General enquiries on this form should be made to:
Defra, Science Directorate, Management Support and Finance Team,
Telephone No. 020 7238 1612
E-mail: research.competitions@defra.gsi.gov.uk

SID 5 Research Project Final Report

- **Note**
  In line with the Freedom of Information Act 2000, Defra aims to place the results of its completed research projects in the public domain wherever possible. The SID 5 (Research Project Final Report) is designed to capture the information on the results and outputs of Defra-funded research in a format that is easily publishable through the Defra website. A SID 5 must be completed for all projects.
- This form is in Word format and the boxes may be expanded or reduced, as appropriate.
- **ACCESS TO INFORMATION**
  The information collected on this form will be stored electronically and may be sent to any part of Defra, or to individual researchers or organisations outside Defra for the purposes of reviewing the project. Defra may also disclose the information to any outside organisation acting as an agent authorised by Defra to process final research reports on its behalf. Defra intends to publish this form on its website, unless there are strong reasons not to, which fully comply with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.
  Defra may be required to release information, including personal data and commercial information, on request under the Environmental Information Regulations or the Freedom of Information Act 2000. However, Defra will not permit any unwarranted breach of confidentiality or act in contravention of its obligations under the Data Protection Act 1998. Defra or its appointed agents may use the name, address or other details on your form to contact you in connection with occasional customer research aimed at improving the processes through which Defra works with its contractors.

Project identification

1. Defra Project code: AWO 935
2. Project title: Study to assess the best spacing strategy for the welfare of sheep during transit
3. Contractor organisation(s):
   University of Oxford
   Animal Behaviour Research Group
   Department of Zoology
   South Parks Road
   Oxford
   OX1 3PS
4. Total Defra project costs (agreed fixed price): £ 129,902
5. Project: start date .... 01 May 2005
   end date .... 30 April 2007

6. It is Defra's intention to publish this form.
   Please confirm your agreement to do so...YES ☒ NO ☐

   (a) When preparing SID 5s contractors should bear in mind that Defra intends that they be made public. They should be written in a clear and concise manner and represent a full account of the research project which someone not closely associated with the project can follow.
   Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the SID 5 can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.
   In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

   (b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

There are two opposing hypotheses relating to how sheep brace themselves in transit. The first is that they brace against each other for support during vehicle motion and so are less likely to fall or lose balance when tightly packed than loosely packed; the second is that they brace themselves independently during vehicle motion, and so are less likely to fall or lose balance when loosely packed than tightly packed. Understanding the spacing strategy adopted by sheep in transit will inform policy with regards to acceptable space allowances during transport.

In order to study the spacing strategy adopted by sheep in transit and the effectiveness of that strategy, 4 categories of sheep were transported at 5 space allowances in 2 pens of a commercial rigid lorry over 40 standard journeys of 6 hours.

Sheep categories were shorn ewes (average weight 67.6kg) and lambs (32.5kg) and fleeced ewes (65.0kg) and lambs (40.5kg). The sheep were taken from an 850 ewe commercial flock in Oxfordshire and were naïve to commercial transport. Space allowance ranged from generous (>1.0m^2/animal) to tight (0.2m^2/animal for shorn lambs to 0.4m^2/animal for fleeced ewes), and was categorised according to decreasing space per animal as control, high, medium high, medium low, and low space. Actual space allowance per animal (A) was calculated from the equation $A=kW^{0.67}$ where W equals the average weight of sheep in the pen and k is an empirical constant adjusted for sheep that predominantly stand in transit (0.021), sheep that need to lie in transit (0.026), and sheep that need feed and water on board (0.037). Minimum requirements were taken from legislation and fleeced sheep were given an additional 25% space. The level of replication was 4. Real time video records were made of each journey and analysed for the incidence of fall, slip, and loss of balance, and the percent of dependent and independent sheep, inter-animal spacing, and free pen space.

The incidence of fall, slip and loss of balance was highest in the low and medium low space categories. There was no incidences of fall in the control and high space groups for shorn ewes whilst there were 3.5 incidents/hr in the low space; slip increased from 42 incidents /hr in the control group for shorn lambs to 202 incidents/hr in the low group, and loss of balance increased from 3.2 incidents/hr for shorn ewes in the control group to 19.9 incidents/hr in the low. Significant effects of space were maintained when the rate of events were considered per animal per hour.

Given sufficient space, sheep stood independent of their pen-mates, for e.g. 68% of fleeced ewes were not touching their pen-mates in the control group compared to only 17% in the low space. This independent stance was supported by a negative coefficient of variation residual for the observed–expected values of inter-animal distance (at the rump). As expected, free pen space reduced with decreasing space allowance given to the sheep, so that shorn lambs in the low space had only 4% free pen space compared to 25% in the high space and 76% in the control.

The best spacing strategy for sheep is the strategy they chose to adopt if given the opportunity and is the one that is most effective in terms of preventing falls, slips, loss of balance etc. An independent strategy has therefore been shown to be their best strategy. The low and medium low space provision (taken from minimum requirements and the first equation) did not allow the sheep to adopt an effective strategy against the motion of the vehicle, so are considered inappropriate. Space allowances provided by the second equation ($A=0.026W^{0.67}$) and above were better suited to the effective independent spacing strategy adopted by sheep in transit.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

Aims:

The project tested the two opposing hypotheses relating to space allowance for sheep in transit:

Hypothesis 1. That sheep brace against each other for support during vehicle motion and are less likely to fall or lose balance under a variety of ride conditions when tightly packed than loosely packed

Hypothesis 2. That sheep brace themselves independently during vehicle motion, and are less likely to fall or lose balance under a variety of ride conditions when loosely packed than tightly packed

Objectives:

01. To study the effects of five space allowances (tight to generous) on the incidence of fall, slip, and loss of balance, of four categories of sheep in transit

02. To study the effects of five space allowances (tight to generous) on the percent of dependent and independent sheep, inter-animal spacing, and free pen space, of four categories of sheep in transit

03. To recommend the best spacing strategy for sheep in transit

All objectives have been successful met in full.

