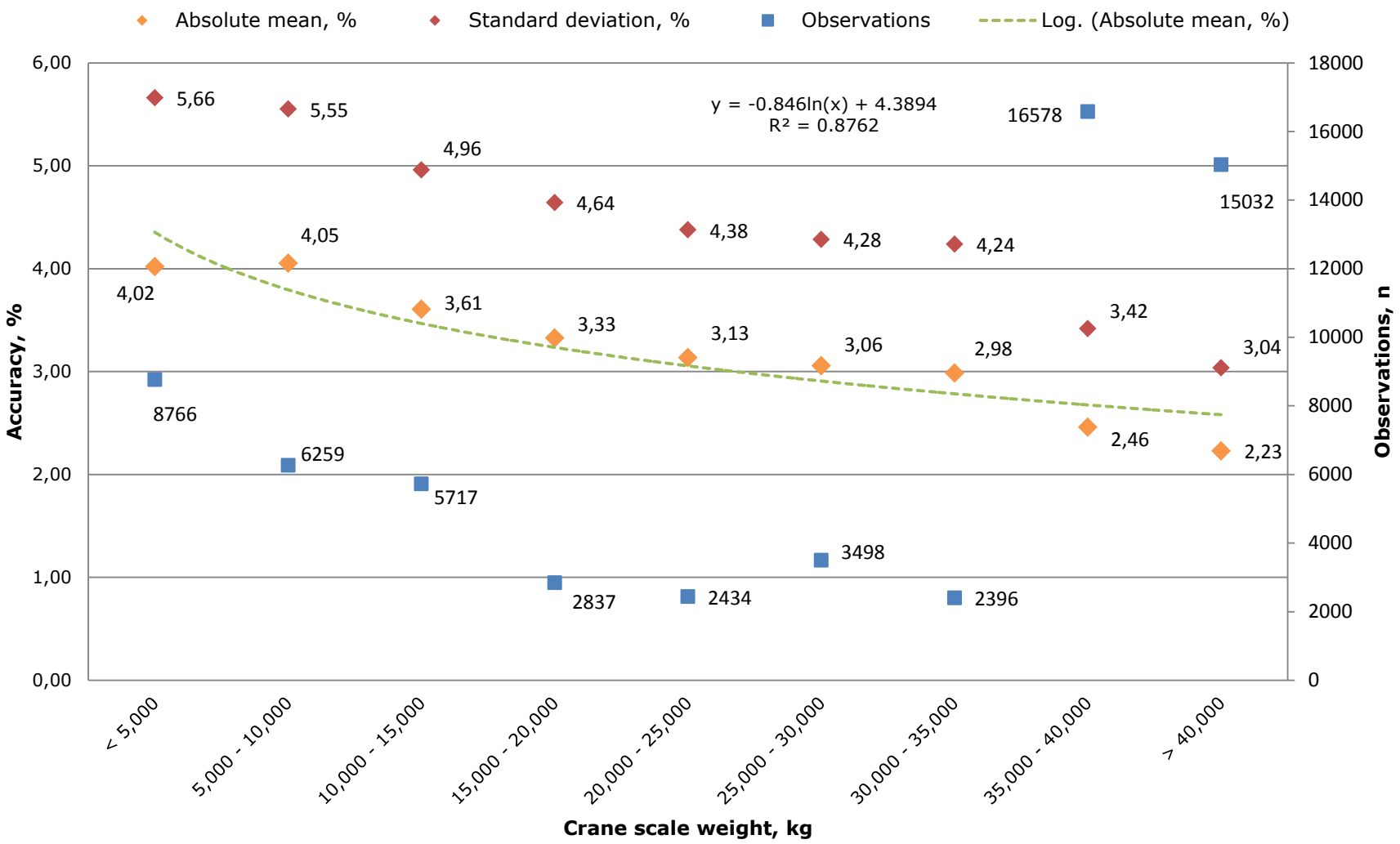
Reported results from both crane scale studies of timber truck and trailer and forwarder systems included:

- Accuracy by number of observations.
- Accuracy by weight classification of total measured timber.
- Time period accuracy, measured by quarters.
- Crane scale manufacturer accuracy.
- Measuring principle accuracy.
- Timber assortment accuracy.
- Contractor performance.

