

**THE RELATIONSHIP BETWEEN LIVESTOCK DISTRIBUTION CHANNELS
AND ANIMAL WELFARE**

By

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A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

Seale-Hayne Faculty of Land, Food and Leisure

June 2001

The Relationship between Livestock Distribution Channels and Animal Welfare

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Abstract

Major changes are taking place in all sectors of the livestock and meat producing industries from farm to consumer which impinge on the processes and patterns of livestock distribution from farm to slaughter. These changes are identified and described.

A survey of the complete journeys from farm to abattoir of 18,393 slaughterweight lambs sold direct from farm to abattoir, via livestock auction markets and via electronic auctions was conducted. Lambs sold direct from farm to abattoir experienced shorter journeys (in terms of both median duration and distance) than lambs sold through either of the other two channels. Lambs sold through electronic auctions, on average, travelled longer distances but for shorter times than lambs sold through livestock auction markets. Although these results are broadly consistent with the common perception of direct sale lambs experiencing simpler journeys than lambs passing through the other channels, they do not support this view unequivocally. The journeys were diverse in all three distribution channels and ranged from direct and uninterrupted transfer from farm to abattoir ($n=4,888$) to highly complex itineraries including up to three periods of transportation interspersed with two holding periods at assembly points, staging posts or auction markets ($n=1,034$). Journeys also included those with between 2 and 8 pickups *en route* ($n=2,369$), and those involving holding at assembly points, staging posts or livestock auction markets before transfer to abattoir ($n=10,102$). A total of 26 different journey structures were identified: 18 in direct farm to abattoir sales, 9 in sales via livestock auction markets and 13 within the electronic auction system.

The effect of journey structure on the welfare of slaughterweight lambs (90 transported and 45 non-transported controls) was investigated in an experiment comprising 3 journey types (direct transfer from farm to abattoir, a journey involving 3 additional pickups *en route* and a journey incorporating holding at a livestock auction market) with non-transported controls held in a pen for the duration of the transport period. Transportation *per se* affected the liveweight and behaviour of the lambs: transported lambs lost more weight during the transport period and spent less time ruminating and less time lying down than non-transported lambs. Multiple pickup and Market lambs lost more weight and spent less time ruminating whilst lying than Direct lambs. Ultimate carcass pH (pH_u) was higher for Multiple pickup and Market lambs than Direct lambs. There were no differences in liveweight loss, ruminating behaviour or pH_u between Multiple pickup and Market lambs. Direct and uninterrupted transfer from farm to abattoir is preferable to more complex itineraries, but it is essential to consider journey structure, rather than simply the marketing channel, when judging the impact of livestock transport on animal welfare.

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Acknowledgements

Many people contributed to the completion of this programme of study and I would like to extend my gratitude to the following:

The University of Plymouth Seale-Hayne Faculty for awarding the Faculty Studentship. The Royal Society for the Protection of Animals (RSPCA), The Livestock Auctioneers' Association, The National Sheep Association, Devon County Council, North Cornwall District Council, Restormel Borough Council, South Hams District Council and West Devon Borough Council for additional funding.

My supervisors, Dr John Kirk, Dr John Eddison and Dr Sharon Cullinane for their valued academic insights, support and encouragement.

The livestock auctioneers, abattoirs, hauliers and farmers who participated in the survey.

Richard Newington, Seale-Hayne Farm Manager, for allowing the use of lambs for experimentation and providing help and advice.

The Institute of Grassland and Environmental Research for the loan of behaviour monitoring equipment and to Mark Rutter and Rob Champion for instruction in its use.

Peter Russell and Patrick Bugg for their help with the housing and equipment.

Carolyn Streets and Catherine Caveney for their assistance with the management and handling of the lambs.

Liz Folland for her guidance and advice in the laboratory.

The abattoir for purchasing lambs and permitting data collection on the premises.

Raymond Pedrick for transport services, supplying additional livestock and use of premises. Andrew Hext for supplying additional livestock and use of premises and Ken Luscombe for use of premises.

Finally, my children, Abigail, Robert and Alec, my husband John and my mother, Lynette Fleming, for their tolerance, understanding and unending support.

Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other university award.

This study was financed with the aid of a studentship from the University of Plymouth Seale-Hayne Faculty of Land Food and Leisure. Additional financial support was secured from The Royal Society for the Protection of Animals (RSPCA), The Livestock Auctioneers' Association, The National Sheep Association, Devon County Council, North Cornwall District Council, Restormel Borough Council, South Hams District Council and West Devon Borough Council.

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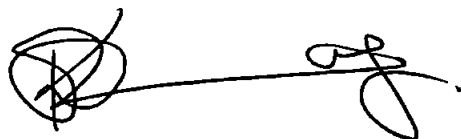
1996. University of Reading Agricultural Club Annual Conference. Animal Health and Farmer Wealth, Reading.

1997. 31st International Congress of the International Society for Applied Ethology, Prague.

1998. Sheep Veterinary Society Spring Meeting, Scarborough.

1998. 32nd International Congress of the International Society for Applied Ethology, Clermont-Ferrand.

2000. 34th International Congress of the International Society for Applied Ethology, Florianópolis.

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5th Oct. 2001.

Chapter 1 Livestock Production

The western and northern regions of the UK have a strong tradition of ruminant livestock production supported either by the long growing season for grass or availability of large areas of rough grazing in the uplands, or both. Physical characteristics of climate, site and soil influence the nature of agricultural activity, and dairying, beef and sheep production have been of particular importance in these regions for many centuries. This, despite national government and EU policy intervention, remains the position today. Livestock production is examined from an historical perspective and the importance of ruminant production in Cornwall and Devon identified. That most livestock ultimately travel from farm to abattoir is unequivocal and this chapter characterises the production sector as a precursor to examining the processes and patterns of livestock distribution from farm to slaughter.

1.1 Colonisation to CAP Reform

Hoskins (1972) reported that early land colonisation began in the 12th Century remaining active until the Black Death in the 14th Century and then renewed by population pressure in the 15th Century. The earliest colonisation began in the west and north, including Wales, the Marches, Pennines and Lake District, together with the Essex marshlands and Kent orchards and hop-fields (Hill 1992). This took many forms, including that of peripheral moorland regions, with protected inner areas being reached in the 14th Century. Much woodland was felled - many farms in Cornwall and Devon with names incorporating 'beare' or 'wood' bear witness to their origins. Heaths were appropriated and waterlogged land ditched and hedged. Salt marsh was reclaimed from the sea for fattening cattle. The landscape of small enclosed fields, not usually of more than an acre, surrounded by hedge

banks, became established. 'Open Field' enclosure began in the 15th Century and it was not until about 1850 that nearly all agricultural land in England was enclosed.

Livestock played a prominent role in the utilisation of both lowland and upland areas. For example, Hatcher (1988) indicates that sheep and cattle were kept in 'substantial numbers' (not quantified) in most parts of Cornwall and Devon. The expanding cloth trade was driven by a gradual intensification of pastoral farming and the number of sheep in Devon was as great, if not greater than in any other county in England. In areas of mixed farming, the balance between arable and pastoral activities was largely dictated by the price of corn and, during the 15th Century, sheep were probably grazed on rough pastures and then folded on newly reclaimed arable land to manure and tread down the ground (Hoskins 1972).