Method:

Four categories of sheep were transported at 5 space allowances in 2 pens of a commercial rigid lorry over 40 standard journeys of 6 hours.

Animals: Sheep categories were shorn lambs (SL), fleeced lambs (FL), shorn ewes (SE), and fleeced ewes (FE). Sheep were sourced from the FAI commercial flock of 850 lowland ewes (breeds: mule ewes, Hartline and Roussin) producing fat lamb (Suffolk crosses and Coopworth) and were naïve to transport in a commercial lorry. They were individually weighed the day before transport, and accepted for transport if within +/- 5kg of our target weight for each category. Sheep weights did fluctuate however over the course of the experiment, so that at times target weight could not be met; space allowance and numbers of sheep per pen were then recalculated according to the treatment equation (see below).

Treatment groups: Space allowances of low (L), medium low (ML), medium high (MH), and high (H) were derived from the EU Directive (1995) and Equations 1-3 of the EU Scientific Committee on Animal Health and Welfare (2002) given below; a control group allowing >1.0m^2 was also included, and fleeced sheep were given an additional 25% space.

Equation 1 $A = 0.021w^{0.67}$ for sheep standing during transport
Equation 2 $A = 0.026w^{0.67}$ for sheep which may need to lie down
Equation 3 $A = 0.037w^{0.67}$ for journeys which require sheep to be fed and watered on the vehicle during transit

Each space allowance was replicated 4 times per sheep category.

Transport: The front (3.06 x 2.2m, 6.39m^2) and middle pen (2.74m x 2.2m, 6.03m^2) of the lower deck of a two deck rigid lorry, driven by the same haulier, were used through out the experiment. Treatment and animal category were randomly allocated to pen and journey (in accordance with season/availability of sheep category). A 6 hour standard journey (inclusive of a mandatory ¾ hour driver rest after 4.5 hours) on a pre-determined route with a mix of A roads, motorway and B roads (detailed in Appendix 1) was used.

Prior to transit, a wide angle lens CCTV camera was positioned in the roof above the centre of each pen ensuring a clear view of the whole pen. Real time video records (Sanyo TLS-4024P) were made of each journey and a detailed log of the journey recorded (road type, incidents of braking, cornering etc). Temperature and humidity were recorded hourly via 2 TinyTag dataloggers per pen, positioned on the side walls at sheep body height.

Objective 01. To study the effects of five space allowances (tight to generous) on the incidence of fall, slip, and loss of balance, of four categories of sheep in transit

Continuous sampling of behaviour was conducted from video and the following recorded: the number of incidents of loss of balance, fall, slip, knee drop, ride, and trample, maximum percent lie down (voluntarily and forced), head butt and walk (defined in Appendix 2), and the time taken to stand after falling or being forced to the pen floor.

Statistical analysis: Behaviour was expressed as a) the number of incidents of each event per hour and b) incidents per animal per hour, over the whole journey, and that on A, and B roads, and motorways, and during the first, second and third stages of the journey. The pen was the statistical unit. The effects of space allowance, road type and their interaction were examined using Analysis of Variance repeated measure (for road type) with appropriate transformations for normality of data where required. Significant correlations for temperature and relative humidity (RH) were included as covariates in the model. Post hoc Tukey pair wise comparisons were conducted to determine main factor significant differences. The analysis was then repeated with journey stage as the repeated measure.

The 4 assumptions of the statistical test were upheld, i.e. those of i.. Independence, ii. Homogeneity of variance, iii. Normality of error, and iv. Linearity/additivity. i. Independence was maintained as the pen was the statistical unit of replication, and where multiple observations per pen were tested (events/hr by road type, or journey stage) a repeated measures analysis was conducted. ii. to iv. were tested by plotting standardised residuals against fitted values, histogram of residuals, and normal probability plots of residuals after the model had been fitted. Appropriate transformations of the data were performed where needed (usually log, arcsin(square root) or square root) and interactions fitted (space allowance*road type or space allowance*journey stage) to assist with non linearity. (Grafen and Hails, 2002)

Objective 02. To study the effects of five space allowances (tight to generous) on the percent of dependent and independent sheep, inter-animal spacing, and free pen space, of four categories of sheep in transit

50 video frames per journey (10 random samples per hour) were captured (Dazzle digital video creator, Pinnacle Studio), and the X (head), and Y (rump) coordinates of each sheep recorded in software units with each mouse click (unpublished software). The inter-animal spacing for the three points was then calculated and treated in line with (Febrer et al 2006). Since space allowance affects the mean and variation of inter-animal distances, the coefficient of variation (CV i.e. standard deviation divided by the mean of all pairs of inter-animal distances) was used. For each image 1000 simulations of indifferent sheep were performed to calculate the expected CV if the sheep were distributed at random within that image. The CV residual (observed – expected CV) was given for the head and rump positions. A positive CV residual suggests social attraction (dependence) and contact (CV residual greater than expected for indifferent sheep), whilst a negative CV residual suggests social aversion or independence (CV residual less than that expected for indifferent sheep).

In addition, the number of dependent (touching other sheep) and independent sheep in a stand or lie position were recorded for 15 frames (3 random samples per hour), and the free pen space calculated for 4 frames per journey (randomly selected through out the journey). For the latter, the outline of all unoccupied floor space in the pen was outlined (Image J software) and measured in pixels; this was divided by the total pen area in pixels to calculate the percent free pen space.

