Space allowance during commercial long distance transport of cattle in North America1

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ABSTRACT: The objective of the present work was to study space allowance in cattle during commercial long haul transport (≥400 km; n = 6,152 journeys). Surveys, delivered to livestock transport carriers, gathered information on the number, BW, and distribution of cattle by trailer compartment as well as the characteristics of the transport vehicles used. Space allowance (SA; m²/animal), allometric coefficient (k = SA / BW0.6667), and the percentage of deviation from recommended SA (DRSA; %) in the Canadian Codes of Practice were calculated for each compartment of the trailers. All quad-axle (77%) and tri-axle (23%) cattle trailers were reported with 5 compartments (nose, deck, belly, back, and doghouse). Sixty percent of all animals were carried in the middle compartments (deck and belly), 30% in the rear (back and doghouse), and 10% in the front or nose. Approximately 30% of the journeys required that the cattle be redistributed at the Canada-USA border to comply with different axle weight regulations, and most journeys moved them between the deck and the doghouse. Total loaded weight increased and the number of animals decreased with increasing BW of the animals. Space allowance, k-value, and DRSA were least for calves and feeders compared with fat and cull cattle (P < 0.01). Both total loaded weight and number of animals increased with the number of axles in the trailer, being greatest in quad-axle trailers pulled by push tractors, which were most frequently used. Space allowance (k-value) was least in vehicles with greater number of axles and transporting the lightest cattle (i.e., quad-axle trailers transporting calves and feeders). Space allowance, k-value, and variability among journeys were least in the middle compartments (belly and deck), followed by the back, then doghouse and nose compartments of the trailers showing the largest values (P < 0.05). Many factors contributed to the variability in SA such as body size (smaller animals are placed more densely), compartment of the trailer (greater density in belly and deck), and number of axles on the vehicle (greater density with more axles). The present study provides a framework to assess and understand factors affecting SA during commercial long distance transport of cattle. This information is vital in assessing the consequences of changing industry standards, guidelines, recommended values, laws and regulations on animal welfare, the industry, and economics.

Key words: livestock, loading density, road transport, survey

INTRODUCTION

Both excessive and insufficient space allowance (SA) during cattle transportation have the potential to be detrimental for animal well-being and profitability. Research findings have shown that inappropriate SA can increase the frequency of falls, injuries, bruising, mortality, cortisol and creatine kinase concentrations, and reduce meat quality (Tarrant et al. 1988, 1992; González et al., 2012c). Space allowance during animal transport is a highly debated issue which has led to the development and enforcement of regulations and standards around the world. For instance, the World
Organization for Animal Health (OIE) has recognized the importance of proper SA because it was considered crucial to maintain good animal welfare (OIE, 2004; Broom, 2005). Similarly, the European Parliament has legislated minimum SA for cattle during transport (CEC regulation 1/2005; CEC, 2005). In agreement with this trend, the Canadian Food Inspection Agency proposed amending the Health of Animals Regulations which deals with cattle transport (Canada Minister of Justice, 2009).

The Canadian Cattlemen’s Association (CCA) expressed the view that any regulatory changes considered by CFIA must reflect Canadian conditions and data and must be knowledge-based (CCA, 2006). However, there is no published data reporting commercial loading densities currently used by the Canadian industry which can be used to assess the impact of and aid in the formulation of sound changes to the Regulations, if any are required.

Loading density is a complicated issue to deal with under commercial situations because drivers have to comply with both maximum axle weight regulations and recommended SA. Therefore, several considerations come into play including the number of axles in tractors and trailers, cattle BW, condition, presence of horns, environmental conditions, and distance animals will be transported. The objective of the present study is to characterize factors affecting loading density during commercial transport of cattle in North America.

**MATERIALS AND METHODS**

Information for the present study was collected during commercial transport of cattle. The care and handling of animals during transportation was therefore not supervised or controlled by the research team.

Surveys were designed in collaboration with different research teams, government organizations, owners and managers of transport companies, truck drivers, and beef producers to collect data regarding the characteristics of cattle transport during long hauls departing from, and arriving in the province of Alberta. Data were only collected on journeys transporting cattle for distances equal to or farther than 400 km between the place of origin where cattle were loaded and the place of final destination where cattle were unloaded. The surveys contained a set of questions separated into 5 sections which gathered information regarding the livestock, driver and equipment, animal loading, conditions during transport, and unloading. A detailed description and sample of the survey and calculations used are presented elsewhere (González et al., 2012a).

Cattle transport vehicles in the present study comprise a tractor (auto traction unit consisting of the cab, engine, drive-train, and frame) and a trailer (or semi-trailer being an unpowered vehicle pulled by the tractor and consisting of rear axles but lacking front axles). Information about each trailer and tractor were also documented and included year, make, number of axles, configuration, and dimensions of each compartment. Tractors were classified according to the number of axles as tandem (2 axles), tri-drive (3 axles permanently down or in use), or push (3 axles with one of them placed down or up when in use or not in use, respectively). Similarly, trailers were classified according to the number of axles as tandem (2 axles), tri-axle (3 axles), and quad-axle (4 axles), which dictates the size of the compartments, as well as the maximum weight (Table 1) and number of animals to be loaded onto the trailers. However, tri-drive tractors were only reported twice (0.03% of all loads) as it was also the case of tandem trailers in the present study. Therefore, no data analysis considered the use of tri-drive tractors or tandem trailers. Road transport regulations within the United States allow the use of the fourth axle of quad-axle trailers and the third axle of a push-tractor by engaging them. However, this is not allowed by the Canadian Department of Transport.