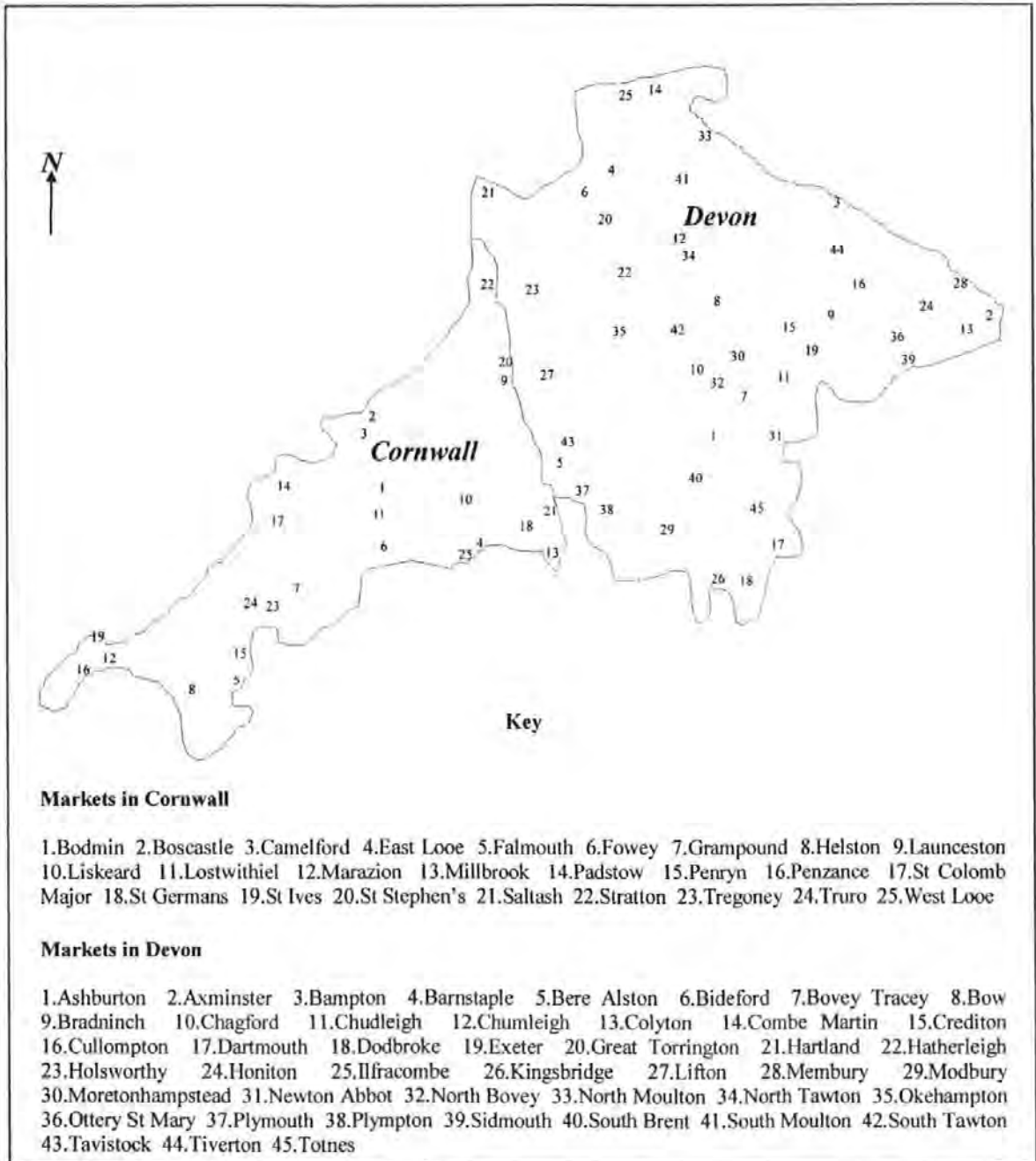
In the fourteenth and fifteenth centuries, Hatcher (1970) indicated that the cattle pastures of north east Cornwall were of the finest quality and graziers from Devon and Somerset pastured 'substantial numbers' of cattle on them. However, Thirsk (1967) reported that sixteenth Century Cornwall, with a small population, comprised a 'series of cultivated oases set in a large expanse of moor', with fertile land near the coasts, providing little more than subsistence farming. Devon was more densely populated than Cornwall and most of the north of the county was devoted to livestock production with Exmoor and Dartmoor used for summer grazing. Corn and fruit growing was concentrated in the Exe Vale, around Torbay and into the South Hams.

By the beginning of the seventeenth Century, Cornwall was able to meet not only local demand for corn, but also supplied all ships calling at native ports and exported grain to France and Spain. Both Cornwall and Devon are reported to have had strong trading links

with Wales, Ireland, France and Spain (Thirsk 1967). Welsh sheep were transported across the Bristol Channel and cattle imported from Ireland for fattening. By the early seventeenth Century it was reported that 100,000 head of cattle were imported annually to England from Ireland. Many of these were brought into the West Country. As the regional cities of Plymouth, Bristol and Cardiff expanded, they became dependent on food supplies from the two counties. By 1869, approximately 1 million animals were imported annually into Britain for slaughter from many countries including, Austria, Holland, Ireland, Canada, America and Argentina (Gregory 1984).

Marketing of livestock and other agricultural produce was largely conducted at weekly markets and seasonal fairs. During the sixteenth Century Everitt (1967) reported that there were 760 markets in England (25 in Cornwall and 45 in Devon; Figure 1.1). This may have been only one third of the number in existence two centuries before and there may also have been many unofficial markets which flourished briefly and then disappeared. The average cattle market area was within a radius of 7 - 12 miles but for sheep markets, especially the large markets of the midlands and the north, the area may well have extended to a radius of 70 miles and beyond. For example, Falkirk market served most of Scotland during the eighteenth and nineteenth centuries holding sales three times a year and selling up to 50,000 cattle, 30,000 sheep and 3,000 horses at each (Gregory 1984). In many market towns, shambles (butchers' slaughterhouses) and butchers shops occupied large sites indicating the importance of the meat market.

Figure 1.1 Markets in Cornwall and Devon in the Sixteenth and Seventeenth Centuries



Source: Everitt 1967

The annual or seasonal fairs provided the principal market place for breeding and store livestock. Cattle and sheep were often driven large distances, sometimes from one fair to

another and resold several times. There was a general drift of store livestock from the north and west to the south and east, partly because the south and east was more suited to fattening and corn growing and partly because of the draw of the markets in the more densely populated southern regions of the country.

The rapidly rising London population, which between 1700 and 1871 increased from an estimated 675,000 to 3,890,000, provided an important market for livestock (Table 1.1).

Table 1.1 The London Market for Livestock 1725 -1853

	Cattle (head)	Sheep (head)
1725	60,000	70,000
1810	140,000	1,000,000
1828	150,000	1,500,000
1853	277,000	1,600,000

Source: Forshaw and Bergstrom 1980

Technical advances during the eighteenth Century resulted in improved productivity of many agricultural commodities. Livestock was no exception, and the average weight of carcasses sold at Smithfield more than doubled between 1710 and 1795 (Forshaw and Bergstrom 1980; Plumb 1950; Table 1.2).

Table 1.2 Average Weights of Livestock Carcasses Sold at Smithfield 1710 and 1795

	1710	1795
Oxen	370lb	800lb
Calves	50lb	150lb
Sheep	38lb	80lb

Sources: Forshaw and Bergstrom 1980; Plumb 1950

The coming of the railways transformed the marketing of livestock, taking away many cattle fairs and weekly markets either by creating new market sites close to the railway network or bringing local markets into competition with the bigger market places of the regional centres (Hoskins 1972; Gregory 1984). Hogg (1935) indicates that mutton from North Devon, where sheep were kept in 'large numbers', was supplied to Smithfield through 'dealer-slaughtermen' who had slaughterhouses at most railway stations between Barnstaple and Exeter and Holsworthy and Exeter.