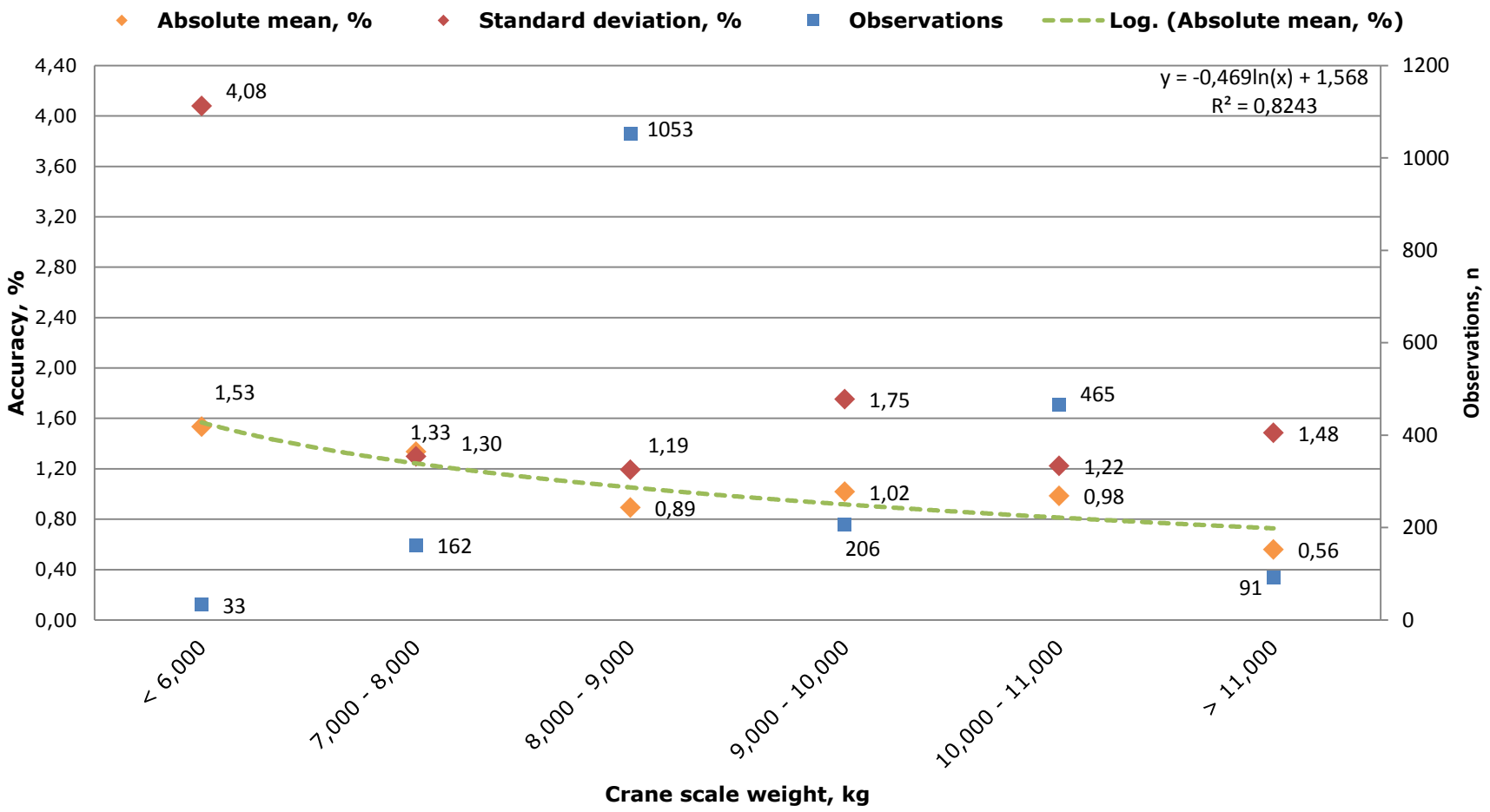
Crane scale accuracy by scale type