### Table 1. Floor space (m²) of each compartment and of total trailer, and approximate vehicle maximum weights during commercial long haul transport of cattle in North America (≥400 km)

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Tri-axle</th>
<th>Quad-axle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>8.16</td>
<td>7.65</td>
</tr>
<tr>
<td>Deck</td>
<td>19.68</td>
<td>18.39</td>
</tr>
<tr>
<td>Belly</td>
<td>19.68</td>
<td>18.39</td>
</tr>
<tr>
<td>Back</td>
<td>12.66</td>
<td>14.36</td>
</tr>
<tr>
<td>Doghouse, ¼</td>
<td>9.69</td>
<td>11.08</td>
</tr>
<tr>
<td>Doghouse, ½</td>
<td>6.80</td>
<td>7.80</td>
</tr>
<tr>
<td>Total area</td>
<td>76.69</td>
<td>77.67</td>
</tr>
<tr>
<td>Allowed weight tandem tractor, kg</td>
<td>16,000</td>
<td>17,000</td>
</tr>
<tr>
<td>Empty vehicle</td>
<td>46,500</td>
<td>46,500</td>
</tr>
<tr>
<td>Maximum total loaded weight Canada</td>
<td>47,000</td>
<td>47,000</td>
</tr>
<tr>
<td>Maximum drive axles weight Canada</td>
<td>17,000</td>
<td>17,000</td>
</tr>
<tr>
<td>Maximum trailer axles weight Canada</td>
<td>24,000</td>
<td>24,000</td>
</tr>
<tr>
<td>Maximum total loaded weight USA</td>
<td>44,900</td>
<td>44,900</td>
</tr>
<tr>
<td>Maximum drive axles weight USA</td>
<td>15,420</td>
<td>15,420</td>
</tr>
<tr>
<td>Maximum trailer axles weight USA</td>
<td>19,730</td>
<td>23,600</td>
</tr>
<tr>
<td>Allowed weight push tractor (USA only), kg</td>
<td>16,500</td>
<td>17,350</td>
</tr>
<tr>
<td>Empty vehicle</td>
<td>44,900</td>
<td>47,000</td>
</tr>
<tr>
<td>Maximum total loaded weight</td>
<td>19,730</td>
<td>19,730</td>
</tr>
<tr>
<td>Maximum drive axles weight</td>
<td>19,730</td>
<td>23,600</td>
</tr>
</tbody>
</table>

1 Total trailer area calculated as the sum of the area of the nose, deck, belly, back, and ¼ doghouse.

2 The steering axle is 5,500 kg.
Regulations and the extra axles can only be engaged by drivers upon arrival to the border, which may also require a re-distribution of animals (weight) among compartments. Trailers have different compartments to allow separation of animals in different groups within the trailer and a trailer has 5 compartments in the standard configuration: nose, deck, belly, back, and doghouse as shown by González et al. (2012a). Nose decking can also be used for calves by placing a false floor and creating an additional compartment. The size of the belly, deck, and doghouse compartments can be changed by using gates to regulate SA, keep animals in different groups, or reduce livestock pressure when travelling in mountainous terrain. The “doghouse L” can be used to increase the size of this compartment from 50% (½ doghouse) to 75% (¾ doghouse) of the size of the back compartment. Therefore, trailer configuration, number and location of gates and decks, and number and BW of animals per compartment were documented for transport within Canada and the United States. Each trailer used in the present study was measured by the research team to ensure gate positions and compartment size for accurate SA calculations. Minimum and maximum ambient temperature, loading start time, and unloading end time of animals during the journey was also requested and used to calculate midpoint temperature and total transport time, respectively.

**Data Processing and Calculations**

Cattle were classified into 5 categories according to BW, and origin and destination (e.g., farm or feed yard) into fat, feeders, calves, breeding, and cull cattle as described elsewhere (González et al., 2012a). However, Breeding cattle were collapsed into the Fat cattle category for the purpose of analysis in the present paper because of the small sample size. Animals were considered “Fat” cattle when loaded at a feed yard and unloaded at a slaughterhouse. Animals were considered “Feeders” if loaded at a feed yard or auction market, and their BW was between 275 and 500 kg. Animals were considered “Calves” if they were transported to a farm, auction market or feed yard, and weighed less than 275 kg. “Cull” cattle were defined as cows and bulls going from an auction market or farm to feed yard or slaughter. Animals defined as “Breeding” cattle were going from a farm or auction to a farm or ranch. Loading density was calculated using 3 different methods for each compartment and journey: SA as in Eq. [1]; deviation from the recommended SA as in Eq. [3] (DRSA) from the Canadian Codes of Practice as in Eq. [2] [Canadian Agri-Food Research Council; CARC, 2001] as presented by Whiting (2000); and allometric coefficient (k-value) as in Eq. [4] (Petherick and Phillips, 2009). The k-value is useful for comparisons of loading densities across all the BW range as it avoids the need to include BW for understanding.

\[
\text{Observed SA (m}^2/\text{animal}) = \text{Area compartment / No. Animals} \quad [1]
\]

\[
\text{Recommended SA (m}^2/\text{animal}) = 0.01229 \times \text{BW}^{0.7403} \quad [2]
\]

\[
\text{DRSA (\%)} = (\text{Observed SA} – \text{Recommended SA})/ \text{Recommended SA} \times 100 \quad [3]
\]

\[
\text{Allometric coefficient (k-value)} = \text{Observed SA} / (\text{BW}^{0.6667}) \quad [4]
\]

where BW is average BW (kg/animal) of the animals loaded in a compartment, and Area is calculated as length × width for each compartment. Area and SA were adjusted whenever gates were used within the compartments as stated by the truck drivers. Under the same circumstances, more animals per compartment led to less SA and decrease k-value, and greater loading density, all indicative that animals are loaded more densely. Negative values in DRSA indicated that animals were given less space than recommended, whereas positive values indicated more space compared with the recommendations.