The first significant pressures from overseas competition for livestock and livestock products began in the late nineteenth Century with the innovation of refrigerated transport (Tracey 1989; Hill 1992). Amongst other commodities from a range of sources, beef was imported from The Argentine, a variety of meat and dairy products from New Zealand, and pork, butter and bacon from Denmark. Interventionist measures were introduced in the 1930s which resulted in some limitation to increases in total imports and a shift in the pattern away from foreign countries to those of the Empire. Subsidies were introduced for wheat, cattle and pig production. Milk Marketing Boards were set up to improve the bargaining position of British dairy farmers who were paid the same price irrespective of differences in transportation costs. These measures did little for British agriculture which was still exposed to high levels of imports, particularly from Empire countries. By the outbreak of the Second World War, home production accounted for only 30% of the total

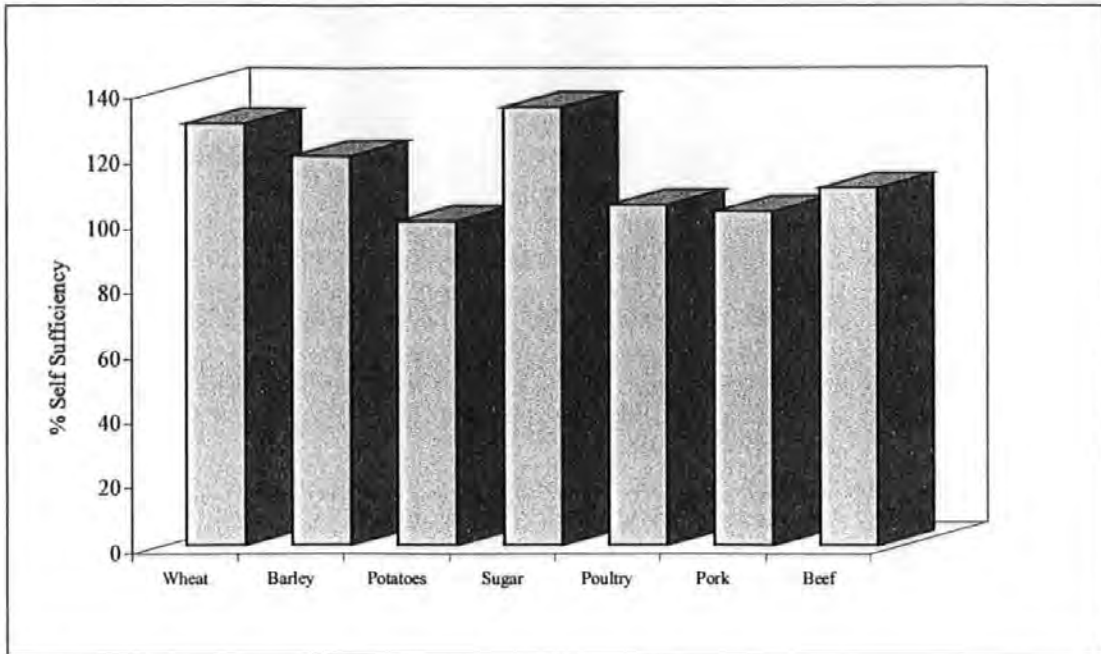
food supply in terms of calories (Tracey 1993).

Post 1945 agricultural policy, embodied in the 1947 Agriculture Act, sought to increase production to enhance levels of self sufficiency ensuring that the war-time food shortages would not be repeated, and to promote 'a stable and efficient agriculture industry' to provide adequate food at cheap prices. Support for selected products, in the form of guaranteed prices and intervention and determined by an annual review of agriculture, was introduced and became institutional.

On accession to the European Economic Community in 1973, the Common Agricultural Policy (CAP) superseded UK national policy, and whilst support mechanisms changed, the protectionist regime remained. Agricultural productivity exceeded all expectations and, by the early 1980s, commodity surpluses had become an embarrassment and FEOGA¹ spending on export refunds, market intervention and structural measures, unacceptable. Production constraints were introduced with milk delivery quotas and support price freezing in 1984 and stabilisers for a range of products in 1988. However, surpluses continued to rise with, for example, beef stores in intervention in 1992 of almost 800,000 tonnes and butter stores of over 200,000 tonnes. Self-sufficiency exceeded 100% in a range of commodities (Figure 1.2) and FEOGA spending had increased to 35.8 billion ECU in the same year, representing 59% of the total EC budget (Tracey 1993).

¹ Fonds Européen d'Oriantation et de Garantie Agricoles

Figure 1.2 European Union Self Sufficiency - Selected Commodities 1992



Source: European Commission 1995

The CAP was reformed in 1992 and sought to limit production further. The Integrated Administration and Control System introduced compulsory set-aside for a range of arable crops, and quotas were established for suckler cows and ewes. Support was partly disassociated from production and surpluses of many commodities were subsequently substantially reduced.

1.2 The Importance of Ruminant Livestock Production in Cornwall and Devon

Ruminant livestock production (dairying, beef and sheep), are the dominant sectors within the agricultural industry in Cornwall and Devon. This is illustrated in terms of land use, the agricultural labour force, agricultural contribution to the regional economy and industry sector output. Farm incomes by farm type are given in Section 1.2.7. Descriptive data for the two counties are presented with reference to those for the South West region, the Eastern region and England for comparison (see Appendix 1 for land use regional definitions).

1.2.1 Land Use

In 1997, 71% of the total land area of England was used for agriculture. In the Eastern region this extended to 77%, and in the South West 76% (MAFF 1998a). Comparison of the two regions exemplifies the east west divide in the country, with cereal production dominating in the Eastern region and dairying and beef and sheep production dominating in the South West. This divide has been in evidence for many centuries but the post war drive for increased food production exacerbated the effect of natural climatic and topographical factors resulting in a marked reduction in grassland² in the Eastern region from 36% of the agricultural area in 1944 to 13% in 1997. Conversely, grassland in Cornwall and Devon increased from 62% and 66% of the agricultural area in 1944 to 72%