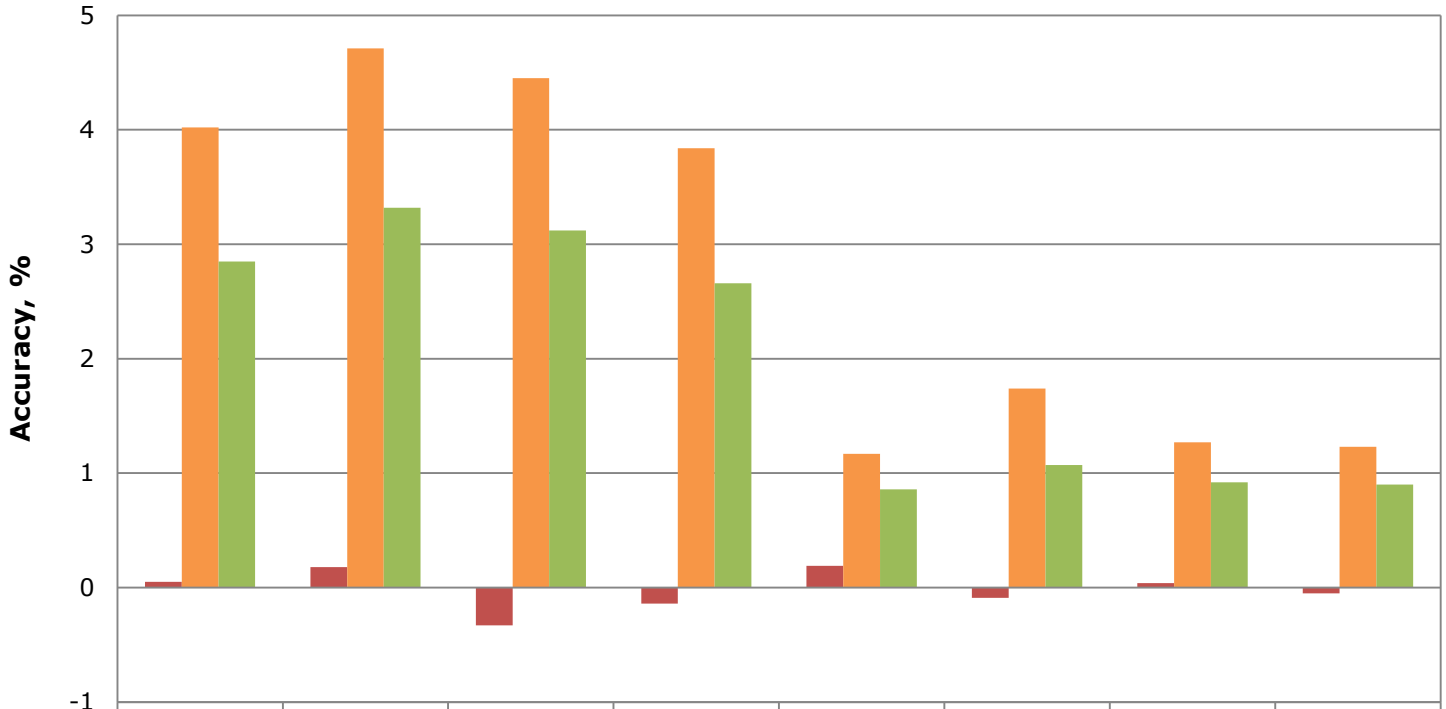
Truck and trailer accuracy by weight classification