Statistical analysis: Data analysis (variables: CV residual for a) head and b) rump positions, percent stand or lie in-contact and independent and percent free pen space) followed that outlined above in Objective 01.

03. To recommend the best spacing strategy for sheep in transit

The hypothesis that holds true for most physical and spacing parameters will be deemed the most appropriate. The range of space allowances under which the hypothesis holds will be given for each category of sheep, and the appropriate terminology and definition of that space investigated.

Results & Discussion:

Actual space allowances and weights of sheep used in the experiment are given below in Table 1.

Table 1. Average space allowance, number of sheep per pen and sheep weight, by sheep category and treatment. The equation used to calculate each space allowance is given for shorn sheep; fleeced sheep were given an additional 25% space and minimum (MIN) and intermediate (INT) allowances are noted.

Sheep Category	Weight (range)	Control (n)	High (n)	Medium High (n)	Medium Low (n)	Low (n)
Fleeced Ewe	65.0 (54.8-76.4)	1.56 (4)	0.78 (8)	0.56 (11.3)	0.42 (15)	0.4 (15.5)
Shorn Ewe	67.6 (57.8-74.5)	1.56 (4)	0.69 (9) (E3)	0.44 (14.3) (E2)	0.35 (18.3) (E1)	0.30 (20.5) MIN
Fleeced Lamb	40.5 (39.2-43.5)	1.04 (6)	0.54 (11.5)	0.46 (13.5)	0.40 (15.5)	0.32 (19.8)
Shorn Lamb	32.5 (27.7-41.0)	1.04 (6)	0.39 (16) (E3)	0.30 (20.3) (INT)	0.27 (23.5) (E2)	0.23 (27.8) (E1/MIN)

Objective 01. To study the effects of five space allowances (tight to generous) on the incidence of fall, slip, and loss of balance of four categories of sheep in transit

Results of the data analysis for this objective are given in Appendix 3. Table 3.1 details the effects of sheep category, whilst Tables 3.2-3.5 detail the effects of all factors by individual sheep category and a) rates of events per hour and b) rates per animal per hour. Significant effects of sheep category, space allowance, road type, journey stage, interactions and covariate effects are summarised below.

Sheep category:

- Loss of balance was greater in SE (9.1 incidents/hr) and least in FL (3.9 incidents/hr).
- Fall was greater in both shorn categories (2.0 and 0.6 incidents/hr for SE and SL respectively compared to ~0.15 for fleeced sheep)
- Ride was least in FE and greatest in SL (0.6 compared to 4.2 incidents/hr)
- Trample was least FE and greatest in SL (0.3 compared to 13.6 incidents/hr)
- Maximum percent lying down voluntarily was least in ewes (~11%), intermediary in FL (51%) and greatest in SL (78%)
- Head butt was least in ewes, particularly SE (1.7 incidents/hr), intermediary in SL (9.8 incidents/hr) and particularly high in FL (20 incidents/hr)
- There was no effect of sheep category on knee-drop, slip (average 123 incidents/hr (range 16.8-312.6)) or walk.

Space category:

- Loss of balance was greatest in the L and ML treatment groups, and is given by sheep category in Figure 1 below.

- There was no incidence of fall in the control treatment for all sheep categories, and fall was greatest in low space for shorn sheep (3.5 and 2.3 incidents/hr for SE and SL respectively). Sheep tended to get up straight away after a fall, however when they were forced to the pen floor by other sheep, they took on average 307 seconds to regain their feet, detailed below in Table 2.

Table 2. Time taken to regain a standing posture (seconds) after being forced to the pen floor, by sheep category.
Figures in parenthesis are minimum-maximum

Space category	Fleeced Ewe	Shorn Ewe	Fleeced Lamb	Shorn Lamb
Medium Low	0	60.0 (33.0-88.0)	172.3 (31.0-447.0)	0
Low	367.5 (35.0-700.0)	174.4 (8.0-1006.0)	34.3 (18.0-46.0)	434.7 (6.0-3560.0)

- There were no incidences of knee drop in the control group for FE. Knee drop was greatest in the L treatment group for FE (1.5 incidents/hr), SE (4.3 incidents/hr) and SL (2.3 incidents/hr).

- Slip was least in the control and H treatments for FE, FL and SL, and control group for SE. Slip was highest in L and ML treatment groups for FE and MH-L treatment for SL, as shown in Figure 2.

Figure 1. The effect of space allowance on loss of balance (rates/hr) by sheep category