² Excludes Common Rough Grazing

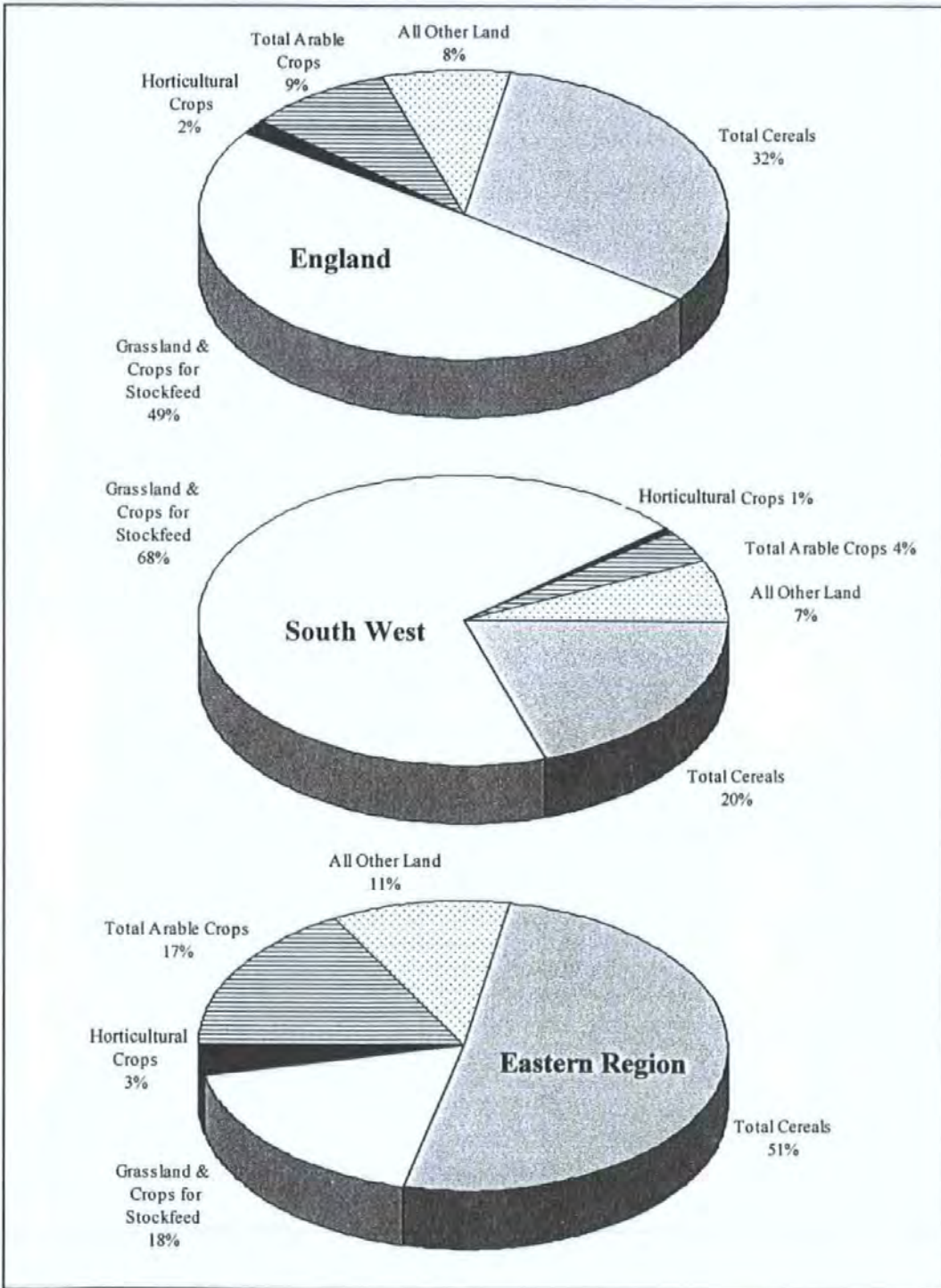
and 76%, respectively in 1997, both reaching a peak of approximately 80% in 1973 (Ministry of Agriculture and Fisheries 1947; MAFF 1974; MAFF 1998a).

Nationally, the area of grassland decreased from over 5,500,000ha in 1944 to less than 4,300,000ha in 1997 (Ministry of Agriculture and Fisheries 1947; MAFF 1998a). Addiscott (1988) reports that over 5,000ha of grassland was sacrificed to arable production during, and immediately after, World War II.

In England, grassland and crops grown mainly for stockfeed³ extended to almost 50% of the agricultural area in 1997, with cereals occupying 32% (MAFF 1998a). Agricultural land utilisation for England, the South West, the Eastern region and Cornwall and Devon is illustrated in Figures 1.3 and 1.4.

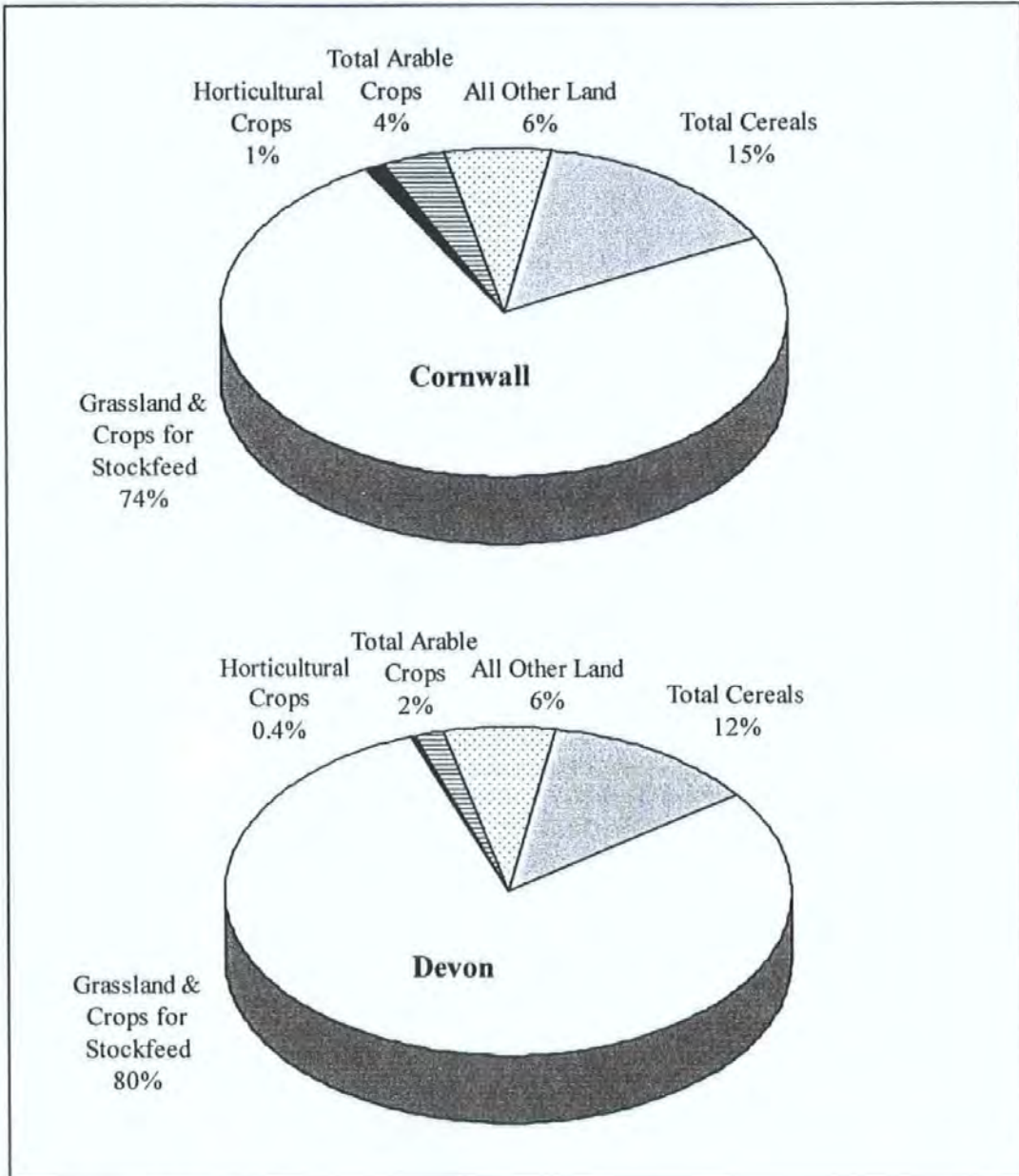
³ Includes grassland (as defined above), turnips, swedes, kale, kohlrabi, cabbage, savoy, rape, field beans, peas for harvesting dry, maize, fodder beet, mangolds and other crops.