**Statistical Analysis**

Descriptive statistics were obtained using the MEANS procedure for parametric data, whereas the FREQ procedure was used for discrete and categorical data such as proportion of loads for each tractor-trailer combination (SAS Inst. Inc., Cary, NC). Mixed-effects regression models were constructed in the MIXED procedure using fixed categorical effects (e.g., tractor axles, trailer axles, cattle category) and all possible interactions. Transport company was considered a random effect and its interaction with fixed effects was the error term. Thus, the experimental unit was the company for all analysis and each truck load was an observational unit within company. Space allowance differed significantly among compartments of the trailers, and therefore analyses were run for each compartment separately to assess the effects of fixed factors. Reported minimum and maximum temperatures within each journey were used to calculate average temperature as reported by González et al. (2012a). In addition, midpoint temperature for each journey was assigned to 1 of 3 categories (dummy variable) according to temperature range \(\leq 0^\circ\text{C}, >0\) and \(\leq 20^\circ\text{C}, >20^\circ\text{C}\) to analyze changes in SA according to midpoint temperature. Similarly, total transport time was assigned to 1 of 4 categories being less \(\leq 10\),
RESULTS AND DISCUSSION

There were 6,880 surveys or truck loads collected but 6,152 were left in the final dataset for analysis. In addition, data from some cells within the remaining surveys might not have been entered by truck drivers or were discarded from the analysis because of lack of clarity for the research team as explained by González et al. (2012a). Data from a total number of 327 vehicles (tractor-trailer units) which relocated 290,866 animals were collected. More information about data processing and descriptive statistics concerning other data collected including transport distance and time, weather conditions, and management differences among cattle categories were reported by González et al. (2012a,b).

**Number of Animals, Animal Weight Loaded, and Type of Vehicles**

As expected, there was a strong relationship between the number of animals loaded per trailer and BW ($r = -0.92$; $P < 0.001$). Results are therefore presented for each cattle category because BW is more uniform within them. The number of animals loaded per trailer was greatest for calves, intermediate for feeders, followed by fat cattle, and finally cull and breeding cattle categories had the lowest number of animals per trailer ($P < 0.001$; Table 2). The number of animals in each compartment for each cattle category

<table>
<thead>
<tr>
<th>Item</th>
<th>Fat</th>
<th>Feeder</th>
<th>Calves</th>
<th>Cull</th>
<th>Breeding</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>5,012</td>
<td>944</td>
<td>94</td>
<td>43</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Trailer</td>
<td>43.8 w</td>
<td>70.5 x</td>
<td>113.4 y</td>
<td>40.5 z</td>
<td>38.8 z</td>
<td>1.39</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nose 1</td>
<td>4.0 w</td>
<td>7.1 x</td>
<td>9.9 y</td>
<td>3.7 w</td>
<td>4.4 w</td>
<td>0.22</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nose 2</td>
<td>-</td>
<td>8.2 w</td>
<td>11.1 x</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deck</td>
<td>13.4 w</td>
<td>20.5 x</td>
<td>30.6 y</td>
<td>12.6 x</td>
<td>13.0 x</td>
<td>0.58</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deck 1</td>
<td>5.0 w</td>
<td>10.5 x</td>
<td>15.6 y</td>
<td>7.4 w</td>
<td>5.2 w</td>
<td>0.99</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deck 2</td>
<td>8.1 w</td>
<td>11.2 x</td>
<td>17.4 y</td>
<td>7.8 w</td>
<td>6.0 w</td>
<td>0.67</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Deck 3</td>
<td>-</td>
<td>-</td>
<td>10.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Belly</td>
<td>14.6 w</td>
<td>21.6 x</td>
<td>31.2 y</td>
<td>13.6 w</td>
<td>14.8 w</td>
<td>0.45</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Belly 1</td>
<td>8.3 w</td>
<td>12.4 w</td>
<td>18.7 y</td>
<td>-</td>
<td>6.9 w</td>
<td>2.60</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Belly 2</td>
<td>8.6 wx</td>
<td>12.1 x</td>
<td>19.0 y</td>
<td>-</td>
<td>5.0 w</td>
<td>1.80</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Back</td>
<td>8.5 w</td>
<td>13.1 x</td>
<td>19.2 y</td>
<td>8.3 w</td>
<td>9.2 w</td>
<td>0.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Doghouse</td>
<td>4.0 w</td>
<td>8.1 x</td>
<td>14.1 y</td>
<td>4.1 w</td>
<td>2.8 w</td>
<td>0.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L in use (½)</td>
<td>4.2 a</td>
<td>8.6 a</td>
<td>14.5 b</td>
<td>4.5 b</td>
<td>2.6</td>
<td>0.39</td>
<td>-</td>
</tr>
<tr>
<td>L not used (½)</td>
<td>3.6 a</td>
<td>6.7 b</td>
<td>13.1 b</td>
<td>2.9 a</td>
<td>2.7</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Doghouse 1</td>
<td>2.9 w</td>
<td>5.7 wx</td>
<td>6.0 x</td>
<td>-</td>
<td>-</td>
<td>0.78</td>
<td>0.03</td>
</tr>
<tr>
<td>Doghouse 2</td>
<td>1.7</td>
<td>2.7</td>
<td>3.7</td>
<td>-</td>
<td>-</td>
<td>0.89</td>
<td>0.36</td>
</tr>
</tbody>
</table>

- **Note:** Means without a common superscript differ ($P < 0.05$).
- a, b Within a column and compartment, means without a common superscript differ ($P < 0.05$).
- The greatest SEM of all cattle categories is presented.
- Nose 1 refers to the whole compartment when the deck was not used or to the lower sub-compartment when the deck was used. Nose 2 represents the top sub-compartment.
- The deck and the belly could have been divided into 2 or 3 sub-compartments when 1 or 2 gates were used, respectively.
- Doghouse 1 refers to the larger and Doghouse 2 to the smaller when the gate was used.
followed a similar pattern to the total number of animals per trailer and the belly and deck carried the largest number of animals followed by the back, whereas the doghouse and nose carried the least number of animals (Table 2). The relationship between the number of animals and BW suggests that the industry strongly considers BW when deciding on the number of animals to load. However, the fact that cull and breeding cattle had the fewest number of animals per trailer may suggest that more space is provided to animals with poorer body condition (cull) or high value (breeding). Interestingly, larger variation in the number of animals was observed within calves and feeders and least in fat cattle (data not shown). This may be a consequence of decreased variation in BW for fat cattle whose sale weight is more important, whereas BW of weaned and feeder cattle can vary according to age, sale prices, forage quality during the growing season, and genetics. These data suggest that compliance with loading density values may be more difficult and less practical to carry out in feeders and calves under commercial transport conditions because of the larger variation in BW.