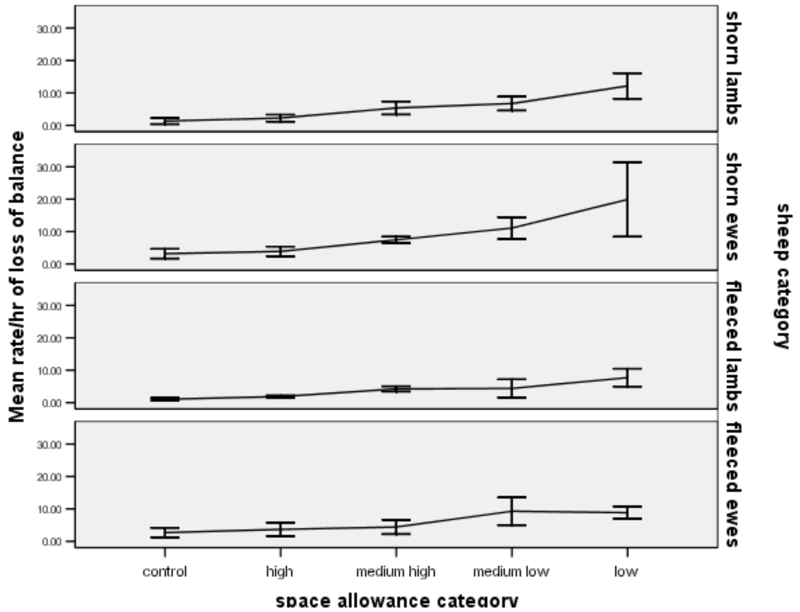
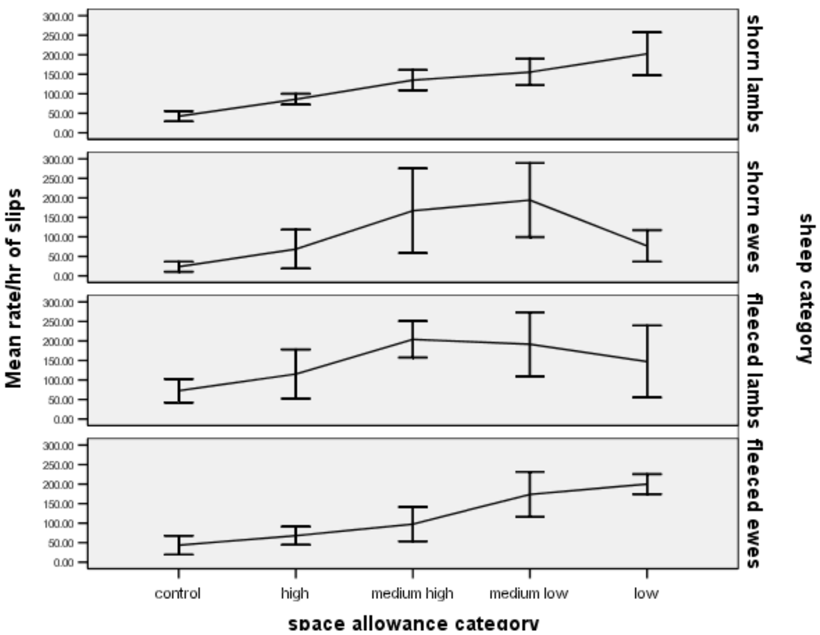


Figure 2. The effect of space allowance on slipping (rates/hr) by sheep category



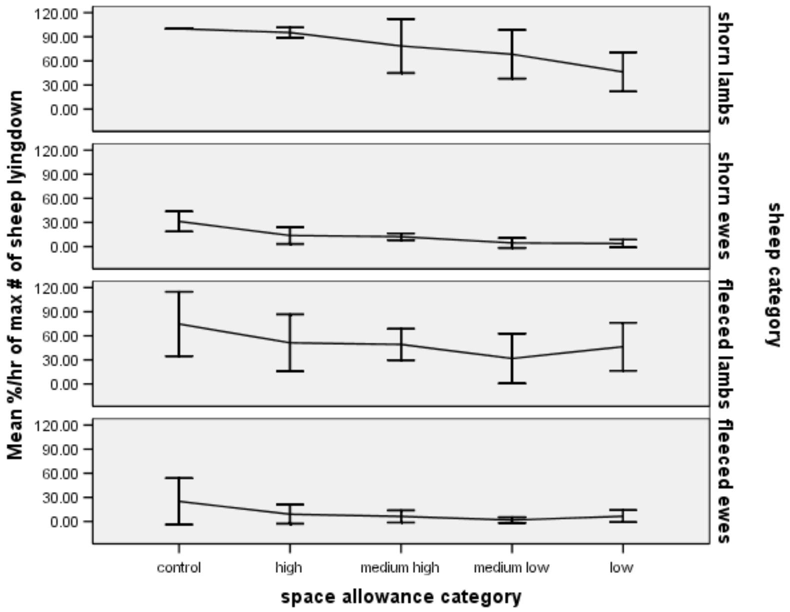
- Ride was highest in the L treatment group for SE (10.5 incidents/hr), FL (3.9 incidents/hr) and SL (14.0 incidents/hr).

- Trample was greatest in the L group for FE (1.5 incidents/hr), and L and ML groups for SE (2.0-3.6 incidents/hr). Trample was intermediary in the in the MH and ML groups for SL (~12 incidents/hr) and greatest in the L group (37.3 incidents/hr). There was no effect of space on trample in FL.

- The maximum percent of sheep lying down was greatest in the control group for SE (31%) and least in the L group for SL (46%), shown in figure 3 below.

- Walking occurred most in the control group for SL (15 incidents/hr) and control and H groups for FE, SE (both ~15 incidents/hr), and FL (~7 incidents/hr).

Figure 3. The effect of space allowance on the maximum percent of sheep lying down during the journey by sheep category



Road Type:

- Loss of balance and slip were greater on B roads than A roads than motorways for all sheep categories, and are shown below in Figures 4 and 5 respectively.

- Fall (for SE, FL), knee drop (for FE, SE), trample (for SE, SL), head butt (for FE, SE), and walk (for FE, SE) were all greater on B roads than A roads than motorways.

- Fall (FE), ride (FL), and trample (FE), and the maximum percent sheep lying down in transit (all categories) were higher on A roads than B roads than motorways.