Figure 1.3 Agricultural Land Use in England, the South West and the Eastern Region 1997



Source: MAFF 1998a

Figure 1.4 Agricultural Land Use in Cornwall and Devon 1997



Source: MAFF 1998a

1.2.2 Livestock Numbers

As described above, land use in Cornwall and Devon is dominated by grassland and crops for stockfeed, which indicates the importance of ruminant livestock production. In 1997,

the dairy and beef breeding herds in the two counties both accounted for approximately 15% of the national herds and the sheep breeding flock to 13.5% of the national flock. Pig production is less important in the two counties and, in 1997 the pig breeding herd accounted for approximately 4.5% of the national herd (Table 1.3; MAFF 1998a). Within the South West, the dairy breeding herd extended to over 605,000 head, accounting for over 35% of the national herd, whilst in the Eastern region the herd extended to less than 49,000, accounting for 2.9% of the national herd. Examination of the breeding livestock numbers of beef and sheep identify similar differences between the regions. The pig breeding herd extended to over 155,000 head in the Eastern region, accounting for over 24% of the national herd, illustrating the importance of pig production.

Table 1.3 Breeding Livestock Numbers for Dairy Cattle, Beef Cattle and Sheep in England the Eastern Region, the South West, Cornwall and Devon 1997. Percentage of National Numbers in Parentheses

	England	Eastern	South West	Cornwall	Devon
Dairy Breeding Herd	1,700,250	48,795 (2.9%)	605,263 (35.6%)	91,617 (5.4%)	165,629 (9.7%)
Beef Breeding Herd	789,993	47,423 (6%)	199,302 (25.2%)	44,270 (5.6%)	73,474 (9.3%)
Pig Breeding Herd	644,897	155,110 (24.1%)	88,534 (13.7%)	7,876 (1.2%)	21,303 (3.3%)
Sheep Breeding Flock	9,024,128	222,872 (2.5%)	1,956,381 (21.7%)	308,799 (3.4%)	910,888 (10.1%)

Source: MAFF 1998a

Examination of breeding livestock numbers per 100ha of land used for agriculture in 1997 identifies that, within the South West, ruminant livestock exceeded the national average in all cases, whilst in the Eastern region only the pig breeding herd exceeded that national average (Table 1.4; MAFF 1998a). Within Cornwall and Devon beef and sheep exceeded

both the South West regional and national figures, the dairy herd exceeded national figures and the pig herd was below both regional and national figures.

Table 1.4 Breeding Livestock Numbers per 100ha of Agricultural Land in England, the Eastern Region, the South West, Cornwall and Devon 1997

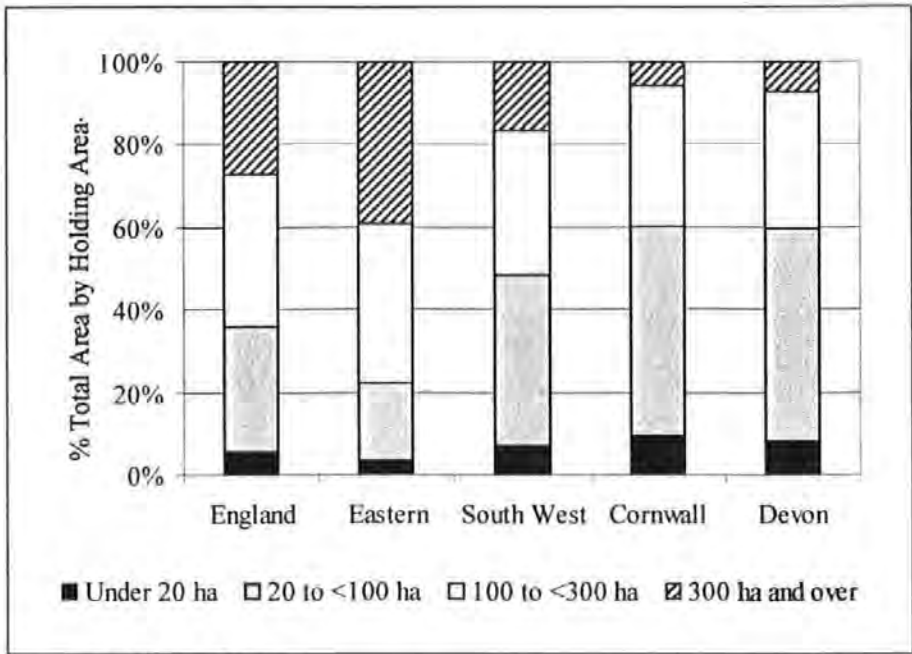
	England	Eastern	South West	Cornwall	Devon
Dairy Breeding Herd	18	3	34	34	32
Beef Breeding Herd	9	3	11	16	14
Pig Breeding Herd	7	11	5	3	4
Sheep Breeding Flock	98	15	109	113	177

Source: MAFF 1998a

1.2.3 Farm Structure

Farm size structure is a further indication of the east west divide. In 1944, over 66% of the agricultural land in England comprised farms of less than 101ha. In the South West, this extended to approximately 74% and in Cornwall and Devon, 92% and 88%, respectively. In the Eastern region, 52% of the land comprised farms of this size in 1944 (Ministry of Agriculture and Fisheries 1947). By 1997, data for England indicate that the percentage of agricultural land comprising farms of less than 100ha had declined to less than 36%. In the South West this had fallen to 48% and in Cornwall and Devon to approximately 60%, in both cases. In the Eastern Region only 22% of agricultural land comprised farms of less than 100ha in 1997 (MAFF 1998a; Figure 1.5).

Figure 1.5 Analysis of Agricultural Area by Holding Area 1997



Source: MAFF 1998a

In association with changes in farm size structure, the number of agricultural holdings also declined with a consequent increase in average holding area. Nationally, the number of agricultural holdings declined by almost 53% between 1944 and 1997 (Ministry of Agriculture and Fisheries 1947; MAFF 1998a; Table 1.5). In the South West this extended to an average of 40% and in Cornwall and Devon 49% and 28%, respectively. Within the Eastern region, the number declined by over 61%. Average holding size in England increased from 28.7ha to 63.7ha between 1944 and 1997 (Ministry of Agriculture and Fisheries 1947; MAFF 1998a; Table 1.5). In the South West, average holding size increased from 28ha to 50.6ha and in Cornwall and Devon from 18ha to 40ha and 27.9ha to 44.3ha, respectively. In the Eastern region, average farm size increased from 32.5ha to 84.9ha.

Table 1.5 Number of Agricultural Holdings and Average Holding Area (ha) in 1944 and 1997

	1944		1997	
	Holdings (No.)	Average Holding Size (ha)	Holdings (No.)	Average Holding Size (ha)
England	307,077	28.7	144,777	63.7
Eastern region	44,529	32.5	17,326	84.9
South West	59,822	28.0	35,603	50.6
Cornwall	13,095	19.0	6,733	40.4
Devon	16,286	27.9	11,647	44.3