The number of animals loaded not only depended on the cattle category but also of the number of axles in the vehicles. Table 3 presents the number of animals, scale weight before transport, and frequency of journeys for each cattle category and trailer/tractor combination. Means for breeding cattle are not presented because of a small number of observations. Approximately one-half of all journeys were made by quad-axle trailers pulled by push tractors and over one quarter by quad-axle trailers pulled by tandem tractors (Table 3). Tri-axle trailers were used less frequently, which is most likely a result of the large proportion of hauls exporting cattle to the United States during the present survey since 4 axles are allowed to be used in the United States (González et al., 2012a). Vehicles with a greater number of axles could accommodate more weight and therefore they were used more frequently for long distance transport (cattle category × trailer axle × tractor axle $P = 0.06$; Table 3). This triple interaction indicated that the change in loaded weight according to the number of axles of the vehicle (tractor-trailer combination) did also depend on the cattle category being transported. Thus, loaded weight decreased linearly with the number of axles of the unit if fat cattle were being transported, being greatest in quad-axle trailers pulled by push tractors and least for tri-axle trailers pulled by tandem tractors (Table 3). However, loaded weight dropped only with the least number of axles when feeders and calves were transported [i.e., tri-axle trailers pulled by tandem tractors ($P > 0.05$; Table 3)]. Similar to loaded weight, the number of animals loaded (category × trailer × tractor $P < 0.001$) decreased with the number of axles of the vehicle when transporting fat cattle ($P < 0.05$). However, the number of axles in the tractor did not affect the number of animals transported ($P > 0.10$), although fewer feeders were transported by tri-axle trailers compared with quad-axles regardless of tractor type ($P < 0.05$; Table 3). Thus, total weight and number of animals loaded per trailer increased with the number of axles of the vehicle, particularly for fat cattle. However, total loaded weight increased and the number of animals loaded decreased with heavier BW. Therefore, both total loaded weight and number of animals seem to be limited by axle weight regulations during the transport of fat, heavy cattle. However, total loaded weight and number of animals seem to be limited by compliance with recommended SA rather than axle weight during the transport of feeders and calves.

### Table 3. Loaded weight, number of animals per trailer, and frequency of journeys for each trailer and tractor combination according to the number of axles (n = 4,843)\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Quad-axle trailers</th>
<th>Tri-axle trailers</th>
<th>SEM (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Push</td>
<td>Tandem</td>
<td>Push</td>
</tr>
<tr>
<td>Animals, No./trailer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>43.3</td>
<td>43.1</td>
<td>42.0</td>
</tr>
<tr>
<td>Feeder</td>
<td>69.8</td>
<td>69.8</td>
<td>65.8</td>
</tr>
<tr>
<td>Calf</td>
<td>111.1</td>
<td>115.6</td>
<td>115.1</td>
</tr>
<tr>
<td>Cull</td>
<td>36.4</td>
<td>43.6</td>
<td>50.5</td>
</tr>
<tr>
<td>Loaded weight, kg/trailer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>28,243</td>
<td>27,931</td>
<td>27,244</td>
</tr>
<tr>
<td>Feeder</td>
<td>27,695</td>
<td>27,791</td>
<td>27,395</td>
</tr>
<tr>
<td>Calf</td>
<td>25,994</td>
<td>26,915</td>
<td>25,061</td>
</tr>
<tr>
<td>Cull</td>
<td>27,990</td>
<td>27,581</td>
<td>-</td>
</tr>
<tr>
<td>Frequency, % of journeys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All journeys</td>
<td>49.4</td>
<td>27.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Fat</td>
<td>52.7</td>
<td>25.2</td>
<td>11.3</td>
</tr>
<tr>
<td>Feeder</td>
<td>31.7</td>
<td>38.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Calf</td>
<td>13.8</td>
<td>29.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Cull</td>
<td>33.3</td>
<td>28.6</td>
<td>4.8</td>
</tr>
</tbody>
</table>

\(^{w-x}\) Within a row, means without a common superscript differ ($P \geq 0.05$).

\(^{1}\)Category × trailer × tractor $P$-value was 0.06 for loaded weight and $<0.001$ for No. of animals.

\(^{2}\)The greatest SEM of all vehicles groups is presented.

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**Use of Gates, Decks, and Redistribution of Animals at the Border**

Gates and decks are used to adjust SA or keep animals in separate groups. The use of gates and decks by the cattle industry appeared to depend on the number, category, and BW of the animals loaded during the present study. For instance, the deck in the nose was used in 1.6% of all journeys which were transporting either calves or feeders (data not shown). There were no fat, cul, or breeding cattle hauled in trailers using the nose deck because larger animals cannot comfortably stand in this compartment without their backs rubbing on the ceiling beam. The use of gates in the deck, belly, and doghouse
was not a common practice. This was most likely a factor of the high proportion of journeys transporting fat cattle destined for slaughter, which means the loads would have homogeneous BW and be filled to their weight capacity (González et al., 2012a). In fact, only 6.1% of all journeys used 1 gate in the deck, 0.05% used 2 gates in the deck, and 0.9% used the belly gate (data not shown). Gates in the deck were used more frequently when hauling calves (31.5% of all journeys transporting calves), breeding (25%), and cull cattle (25%; data not shown). In contrast, only 6.4 and 5.5% of all journeys transporting fat and feeder cattle, respectively, used gates in the deck (data not shown). This may be due to greater need to regulate SA during the transport of calves because of greater variability in BW and in breeding and cull cattle because fewer animals are loaded and there is potential mixing of animals with different physical conditions. The doghouse gate was used in only 0.6% of all journeys which transported calves and feeders (data not shown). The use of the doghouse “L” which results in a bigger compartment was used in 29.6% of the journeys and more frequently with smaller cattle (62, 52, and 25% of journeys transporting calves, feeders, and fat cattle, respectively; data not shown). These results document different industry management strategies used to manipulate cattle loading density and separation of animals groups, which depends greatly on the type of cattle transported.