Figure 4. The effect of road type on loss of balance (rates/hr) by sheep category

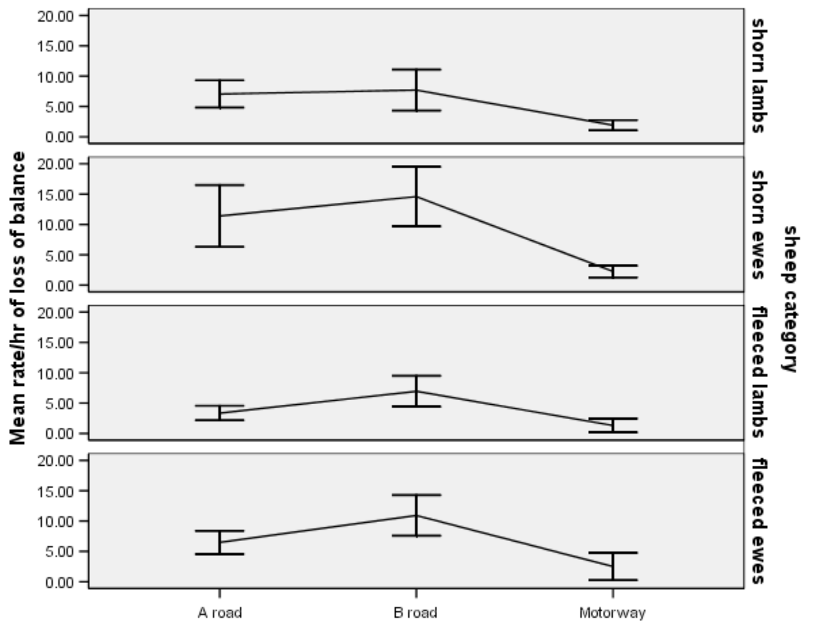
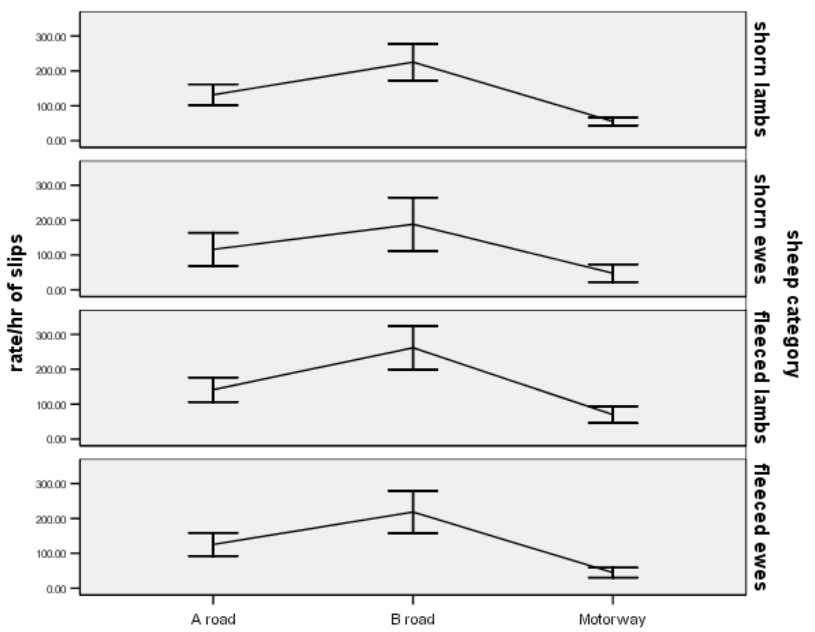


Figure 5. The effect of road type on slip (rates/hr) by sheep category



Stage of journey:

- Loss of balance (for FE, SL), ride (SL) and walk (for SL) were greater on the first than second than third stage of the journey.
- Loss of balance (for SE, FL), knee drop (for SE), slip (all categories), ride (for SE, FL), and head butt (SE) were greater during the second stage than the first than the last stage of the journey.
- Trample (all categories), and the maximum percent lying down (for FE, FL, and SL) were greater in the last stage of the journey than the second than the first stage.

Interactions:

Interactions are detailed in Appendix 3 Tables 3.2-3.5. There was a significant road*space interaction for loss balance (SE, SL), slip (FE, SL), ride (FL), head butt (SE), and walk (SE, SL). There was a significant journey stage*space interaction for ride (SE, SL) and trample (FE, SE), and a road*temperature interaction for FL.

Covariates:

Fleeced lambs slipped less and lay down more with increasing pen temperature, whilst SL walked more at higher temperatures.

Objective 02. To study the effects of five space allowances (tight to generous) on the ratio of dependent to independent sheep, inter-animal spacing, and free pen space, of four categories of sheep in transit

Results of the data analysis for this objective are given in Appendix 4. Table 4.1 details the effects of sheep category, whilst Tables 4.2-4.5 detail the effects of all factors by individual sheep category. Significant effects of sheep category, space allowance, road type, journey stage, interactions and covariate effects are summarised below.

Sheep Category

- CV residuals were small and negative at the rump position for FL, SL and FE (-0.002 to -0.011), but were significantly different from the residual for SE which was slightly positive (0.002).
- CV residuals at the head for SE were strongly positive and much different from those of the other sheep categories (0.172 compared to ~0)

- Lambs lay down significantly more than ewes and no ewes lay in contact with their pen mates, whereas 14% of SL and 7% of FL lay in contact with their pen mates. 14 and 10% of SL and FL respectively lay independently compared to only 1% of the ewes.

- There was no effect of sheep category on free pen space.

Space category

- For FE, CV residual at the rump was more negative in the control group (-0.02) and was positive in the H (0.01) and L groups (0.003).
- For SE, CV residual at the head was positive in all space categories and significantly more so in the control group (0.292 compared to 0.123 - 0.172). Plots of CV residual at the rump and head by space category are given in Figures 6 and 7 below.