Forwarder accuracy by weight classification

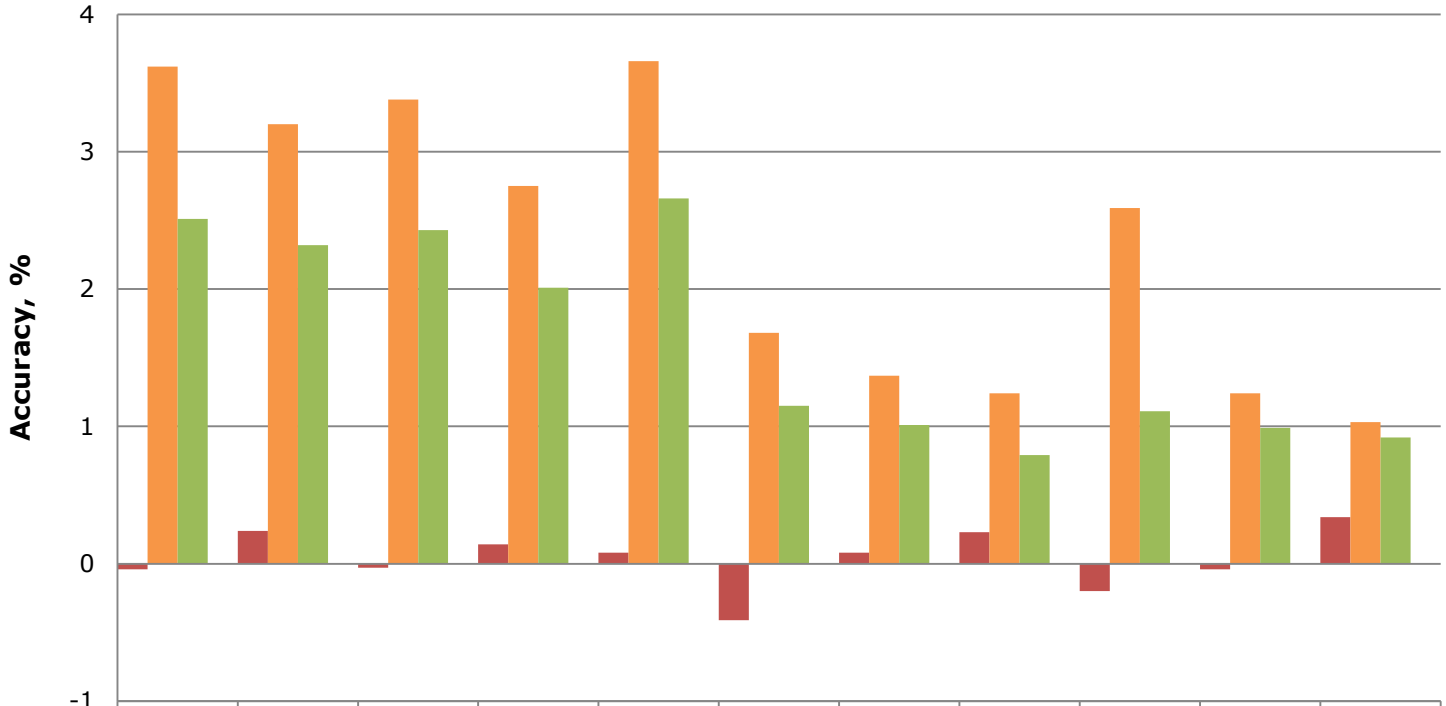


Accuracy by time period



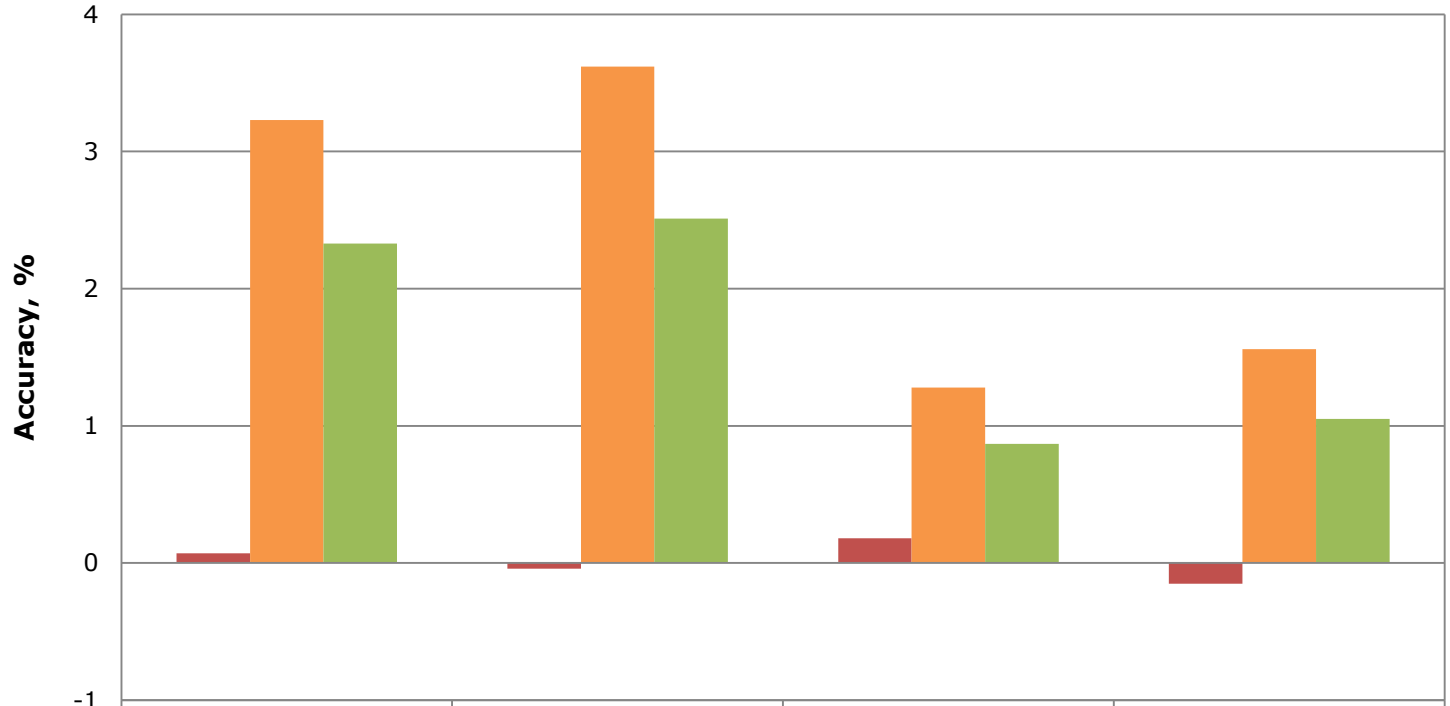
	Truck and Trailer crane scales				Forwarder crane scales			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Average difference, %	0,05	0,18	-0,33	-0,14	0,19	-0,09	0,04	-0,05
Standard deviation, %	4,02	4,71	4,45	3,84	1,17	1,74	1,27	1,23
Absolute mean, %	2,85	3,32	3,12	2,66	0,86	1,07	0,92	0,90
Observations	18479	16847	14276	14877	470	712	540	288

Accuracy by crane scale manufacturers



	A	B	C	D	E	F	G	H	I	J	K
	Truck and Trailer crane scales					Forwarder crane scales					
Average difference, %	-0,04	0,24	-0,03	0,14	0,08	-0,41	0,08	0,23	-0,20	-0,04	0,34
Standard deviation, %	3,62	3,20	3,38	2,75	3,66	1,68	1,37	1,24	2,59	1,24	1,03
Absolute mean, %	2,51	2,32	2,43	2,01	2,66	1,15	1,01	0,79	1,11	0,99	0,92
Observations	2100	2949	6120	1971	44	273	342	661	100	620	14