Close to one third of all journeys crossing the Canada–United States border (29.9%) required that the cattle be redistributed among the compartments of the trailer at the border (data not shown). This is a practice commonly carried out to transfer more weight to the front or rear of the vehicle as extra axles are engaged, thereby complying with different axle weight regulations in each country. Almost all of the journeys that redistributed animals moved them from or to the deck (28.4%) and from or to the doghouse (29.2%), which was evident from the different number of animals per compartment during travel in Canada than in the United States. However, moving animals from or to the other compartments was less frequent (2% of journeys; data not shown). Moving animals around 3 or more compartments upon arrival at the border occurred in 2% of the journeys only (data not shown). It is important to note that all animals not going directly to slaughter (e.g., feeders and calves) have to be unloaded at the border for veterinary inspection, and therefore animals might be relocated to different compartments upon reloading them to continue the journey. The typical industry practice is to lower the fourth axle of quad-axle trailers, which allows more animals to be placed towards the back of the trailer (doghouse). The opposite is true in tri-axle trailers; however, drivers seem to have different methods of distributing weights. The third axle of a push tractor can also be lowered at the border which would allow moving animals from the doghouse to the deck, belly, or nose to transfer weight towards the drive axles (front). It would be beneficial for the cattle transport industry and perhaps for the welfare of animals to align transport regulations among countries so redistribution of animals is not necessary.

**Cattle Loading Density**

The previously reported large differences in the number of animals loaded among compartments of the trailer (Table 2) are not solely related to the size of the compartment. For example, loading density variables, such as SA and k-value, differed greatly among compartments of the trailer ($P < 0.001$). Thus, animals in the belly and deck were provided the least amount of space, whereas those in the nose and doghouse had the most (Figure 1). For instance, k-value was 56% smaller in the belly compared with the nose. The k-value is more useful than SA for studying loading density because the BW of the animal is not required for understanding or comparisons across different BW groups. White et al. (2009) reported a similar trend among compartments in 21 loads of 200-kg calves transported in the United States, where SA in m$^2$/calf was 0.65 in the belly, 0.67 in the back, 0.72 in the deck, 0.91 in the nose, and 0.95 in the doghouse. Such differences among compartments in SA and k-values were also reflected in large deviations from the recommended SA by CARC (2001). On average, animals in the nose were allowed 44.0 ± 2.0% more space, in the belly 7.5 ± 2.1% less space, in the deck 5.5 ± 2.4% less space, in the back 3.9 ± 2.0 more space, and in the doghouse 60.4 ± 2.8% more space than recommended by CARC (2001). Altogether, these results indicate that the compartment should be the observational unit for analysis rather than the trailer when assessing the effects of loading density on animal welfare (e.g., mortality) or meat quality (e.g., dark cutters) outcomes because of

![Figure 1. Overall space allowance (SA) and allometric coefficient (k-value) observed across cattle categories and compartments of the trailer during commercial long haul transport of cattle in Alberta.](image)
the large differences among them. Results on loading density will therefore be presented for each compartment separately throughout the present paper. However, the cattle transport industry may be more interested in total weight and number of animals loaded per trailer for management and planning purposes, although further research is needed to understand and improve weight distribution and therefore SA among compartments.

In addition to differences among compartments of the trailer, SA differed among cattle categories as expected because of the relationship with BW (data not shown). Thus, the \( k \)-value was also different among cattle categories \( (P < 0.001; \text{Table 4}) \) as calves were consistently transported at the lowest SA, followed by feeders, and fat and cull cattle having the greatest SA in both Canada and the United States (Table 4). Such differences were particularly evident in those compartments where animals are placed at the greatest density, (i.e. belly, deck, and doghouse), and it should be related to the aforementioned limit on axle weight for heavier animals. The \( k \)-value indicates SA across all ranges of BW and a value of 0.020 has been suggested as appropriate for cattle transport (SCAHAW, 2002; Petherick and Phillips 2009). Research linked to the survey presented herein indicated that \( k \)-values \(<0.015 \) and \( >0.035 \) are associated with sharp increases in the likelihood of cattle to die during commercial transport, particularly in the deck and belly where less space per animal is allowed (González et al., 2012c). This agrees with findings of Eldridge and Winfield (1988) who reported that medium SA with \( k \)-value of around 0.02 were preferred, based on lower score and frequency of bruising.

The smaller \( k \)-value in feeders and calves was also reflected in SA between 6.8 and 15.4% below the values recommended by CARC (2001), on average (Table 5). Within Canada, all cattle categories were transported with less space than recommended in the deck and belly except for fat cattle in the deck. In contrast, all cattle categories in the back, nose, and doghouse were allowed more space than recommended (Table 5). In addition, the extent of over- or under-stocking differed among cattle categories. Thus, calves were allowed the least space (or loaded at the greatest density), feeders intermediate,

**Table 4.** Allometric coefficients \((k = \text{space allowance} / \text{BW}^{0.6667})\) observed during commercial long haul transport of cattle in North America (>400 km)

<table>
<thead>
<tr>
<th>Item</th>
<th>Fat</th>
<th>Calf</th>
<th>Cull</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SEM</td>
<td>No.</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>0.032 w</td>
<td>0.0021</td>
<td>4,238</td>
</tr>
<tr>
<td>Deck</td>
<td>0.019 x</td>
<td>0.0002</td>
<td>4,175</td>
</tr>
<tr>
<td>Belly</td>
<td>0.018 x</td>
<td>0.0002</td>
<td>4,430</td>
</tr>
<tr>
<td>Back</td>
<td>0.022 x</td>
<td>0.0004</td>
<td>4,431</td>
</tr>
<tr>
<td>Doghouse</td>
<td>0.038 x</td>
<td>0.0012</td>
<td>2,303</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>0.032 x</td>
<td>0.0018</td>
<td>4,507</td>
</tr>
<tr>
<td>Deck</td>
<td>0.020 x</td>
<td>0.0005</td>
<td>4,266</td>
</tr>
<tr>
<td>Belly</td>
<td>0.018 w</td>
<td>0.0001</td>
<td>4,528</td>
</tr>
<tr>
<td>Back</td>
<td>0.021 x</td>
<td>0.0004</td>
<td>4,532</td>
</tr>
<tr>
<td>Doghouse</td>
<td>0.035 w</td>
<td>0.0017</td>
<td>2,825</td>
</tr>
</tbody>
</table>

\( ^w-z \) Within a row, means without a common superscript differ \((P < 0.05)\).