Sources: Ministry of Agriculture and Fisheries 1947; MAFF 1998a

1.2.4 Agricultural Labour Force

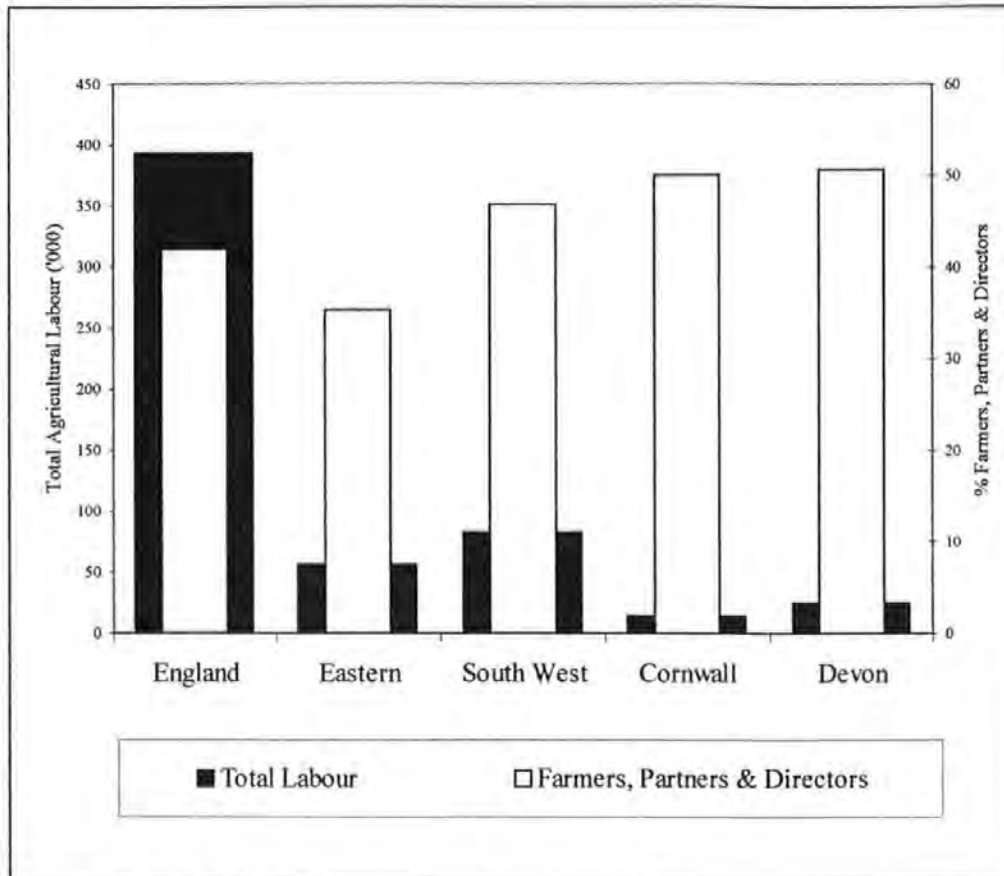
The changes in the size structure and number of farms and led to a reduction in the agricultural labour force. Ilbery (1992) reports that this fell by 36% in Great Britain between 1950 and 1987.

The total agricultural labour force in England in 1997 extended to 393,105, of which 42% were farmers, partners and directors. In the South West, the total agricultural labour force was over 83,000, with nearly 15,000 in Cornwall and over 25,000 in Devon (MAFF 1998a; Figure 1.6). Family labour, as defined by farmers, partners and directors, comprised approximately 50% of the total agricultural labour force in the two counties. In the Eastern region, the total agricultural labour force extended to 56,496 in 1997, of which approximately 35% were farmers, partners and directors.

Hodge and Monks (1991) suggest that in areas where holding sizes are large and a substantial proportion of the total area is under arable production, agricultural employment has been lost at a higher than average rate. Analysis of total labour force per 100ha of

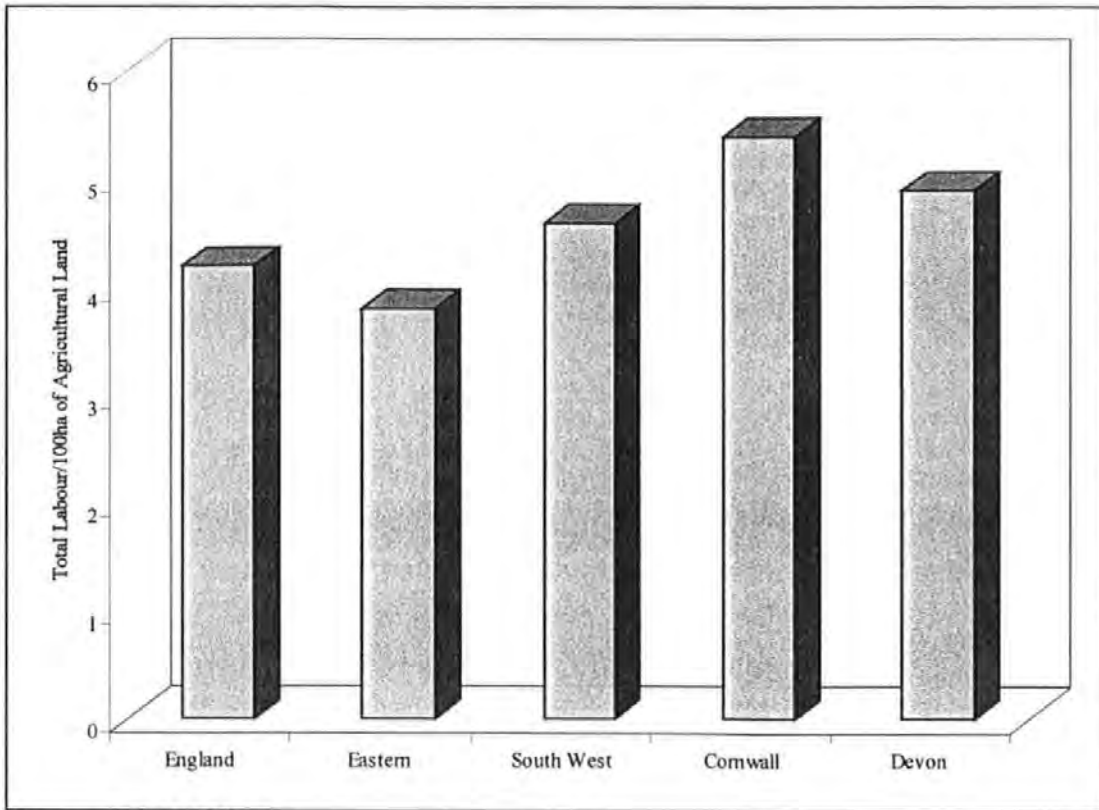
agricultural land indicates that employment in agriculture in the Eastern region was below the national average in 1997. Both Devon and, more markedly, Cornwall had higher than national and South West regional figures (Figure 1.7).

Figure 1.6 Total Agricultural Labour Force and Percentage Farmers, Partners and Directors England, the Eastern region, the South West, Cornwall and Devon in 1997



Source: MAFF 1998a

Figure 1.7 Total Labour, per 100ha Agricultural Land in England, the Eastern Region, the South West, Cornwall and Devon – 1997



Source: MAFF 1998a

1.2.5 Contribution of Agriculture to Regional Economies

In 1997, the gross agricultural product in England was £6,153m, which accounted for 1.1% of the National gross domestic product (GDP). In the South West, in the same year, agriculture accounted for 1.9% of the regional GDP (MAFF 1999; Table 1.6). Regional agricultural contribution ranged from 0.4% in London and the South East and the North East to 2% in the East Midlands.

Table 1.6 Percentage Contribution of Agriculture to Regional and National GDP in 1997

	1997
North East	0.4
North West and Merseyside	0.8
Yorkshire and Humberside	1.4
East Midlands	2.0
West Midlands	1.2
Eastern	1.9
South East & London	0.4
South West	1.9
England	1.3

Source: MAFF 1999

In the South West and the Eastern region, the contribution of agriculture to regional GDP was above the national average, less than only the East Midlands.

1.2.6 Contribution of Industry Sector Output to Gross Agricultural Output

In 1997, gross agricultural output exceeded £15.3 billion. Total livestock and livestock products output⁴ accounted for over 58% and ruminant livestock and livestock products output⁵ over 41%, in the same year. Between 1986-88 and 1997, finished sheep and lambs and poultry outputs increased proportionally, whilst those of finished cattle and calves, milk and pigs decreased (Table 1.7).