Figure 6. Spatial distribution (based on CV residuals of rump positions) in relation to space allowance category

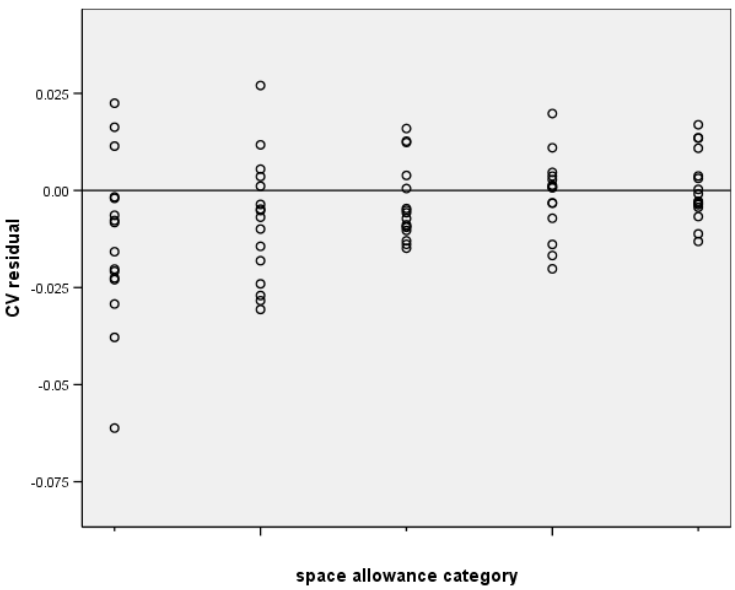
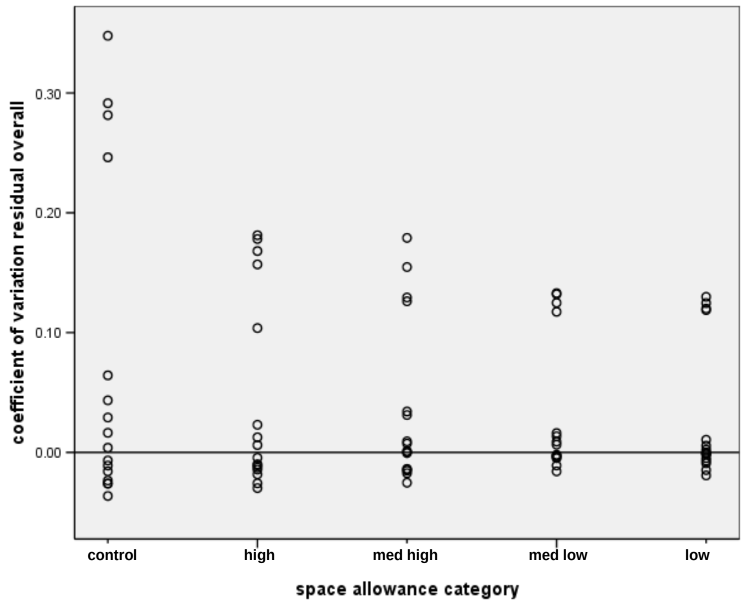
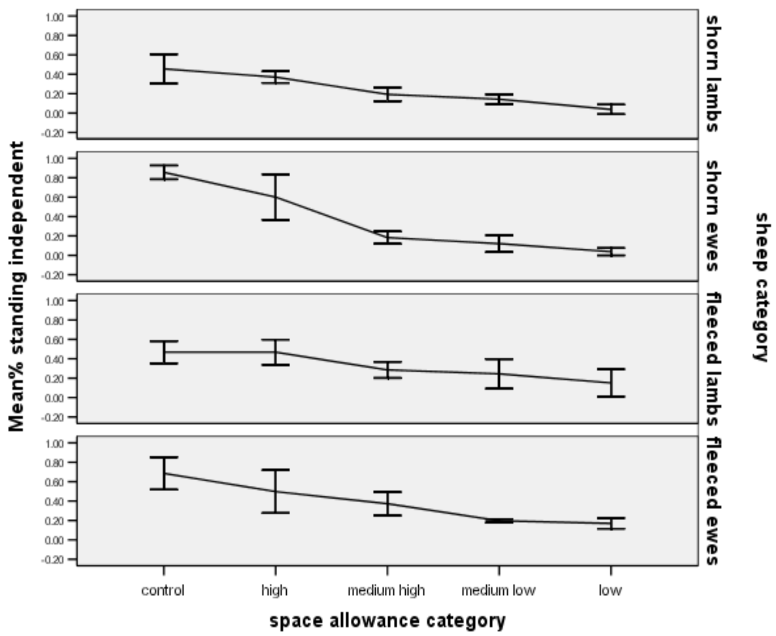


Figure 7 Spatial distribution (based on CV residuals of rump positions) in relation to space allowance category



- Stand in-contact with other sheep was least in the control and H groups for all sheep categories; stand independently was consequently least in L, ML and MH groups.
- Stand in-contact ranged from 28% of FE and 14% of SE in the control group to 81% and 96%, respectively, in the L group. Stand in-contact ranged from 22% of FL and 6% of SL in the control group to 77% (FL) and 84% (SL).
- The percent of sheep standing independently is given in Figure 8 below.

Figure 8. The effect of space allowance on the percent of sheep standing independently, by sheep category



- Lie independent was greatest in Control for SL (34%) and less than 10% for sheep in the MH, ML, and L groups.

- Free pen space was greatest in the control group than the H group than the MH, ML and L groups for all sheep categories, and is shown across sheep category below in Figure 9.

Road type:

- Stand in-contact for FL and stand independent for SL were higher on Motorways than B roads than on A roads
- Lie in-contact for FL and SL and lie independent for SL were higher on A roads than B roads than Motorways

Stage of journey:

- CV residual at the rump was more positive on the first than last than second stage of the journey for FE, whilst CV residual at the head was more positive on the last than the second than the first stage of the journey.
- Stand in-contact (for FL and SL) and stand independent (for SL) were higher during the first than the second than the last stage of the journey.
- Lie in-contact (for FL and SL) and lie independent (SL) were higher on the last than the second than the first stage of the journey.