\(^1\) Allometric coefficient \((k)\) was calculated for each journey from the formulae space allowance = \( k \text{ BW}^{0.6667} \).

\(^2\) The effect of cattle category was significant for all variables at \( P < 0.001 \).

**Table 5.** Percentage of deviation from the recommended space allowance in the Canadian Code of Practice observed during commercial long haul transport of each cattle category (≥400 km)

<table>
<thead>
<tr>
<th>Item</th>
<th>Fat</th>
<th>Calf</th>
<th>Cull</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SEM</td>
<td>P</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>57.5 w</td>
<td>18.4 x</td>
<td>55.6 w</td>
</tr>
<tr>
<td>Deck</td>
<td>6.6 w</td>
<td>-6.8 x</td>
<td>-10.5 y</td>
</tr>
<tr>
<td>Belly</td>
<td>-9.8 w</td>
<td>-12.7 x</td>
<td>-15.4 y</td>
</tr>
<tr>
<td>Back</td>
<td>11.4 w</td>
<td>0.9 y</td>
<td>2.5 y</td>
</tr>
<tr>
<td>Doghouse</td>
<td>70.4 w</td>
<td>28.8 x</td>
<td>6.9 x</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>60.1 w</td>
<td>15.2 x</td>
<td>18.5 x</td>
</tr>
<tr>
<td>Deck</td>
<td>-6.4 w</td>
<td>-13.5 x</td>
<td>-18.2 y</td>
</tr>
<tr>
<td>Belly</td>
<td>-9.3 w</td>
<td>-13.4 x</td>
<td>-15.3 y</td>
</tr>
<tr>
<td>Back</td>
<td>11.7 w</td>
<td>7.8 x</td>
<td>10.7 w</td>
</tr>
<tr>
<td>Doghouse</td>
<td>109.6 w</td>
<td>60.7 x</td>
<td>41.9 x</td>
</tr>
</tbody>
</table>

\( ^w-z \) Within a row, means without a common superscript differ \((P \leq 0.05)\).

\(^1\) Negative values indicate that space allowance was less than recommended, whereas positive values allowed more space than recommended by CARC (2001).

\(^2\) The greatest SEM of all cattle categories is presented.
and fat and cull cattle the most space compared with the recommendations for all compartments.

Other factors can also have an influence on SA under commercial conditions, in addition to the number of axles in the vehicle and cattle category. For instance, CARC (2001) recommends increasing SA at high ambient temperatures and during longer journeys. However, we found no clear evidence that the industry allowed more space at greater ambient temperatures \( (P > 0.10; \text{data not shown}) \), whereas up to 6% more space, on average, was allowed on longer journeys transporting fat cattle in the belly (cattle category \( \times \) transport time \( P = 0.02 \)). The values were 0.0174, 0.0178, 0.0182, and 0.0185 \( \pm \) 0.0003 for <10, 10 to 20, 20 to 30 and >30 h of total transport time \( (k\)-values of 0.0174 and 0.0178 were smaller than 0.0182 \( (P < 0.01) \), and 0 to 10 smaller than 0.0185 at \( P = 0.05 \)). This indicates that the industry is considering the recommendations and trying to maintain better transport conditions when longer transport times are expected. It is important to note that the belly was the compartment with the greatest number of animals loaded and the least space allowed. Therefore, the belly might be the compartment where “special” management should be targeted to ensure the welfare of animals during long distance transport. Ambient temperature and transport time had no other effect \( (P > 0.05) \) on SA for other compartments of the trailer or other cattle categories (data not shown).

**Fitting of Power Formulas to the Observed Space Allowance**

Parameter estimates from fitting observed SA to both the constrained \( (SA = k \ BW^{0.6667}) \) and unconstrained \( (SA = k \ BW^b) \) power formulae are shown in Table 6. Power formulae with BW as the independent variable are widely used to study and recommend SA for cattle in several countries because the relationship between body volume and BW is not linear but rather increases with \( BW^{2/3} \) (SCAHAW, 2002; Petherick and Phillips, 2009). Therefore, these formulae are useful for comparisons among recommendations, regulations, and industries practices, especially between different countries. Petherick and Phillips (2009) suggested fitting the constrained model to compare and explain research findings on animal welfare outcomes during transportation. However, the unconstrained power formula in our study was also fitted to obtain the “best model” which is suitable for comparing observed data after plotting with Canadian recommendations (CARC, 2001).

The best fitting for both constrained and unconstrained models was obtained in the belly, followed by the deck, back, doghouse, and finally in the nose, as reflected in the \( R^2 \) (Table 6). This was a result of less dispersion of data points or variability of SA registered which indicates that the consistency in the industry also differs among compartments, being most consistent in the belly and least in the nose and doghouse (Figure 2). Petherick and Phillips (2009) suggested that \( k\)-values around 0.020 may optimize the ability of animals to gain physical support from each other and reduce falls, struggles, and excessive displacement of animals. In contrast, \( k\)-values of 0.015 may reduce animal welfare because overlapping during standing reduces footing and increases falls (Petherick and Phillips, 2009) and leads to a sharp increase in the likelihood of animals dying (González et al., 2012c). Therefore, \( k\)-values fitted to all compartments indicate adequate SA on average; however, animals in the belly had slightly less space, approaching the lower threshold below which animal welfare could be compromised. The frequency of journeys that transported animals in the belly at densities with a calculated \( k\)-value equal to or less than