Accuracy by measuring principle

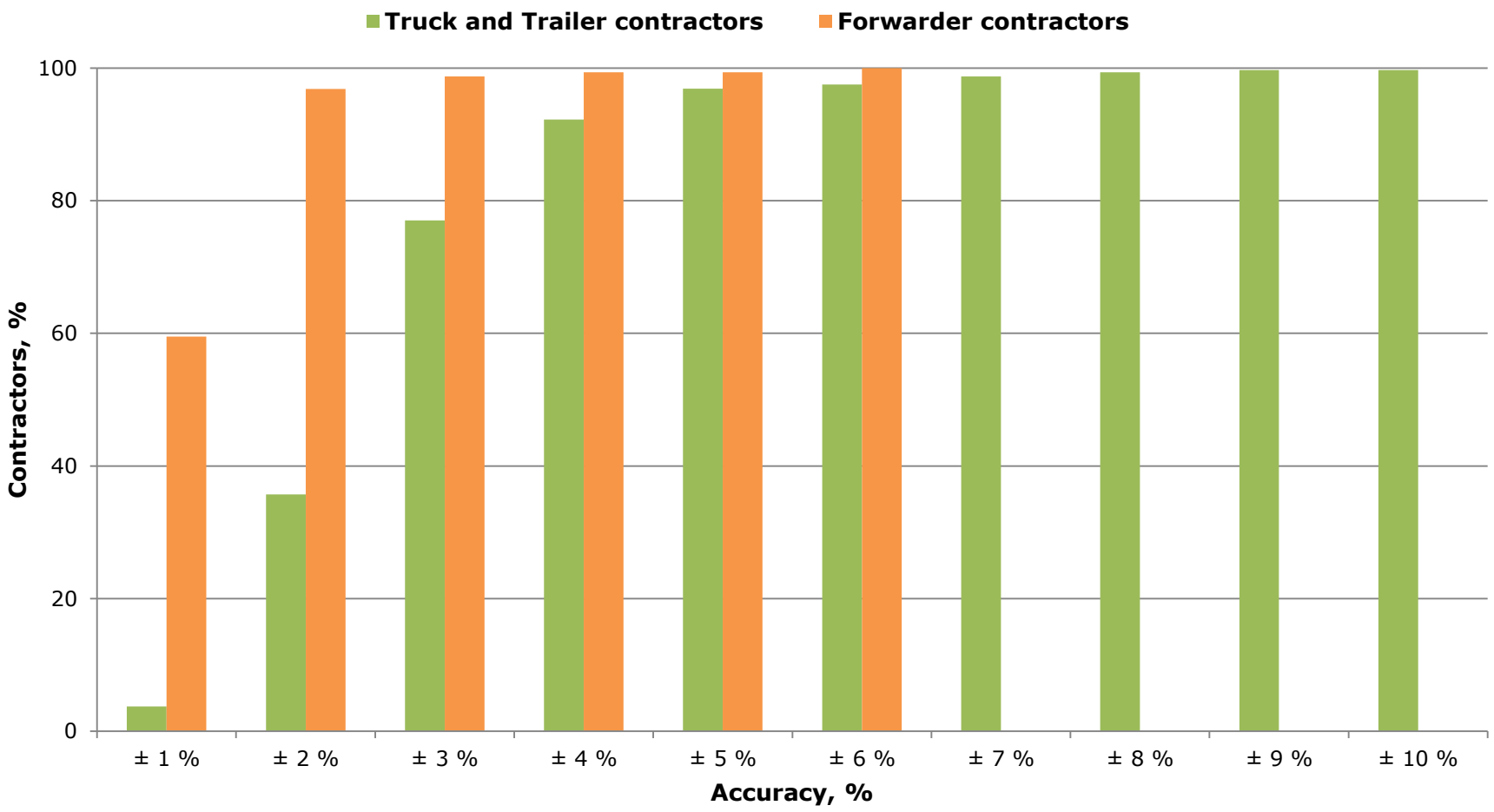


	Hydraulic pressure	Strain gauge	Hydraulic pressure	Strain gauge
	Truck and Trailer		Forwarder	
Average difference, %	0,07	-0,04	0,18	-0,15
Standard deviation, %	3,23	3,62	1,28	1,56
Absolute mean, %	2,33	2,51	0,87	1,05
Observations	11084	2100	1017	993