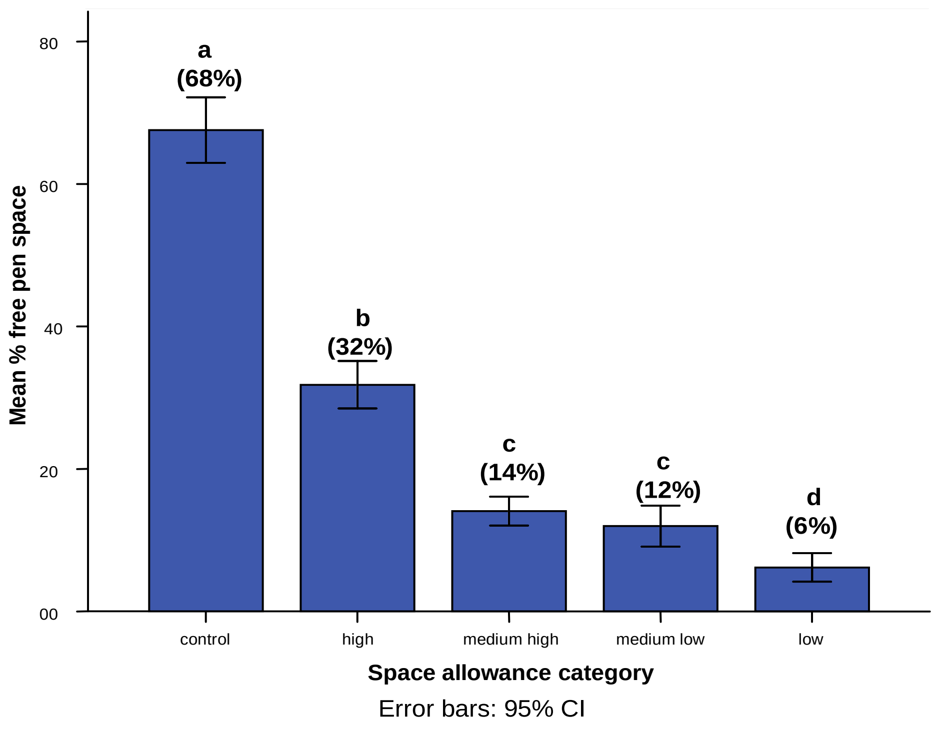
Interactions:

Interactions are detailed in Appendix 4 Tables 4.2-4.5. There was a significant road*space interaction for stand in-contact (SE), stand independent (SE, SL) and lie independent (SL). There was a significant journey stage*space interaction for CV residual at the rump (FE), stand independent (SL), and lie independent (SL).

Covariates:

CV residual (rump) was more positive with lower space (for FL), whilst CV residual (head) was more positive with lower space (for SL). For FL, stand in contact increased with decreasing pen temperature, whilst lie in-contact and independent both increased with increasing pen temperature.

Figure 9. Average free pen space (percent of floor area unoccupied) across all sheep categories and by space allowance.
(Values with different superscripts are significantly different, Tukey post hoc tests)



Objective 03. To recommend the best spacing strategy for sheep in transit

Spacing strategy:

Loss of balance, slip and fall occurred least in the control and high treatment groups, indicating that sheep are better able to brace themselves when given a generous space allowance than when tightly packed. Shorn sheep suffered from a lack of space more than fleeced sheep, indicating that the additional 25% space given to fleeced animals benefits them behaviourally (as well as thermally). The contact and spacing data suggest that given the opportunity, sheep stand close to their neighbours but do not touch, particularly at the rump.

Further evidence for the need for more space for sheep in transit is given by the fact that:

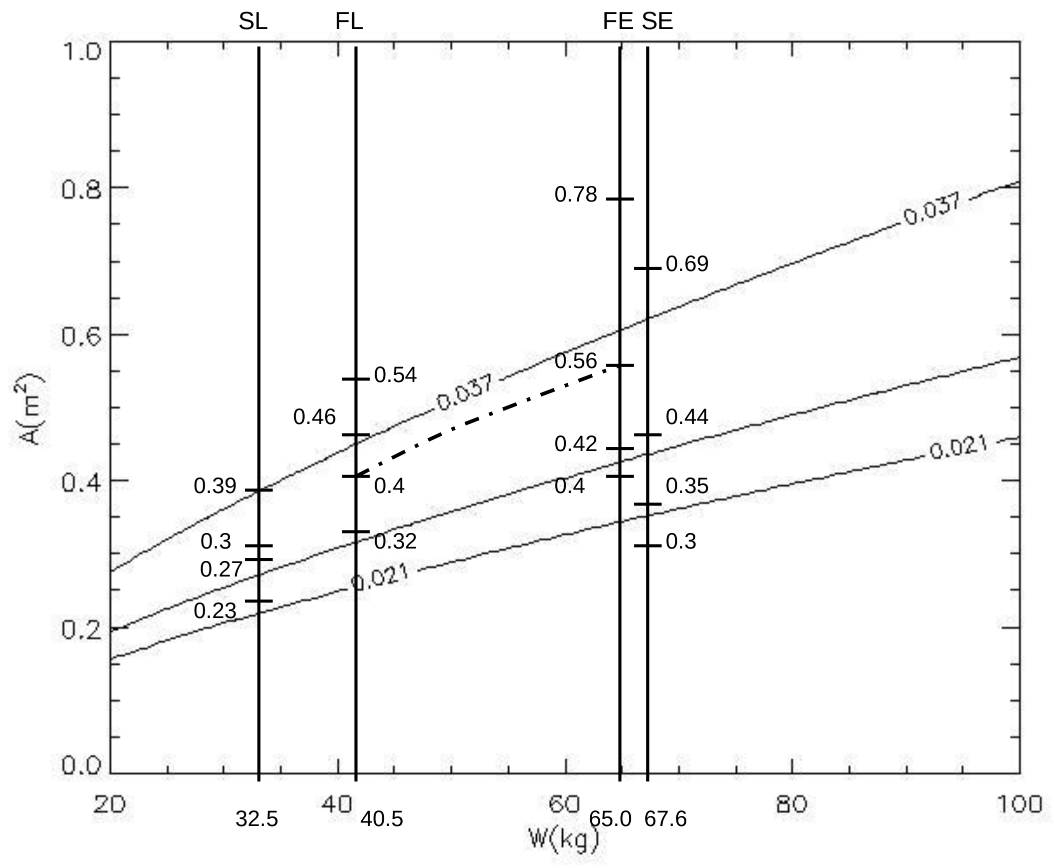
i) Sheep on roads with the worse ride characteristics (B roads) are less able to brace against the motion of the vehicle when at L and ML space
ii) Lambs want to lie down in transit, particularly towards the latter stages of the journey and with increasing temperatures, so should be given space to do so.
iii) Sheep are forced to lie down by their pen-mates in the L and ML treatment groups only; they take on average 5 minutes to regain their feet, with at least one SL taking 1 hour to regain its feet.