⁴ Includes finished cattle and calves, finished sheep and lambs, finished pigs, finished poultry, other livestock, milk, eggs, clip wool and other livestock products.

⁵ Includes finished cattle and calves, finished sheep and lambs, milk and clip wool.

Table 1.7 Industry Sector Output as a Percentage of Gross Agricultural Output at Current Prices. United Kingdom 1986-8 to 1997

	Average of 1986-88	1994	1997
Cereals	16.10	15.12	16.29
Other Crops	5.74	5.81	6.36
Horticulture and Potatoes	15.73	16.97	14.23
Finished Cattle and Calves	16.18	15.05	11.65
Finished Sheep and Lambs	6.75	7.61	6.97
Finished Pigs	7.37	6.19	7.13
Poultry	7.3	6.28	9.21
Other Livestock ⁶	0.84	0.84	0.95
Milk	20.2	20.51	19.73
Eggs	3.2	3.05	2.74
Clip Wool	0.35	0.28	0.23
Other Livestock Products ⁷	0.13	0.18	0.16
Other Direct Receipts ⁸	0.55	2.53	4.12
Value of Physical Increase ⁹	-0.55	-0.43	0

Source: MAFF 1999

Table 1.7 identifies the position within the UK and, whilst such data have not been identified for England regions, an indication of the relative importance of ruminant livestock production in the South West is evident from analysis of holding type. In England in 1997, dairying and cattle and sheep holdings accounted for 40% of total holding numbers and 36% of total agricultural area (MAFF 1998a; Tables 1.8 and 1.9).

In the South West, in the same year, such holdings accounted for 53% of holding number and 55% of the total agricultural area. In Cornwall and Devon, dairying and cattle and

⁶ Horses, breeding livestock exported, rabbits and game, knacker animals, other minor livestock and guidance premium for beef and sheepmeat.

⁷ Honey, goats milk and minor livestock products.

⁸ Set-aside, milk quota cuts, milk outgoers, animal disease compensation payments, co-operative society dividends, payments for grazing of horses and non-marketing of milk. In 1997 also includes calf processing aid scheme, selective cull and over thirty months scheme.

⁹ Breeding and capital livestock, work-in-progress (non capital livestock) and output stocks (cereals, potatoes and some fruit).

sheep holdings accounted for 54% and 63% of holding number, respectively, and 60% and 69% of total agricultural area. In contrast, within the Eastern region dairying and cattle and sheep holdings accounted for approximately 9% of holding number and less than 4% of the total agricultural area.

Table 1.8 Holding Number by Type in England, the Eastern Region, the South West, Cornwall and Devon 1997

	England Holdings (No.)	Eastern Holdings (No.)	South West Holdings (No.)	Cornwall Holdings (No.)	Devon Holdings (No.)
Dairying	18,007	250	6,535	1,194	2,085
Cattle and Sheep	40,523	1,370	12,425	2,459	4,931
Cropping	32,781	9,238	3,305	523	678
Pigs and Poultry	5,347	935	1,096	170	364
Horticulture	8,566	1,572	1,559	403	362
Mixed and Other	39,553	3,961	10,683	1,984	3,227

Source: MAFF 1998a

Table 1.9 Holding Area by Type in England, the Eastern Region, the South West, Cornwall and Devon 1997

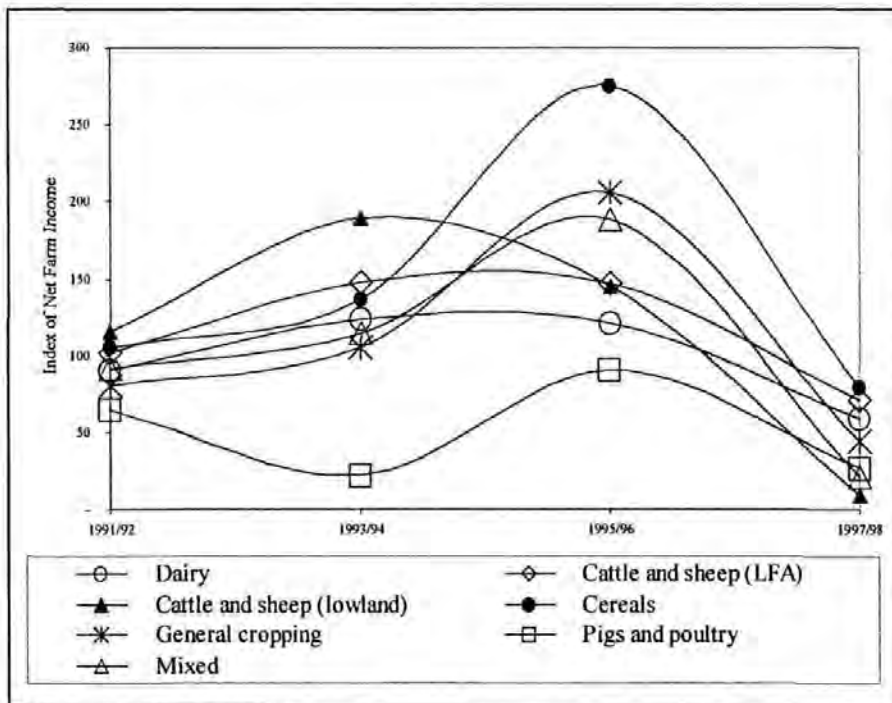
	England Holdings (ha)	Eastern Holdings (ha)	South West Holdings (ha)	Cornwall Holdings (ha)	Devon Holdings (ha)
Dairying	1,287,142	14,206	494,110	78,990	144,132
Cattle and Sheep	1,992,689	41,392	493,646	91,526	214,250
Cropping	4,144,579	1,227,222	372,534	36,148	48,449
Pigs and Poultry	85,150	13,148	17,790	1,822	5,945
Horticulture	103,116	16,567	17,528	5,636	3,677
Mixed and Other	1,610,641	159,266	406,158	58,072	99,146

Source: MAFF 1998a

1.2.7 Farm Incomes

In 1997/8, farm incomes¹⁰ in the UK were below 1991/92 levels across all sectors (Figure 1.8). The greatest decline occurred in Cattle and Sheep (lowland) farms with incomes falling by over 90% between 1991/92 and 1997/98. The increase in incomes in 1995/96, in all sectors, resulted from internal support mechanisms within the 1992 reformed CAP and unexpectedly high market prices, amongst other factors.

Figure 1.8 Indices of Net Income Per Farm 1991/92 – 1997/98 In Real Terms¹¹



Source: MAFF 1999

¹⁰ Measured as occupiers' net income and defined as the return to the farmer and spouse for their managerial and manual labour on all their capital invested in the business.

¹¹ Indices 1989/90 - 1991/92 = 100. Deflated by the Retail Price Index (RPI).

1.3 Discussion

This chapter has demonstrated that the importance of livestock production in Cornwall and Devon, which has a long tradition in the two counties, remains unequivocal. The advantageous climate and topography persist as powerful determining factors of agricultural activity, despite government intervention. Land use, farm structure, the agricultural labour force and sector contribution to the regional economy identify that dairying, beef and sheep production are of particular significance.

Most livestock are ultimately transported to an abattoir and the following chapter examines the distribution channels used. Cornwall and Devon provide the geographic focus, whilst national and regional information is also presented. The factors affecting livestock distribution channel use are discussed.

Chapter 2 Livestock Distribution Channels from Farm to Abattoir

This chapter considers livestock marketing channels and the factors influencing their use.