Accuracy by timber assortment

	Pulpwod	Logwood
Average difference, %	0,00	-0,44
Standard deviation, %	4,23	4,64
Absolute mean, %	2,96	3,23
Observations	58490	5989

Contractor performance



Discussion$_I$

- Reliability of both timber truck and trailer and forwarder crane scales were found to have the majority of their observations within the ± 4 % required accuracy limits.
  - Approximately 81.4 % of Truck and Trailer and 99.2 % of forwarder accuracies were within ± 4 %.
- The largest variations in accuracy results were found to occur among measured timber weight classifications and by time period.
  - Correlation between accuracy and measured weight classes were determined for both Truck and Trailer and Forwarder crane scale accuracy measurements.
  - Increased weight displayed higher accuracies measured by the absolute mean and lower standard deviations.
  - Standard deviations of Truck and Trailer accuracies varied from 5.66–3.04 % between measured weights of <5,000 kg to >40,000 kg.
  - Standard deviations of Forwarder accuracies varied between 4.08-1.48 % with measured crane scale weights of <6,000 kg to >11,000 kg.

Discussion$_{II}$

- Significant differences were established when examining measured accuracies by quarterly time periods in both studies.
  - Accuracies were found to be lowest among the second quarter with approximately 77.5 % and 98.5 % of Truck and Trailer and Forwarder observations meeting the required ± 4 % accuracy limit.
  - Seasonal influences including fluctuation in moisture content and fresh density have been previously noted by Heikkila et al. (2004), which could have influenced the variations in accuracies among the studies.
- Scale manufacturer and model accuracies were found to be higher than previous estimates of Hujo (2006) and similar to recent estimates of Iwarsson Wide and Jönsson (2012), suggesting improvement in crane scale accuracy.
  - Accuracies of Truck and trailer observations varied between -0.04-0.24% with standard deviations of 2.75-3.66%.
  - Forwarder accuracies varied between -0.41-0.34% with standard deviations of 1.03-2.59%.

Discussion$_{III}$

- Accuracies among measuring principles found crane scale utilizing hydraulic pressure to have slightly higher accuracies.
  - Approximately 88.4% and 99.3% of Truck and Trailer and Forwarder crane scales utilizing hydraulic pressure were within ± 4% compared to 87% and 99% of crane scales utilizing a strain gauge measuring principle.
- Measuring accuracies by timber assortments within the Truck and Trailer observations found pulpwood accuracies to be higher, however, the comparatively large number of pulpwood observations likely influenced recorded average errors and standard deviations.
  - Approximately 81.6% and 79.3% of pulpwood and logwood accuracies were within ± 4%.
- When comparing contractor performance, Truck and Trailer and Forwarder contractors were found to have fairly high performance within the study.
  - Approximately 92.2% and 99.4% of Truck and Trailer and Forwarder contractors were within ± 4 % accuracy.

Discussion$_{IV}$

- A distinction should be made when comparing operative data, exhibited by the Truck and Trailer crane scale accuracy study with that of the controlled accuracy observations within the calibration of Forwarder crane scales.
  - Controlled measuring environment and controlled test weightings are likely to influence measured accuracy.
  - Further studies of forwarder crane scales in an operative environment are likely to produce accuracy results on a similar level to that of the operative Truck and Trailer study, and should be examined further.

Conculsions

- As a basis of payment and measurement data utilized within timber procurement and logistics, reliability and accuracy is essential in further increasing efficiency and potentially reducing operating costs in the future.

- With a rather expansive study, crane scale measuring has displayed the ability to be both accurate and reliable.

- In the future, when accuracy requirements are based on weight classification, crane scale measurement is expected to continue to provide an accurate means of measurement.

References$_{I}$

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