The data therefore supports Hypothesis 2; that sheep brace themselves independently during vehicle motion, and are less likely to fall or lose balance under a variety of ride conditions when loosely packed than tightly packed

Space allowance for spacing strategy:

For ewes, our L and ML treatment groups are considered unacceptable under Hypothesis 2, whilst for FL the L group is considered unacceptable. This means that space allowances derived from minimum figures and equation 1 (see Table 1) do not allow sheep to brace themselves independently or lie down adequately in transit, whereas space allowances derived from equation 2 and above are better suited to the successful spacing strategy adopted by sheep. For SL, there is some concern over the ML treatment group (derived from equation 2), with the MH group performing better (intermediate level); the empirical coefficient (k) required for SL may therefore need to be adjusted in equation 2, from 0.026 to 0.029. Figure 10 below illustrates the space allowance given by the 3 equations proposed by the EU (2002) and indicates the space allowances given in this experiment. The dashed line represents an additional ~25% space for fleeced sheep over that provided by equation 2, which equates to an empirical coefficient (k) of 0.033.

Figure 10. Space requirements for sheep according to weight and equations 1-3 proposed by the EU (2002). Actual mean allowance (m^2/animal) provided by space (L, ML, MH, H) and sheep category (SL, FL, FE, SE) have been inserted and the proposed line for fleeced sheep (incorporating k=0.033) given as a dashed line.



Application of equation 2 could mean a loss of 6 shorn sheep and 4 fleeced sheep per pen on the lorry (depending on the size of the pen). The cost of better welfare for sheep in transit would therefore need to be reflected in a fair price paid for the sheep. Frame 1 shows the numbers of SE per pen and the space available to those sheep under the L, ML, and MH spacing categories.

Space allowance versus stocking density:

It has been suggested that stocking density be given in $m^2/100kg$ for sheep (Knowles 1998). The terminology for space definition was investigated and reported in the first year report for this project. To summarise, stating a space requirement in $m^2/100kg$ for a given weight of sheep is mathematically correct, since it has been derived from equation 1. However, extrapolating space allowances between different weights of sheep is incorrect as this leads to an underestimate of space, when extrapolated from ewes to lambs and an overestimate of space when extrapolated from lambs to ewes. Thus stating ranges of stocking densities ($m^2/100kg$) observed in practice is actually difficult to interpret without the weights of the sheep to which the density refers (Warris et al 2002).

Practically, hauliers and farmers would prefer to refer to a set of tables, giving space allowance or numbers permissible in the pen by weight and condition (e.g. fleeced or not); these can easily be produced from the equations, and easily interpreted from m^2/animal. We recommend therefore that space continues to be defined as m^2/animal.

Frame 1. Overhead views of shorn ewes in transit at a) Low, b) Medium Low and c) Medium High space categories.

a) Low space ($0.3m^2$/sheep)

b) Medium Low space ($0.35m^2$/sheep)

c) Medium High ($0.44m^2$/sheep)

Summary:

Where possible, sheep adopt an independent spacing strategy in transit which allows them to brace themselves more successfully against the motion of the vehicle, than being dependent on their pen-mates, even on the most difficult of road types (the B road). Sheep do lie down in transit, particularly lambs and towards the last third of a 6 hour journey; they therefore require the space to do so.

The space allowance that best suits the strategy of the sheep is therefore:

i) Equation 2 (2002) where m^2/animal $A=0.026W^{0.67}$, for shorn ewes

ii) Plus 25% of the space required by equation 2 for fleeced ewes and lambs or the equation $A=0.033W^{0.67}$ may be considered appropriate

iii) An intermediate space allowance for shorn lambs, using an adjusted empirical coefficient so that $A=0.029W^{0.67}$ may be considered appropriate

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

References:

Anon. 1995. EU Directive 95/29/EC

Anon. 2002. The welfare of animals during transport (details for horses, pigs, sheep and cattle). Report of the Scientific Committee on Animal Health and Animal Welfare, European Commission.

Febrer K., Jones, T. A., Donnelly C., Dawkins, M. S 2006. Forced to crowd or choosing to cluster? Spatial distribution indicates social attraction in broiler chickens. Animal Behaviour 72: 1291-1300

Grafen, A and Hails, R. 2002. Modern Statistics for the Life Sciences. Oxford University Press. Chapters 8,9.

Knowles, T.G. 1998. A review of the road transport of slaughter sheep. Veterinary Record 143: 212-219

Warris, P. D., Edwards, J. E., Brown, S. N., Knowles, T. G. 2002. Survey of the stocking densities at which sheep are transported commercially in the United Kingdom. Veterinary Record 150 (8): 233-236.