<table>
<thead>
<tr>
<th>Item</th>
<th>Nose</th>
<th>Belly</th>
<th>Deck</th>
<th>Back</th>
<th>Doghouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>5,349</td>
<td>5,332</td>
<td>5,040</td>
<td>5,376</td>
<td>3,433</td>
</tr>
<tr>
<td>Constrained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(k) (\pm) SE</td>
<td>0.030±0.007</td>
<td>0.018±0.0007</td>
<td>0.020±0.002</td>
<td>0.021±0.002</td>
<td>0.038±0.009</td>
</tr>
<tr>
<td>(b) (\pm) SE</td>
<td>0.667(^2)</td>
<td>0.667(^2)</td>
<td>0.667(^2)</td>
<td>0.667(^2)</td>
<td>0.667(^2)</td>
</tr>
<tr>
<td>(P) (model)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Adj. (R^2)</td>
<td>0.12</td>
<td>0.81</td>
<td>0.50</td>
<td>0.54</td>
<td>0.22</td>
</tr>
<tr>
<td>Unconstrained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(k) (\pm) SE</td>
<td>0.007±0.002</td>
<td>0.007±0.0003</td>
<td>0.003±0.0003</td>
<td>0.010±0.0008</td>
<td>0.0008±0.0002</td>
</tr>
<tr>
<td>(b) (\pm) SE</td>
<td>0.896±0.042</td>
<td>0.818±0.0066</td>
<td>0.935±0.015</td>
<td>0.773±0.012</td>
<td>1.269±0.049</td>
</tr>
<tr>
<td>(P) (model)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Adj. (R^2)</td>
<td>0.13</td>
<td>0.83</td>
<td>0.53</td>
<td>0.55</td>
<td>0.27</td>
</tr>
</tbody>
</table>

\(^1\) Some compartments of the trailers may not have carried animals in them or the exact location of gates was unknown and therefore data from that compartment was not considered for analysis.

\(^2\) No SE is shown because the power parameter was constrained to be 0.667.
0.015 was 20% for calves, 5% for feeders, 0.2% for fat, and 0% for cull cattle (data not shown).

Space allowance during commercial transport of cattle not only depends on the BW of the animals (cattle category) and compartment but also on the number of axles in the vehicle. In this sense, k-value showed a significant trailer × tractor axle interaction for all compartments but the nose and doghouse during travels within Canada and nose and deck during travels within the United States (\( P \leq 0.02 \); Table 7). The number of axles in the trailer or the tractor did not affect SA in the belly in either country (\( P \geq 0.06 \)). The largest space in the deck (\( P < 0.001 \)) and back (\( P < 0.001 \)) was given to animals in tri-axle trailers pulled by push tractors in Canada. In Canada, more space was given to cattle in the nose and doghouse of vehicles with quad-compared with tri-axle trailers and in tandem compared with push tractors (Table 7). Interestingly, in Canada the largest space allowed to cattle in the deck of tri-axle trailers pulled by push tractors did not exist once the load was redistributed to travel in the United States (\( P > 0.10 \); Table 7). In addition, the opposite was true for animals in the doghouse whose SA increased 2-fold after crossing the border from Canada to the United States (Figure 2A). However, this was not the case in quad-axle trailers in which the opposite trend seemed to occur as quad-trailers pulled by tandem tractors had greater SA in the deck and lower in the doghouse after crossing the border (Table 7). These results are a consequence of the need to redistribute animals among compartments to comply with axle weight regulations in each country. Thus, drivers with tri-axle trailers move animals from the doghouse to the deck, whereas the opposite is done in quad-axle trailers pulled by tandem tractors as lowering the fourth axle allows transferring weight towards the back.

In addition to the effects of the number of axles of the vehicle and compartments, there were also interactions with the cattle category being transported. For instance, the industry consistently overloads [according to the CARC (2001) recommendations] cattle in the belly regardless of the number of axles in the trailer or cattle category (Figure 3A). However, the extent of “overloading” compared with the recommendations was greater in feeders transported in quad-compared with tri-axle trailers (\( P < 0.05 \); Figure 3B). A similar trend was found in the deck, but fat cattle were allowed over 20% more space than recommended when transported in tri-axle trailers (Figure 3B). This may be because these compartments are slightly smaller in quad-axle compared with tri-axle trailers, whereas more weight can be transported in the former. This is also reflected in Figure 2A of the belly which shows that the unconstrained fitted broken line is below the recommendations (solid line) throughout all ranges of BW. In contrast, Figure 2B of the deck shows that the fitted broken line is below the recommendations for light animals but above for animals heavier than 550 kg. Nevertheless, there were widespread data points for animals heavier than 550 kg which also reduced the coefficient of determination (Table 7). Animals in the back were transported close to CARC (2001) recommendations with slightly more space (Figure 2C), whereas those in the nose and doghouse were consistently transported at much greater and variable space than recommended (Figure 2D and 2E), which resulted in a large reduction in the coefficients of determination (Table 6). Larger SA were reported when only 1 or 2 animals were placed in these compartments. Interestingly, data from the present survey also found that animals transported at SA greater than 0.035 of k-value had a greater likelihood of dying, although this was also true when cattle in the deck were given a similar amount of space (González et al., 2012c).

### Table 7. Space allowance as measured by the allometric coefficient (\( k = \text{space allowance} / \text{BW}^{0.6667} \)) in vehicles having either a quad- or tri-axle trailer pulled by either a push- or tandem-axle tractor during commercial long haul transport

<table>
<thead>
<tr>
<th>Item</th>
<th>Quad-axle trailers</th>
<th>Tri-axle trailers</th>
<th>( P )-value</th>
<th>( \text{SEM}^1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Push</td>
<td>Tandem</td>
<td>Push</td>
<td>Tandem</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>0.0293</td>
<td>0.0355</td>
<td>0.0203</td>
<td>0.0303</td>
</tr>
<tr>
<td>Deck</td>
<td>0.0186</td>
<td>0.0180</td>
<td>0.0263</td>
<td>0.0189</td>
</tr>
<tr>
<td>Belly</td>
<td>0.0179</td>
<td>0.0177</td>
<td>0.0172</td>
<td>0.0179</td>
</tr>
<tr>
<td>Back</td>
<td>0.0196</td>
<td>0.0197</td>
<td>0.0245</td>
<td>0.0213</td>
</tr>
<tr>
<td>Doghouse</td>
<td>0.0354</td>
<td>0.0382</td>
<td>0.0222</td>
<td>0.0249</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nose</td>
<td>0.0266</td>
<td>0.0395</td>
<td>0.0231</td>
<td>0.0312</td>
</tr>
<tr>
<td>Deck</td>
<td>0.0185</td>
<td>0.0190</td>
<td>0.0176</td>
<td>0.0183</td>
</tr>
<tr>
<td>Belly</td>
<td>0.0180</td>
<td>0.0180</td>
<td>0.0173</td>
<td>0.0180</td>
</tr>
<tr>
<td>Back</td>
<td>0.0197</td>
<td>0.0194</td>
<td>0.0252</td>
<td>0.0227</td>
</tr>
<tr>
<td>Doghouse</td>
<td>0.0357</td>
<td>0.0316</td>
<td>0.0533</td>
<td>0.0333</td>
</tr>
</tbody>
</table>

\(^{2}\) Within a row, means without a common superscript differ (\( P \leq 0.05 \)).
This value was found in only a few extreme cases in the deck but frequently in the nose and doghouse. For instance, $k$-value showed a range from 0.011 to 0.156 (González et al., 2012a) and DRSA from −47% below to 694% above the recommendations (data not shown).

The formulae presented by Randall (1993) used in the New Zealand code of practice ($k = 0.010$ and $b = 0.78$) as well as the Farm Animal Welfare Council (FAWC, 1991) formulae recommended in the European Union (SCAHAW, 2002; $k = 0.021$ and $b = 0.67$) result in similar SA than those recommended by CARC (2001). However, both formulae allow about 5% more space compared with CARC (2001) for heavy animals, whereas the FAWC (1991) allows 23% more space for animals weighing 100 kg and 12% more for 400-kg animals. The Australian recommendations (CSIRO, 2002) are also
very similar to the Canadian, whereas the United States recommendations are more generous allowing more space (USDA, 1997). However, to the best knowledge of the authors this is the first study to report commercial SA and compliance with recommendations during cattle transport. It would be important to assess commercial SA, factors affecting it, and degree of compliance with such recommendations in other countries to assess the feasibility of recommended or regulated values. More recently, Petherick and Phillips (2009) recommended SA during short-haul transport with \( k = 0.02 \) and \( b = 0.66 \). These results in SA being 6.5% greater for animals weighing 200 kg and 6.5% lower for 1,000-kg animals compared with CARC (2001). It was also recommended that SA should be increased by 50% \( (k = 0.027) \) to allow animals to lie down (FAWC, 1991; Petherick and Phillips 2009), which normally occurs in younger stock during transport (Kent and Ewbank, 1986). However, too much space could potentially increase falls and struggles to maintain balance if animals do not lie down.

Deviation from the recommended SA in the belly was similar among cattle categories if transported in tri-axle trailers \( (P > 0.10) \). However, calves and feeders were allowed less space compared with fat and cull cattle when transported in quad-axle trailers \( (P < 0.05) \); Figure 3A). In addition, feeders were transported at decreased SA in quad-compared with tri-axle trailers, but no differences among trailer types were observed for the other categories (Figure 3A). All cattle categories in the deck were loaded at similar deviation from recommended SA within quad-axle trailers \( (P > 0.10) \); Figure 3B). However, fat cattle were allowed 21.3% more space and calves 11.0% and feeders 2.3% less space than recommended when loaded in tri-axle trailers \( (P < 0.05) \). In addition, fat cattle in the deck were allowed 21.3% more space in tri-axle trailers but 6.1% less space than recommended in quad-axle trailers \( (P < 0.05) \); Figure 3B).

Differences in SA among cattle categories, compartments, and tractor-trailer combinations are a result of the interplay between animal BW, size of the compartments, number of axles of the vehicle, and axle weight regulations in each country. The reduced deviations in SA of fat compared with feeder cattle may be due to differences in BW and shape (e.g., length and height). These dictate the BW per unit of body area occupied by the animals \( (kg/m^2) \) which is greater for fat cattle, resulting in greater loading densities \( (kg/m^2) \). This indicates that fat cattle reach the total axle weight limit before the recommended limits for SA. Alternatively, this may be a result of the industry trying to avoid bruising and consequently economic losses in a high value category (fat cattle). In contrast, calves have a decreased BW per unit of body area, and the limit regulated on axle weight is not reached unless an extremely large number of calves are loaded and low SA is given to the animals. However, more weight could still be added to loads of feeder and calves, which indicates that the cattle industry is respecting “its own” SA standards regardless of axle-weight regulations. Finally, it is important to highlight that little is known about the effects varying loading densities may have on animal welfare outcomes except for the few cited studies. Science-based information is too limited to be able to quantify and understand the impact of deviations from these recommendations on animal welfare and further research in this area is encouraged.

In conclusion, concerns regarding low SA during commercial transport of cattle in North America might focus on animals transported in the belly and the deck. There should be even more concern with feeders and calves because there is room to fit more animals because limits on axle weight are not reached except at very high loading densities. Also, the greater the number of axles there are on a transport vehicle (e.g., quad-axle trailers), the more weight can be loaded, which may lead to some extreme...

Figure 3. Percentage of deviation from recommended space allowance (DRSA) from the Canadian Code of Practice (CARC 2001) in the deck and the belly compartments of the trailers during long haul transport of cattle in Alberta (within Canada). a,b within a cattle category, means with different superscript differ among trailer type \( (P < 0.05) \). x, y within trailer type, means with different superscript differ among cattle categories \( (P < 0.05) \).
situations with very low SA. In contrast, too much SA may be a concern for fat and cull cattle, particularly if transported in the nose and the doghouse and in tri-axle trailers. Improving weight distribution among compartments to increase SA in the belly and deck and reduce it in the nose and doghouse may improve economics and animal welfare, particularly in feeder calves. It should be noted that loading density is 1 factor among many that should be considered when assessing animal well-being during animal transport. Additional factors should include transport duration, ventilation, trailer design, weather conditions, and presence of horns among others. These factors in combination with loading density need to be assessed systematically to help determine optimal conditions for cattle during transport. The study presented herein was supported by the Alberta cattle industry and Government organizations to study the complexity of factors affecting loading density during commercial transport. Objectives also included obtaining benchmark information about the current status of the transport industry and relationship with other economic and welfare outcomes such as shrinkage and mortality reported in companion papers. This proactive approach provided a framework and example that may be useful for other livestock industries, regions, and countries around the world to gain an understanding of the commercial practices and implications within these regions. Collaboration and support from the industry is critical and should therefore be seriously engaged.

LITERATURE CITED