The main livestock distribution channels from farm to slaughter in the UK are those via livestock auction markets, sales direct from farm to abattoir and, more recently introduced, sales via electronic auction systems. Aggregate channel utilisation levels for cattle, sheep and pigs, in Great Britain in 1997, showed marked differences between pigs, with over 95% sold direct to abattoirs, and cattle and sheep, with over 46% and 60%, respectively, sold through livestock auction markets (Table 2.1).

There have been shifts in channel utilisation levels in recent years (Table 2.1). Percentage data are presented to illustrate market share of each of the livestock distribution channels because of changes in the total number of animals slaughtered for human consumption between 1991 and 1997 (Table 2.1).

Between 1991 and 1993, the percentage of cattle sold via livestock auction markets and electronic auctions increased, whilst direct sales to abattoirs decreased. Between 1993 and 1997 the situation was reversed, with the percentage of cattle sold via livestock auction markets and electronic auctions decreasing in favour of direct farm to abattoir sales. The percentage of sheep sold via livestock auction markets declined between 1991 and 1997 from 71.6% to 61.2% of the total. Direct farm to abattoir sales increased during the period considered from 28.4% in 1991 to 35.4% in 1997. Sales via electronic auction increased from 2.0% in 1991 to 5.5% in 1995 and declined thereafter to 4.3% in 1997. The dominance of pig sales direct from farm to abattoir increased from 92% in 1991 to over 95% in 1997, with the remainder sold only via livestock auction markets. The net result of

these shifts between 1991 and 1997 were gains to direct farm to abattoir sales at the expense of both of the other marketing channels.

Table 2.1 Number (million head) and Percentage (in parentheses) of Slaughter Cattle, Sheep and Pigs Sold via Livestock Auction Markets, Direct from Farm to Abattoir and via Electronic Auctions Systems in Great Britain – 1991 - 1997

		Livestock Auction Markets	Direct Sales to Abattoirs	Electronic Auctions
Cattle	1991	1.68 (55.0%)	1.32 (43.0%)	0.06 (2.0%)
	1993	1.48 (58.8%)	0.94 (37.4%)	0.99 (3.8%)
	1995	1.56 (56.0%)	1.15 (40.6%)	0.1 (3.4%)
	1997	0.87 (46.1%)	0.99 (52.4%)	0.03 (1.5%)
Sheep	1991	14.52 (71.6%)	5.76 (28.4%)	0.41 (2.0%)
	1993	11.30 (67.1%)	4.90 (29.1%)	0.64 (3.8%)
	1995	12.09 (64.8%)	5.56 (29.8%)	1.02 (5.5%)
	1997	7.48 (61.2%)	8.50 (35.4%)	0.24 (3.4%)
Pigs	1991	1.07 (8.0%)	12.35 (92.0%)	na
	1993	0.75 (5.5%)	12.92 (94.5%)	na
	1995	0.68 (5.3%)	12.24 (94.7%)	na
	1997	0.64 (4.6%)	13.36 (95.4%)	na

Source: MLC 1996a and 2000a *personal communication*

na = not applicable

Major changes taking place within all sectors of the livestock and meat processing industries have resulted in altered supply chain relationships, which impinge on the distribution of animals both within and between livestock marketing channels. These changes, which are interactive, emanate from legislative controls, technological advances,

social and economic pressures affecting production, marketing and the slaughter sector. This chapter continues with an overview of the three main livestock marketing channels and an examination of the factors effecting change.

2.1 The Livestock Auction Market Sector

Livestock were traditionally sold at weekly markets and seasonal and annual fairs all over the country. In the early fourteenth century there may have been 2000 - 2500 markets in England (Everitt 1967). In recent years, the number of livestock markets in the UK has been in decline and by 1940 there were 554 in England and Wales, falling to 235 in 1993 (Livestock Auctioneers' Association 1993; Jones and Steele 1995) and to 194 in 1997 (Livestock Auctioneers' Association 1998). One hundred and forty-six livestock markets were operating in England in 1997 (Livestock Auctioneers' Association 1998). Jones and Steele (1995) report that the decline has not been geographically uniform, with traditional grassland areas least affected. Regional markets range from 4 in the Eastern region to 36 in the South West (Table 2.2; regional definitions - Appendix 1).

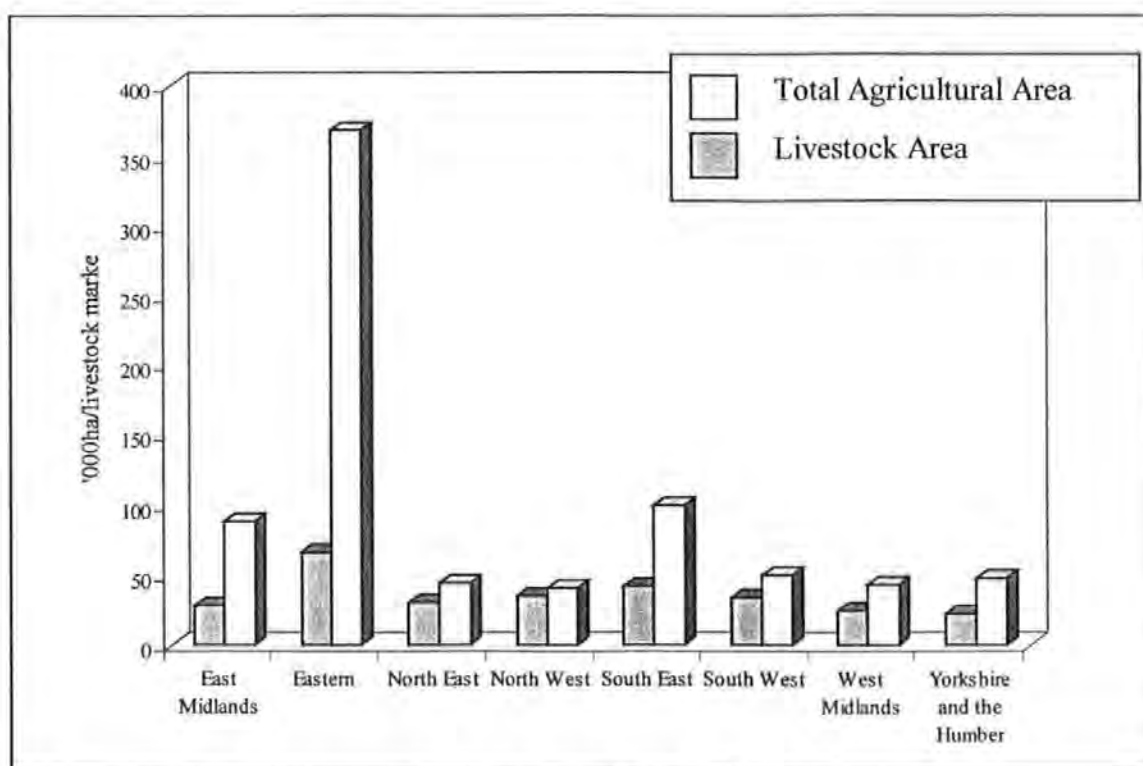
Table 2.2 Number of Markets in the England Regions 1997

Region	Number of Livestock Market
East Midlands	14
Eastern	4
North East	13
North West	22
South East	12
South West	36
West Midlands	22
Yorkshire and the Humber	23

Source: Livestock Auctioneers' Association 1998

The ratio of total agricultural land to markets in the regions shows wide disparity ranging from over 360,000ha per market in the Eastern region to approximately 40,000ha per market in the North West region. However, the ratio of livestock area¹² to markets indicates a more uniform distribution suggesting a direct relationship between ruminant livestock production and livestock market provision (Figure 2.1).

Figure 2.1 Total Agricultural Area and Livestock Area ('000ha) per Livestock Market in the England Regions 1997



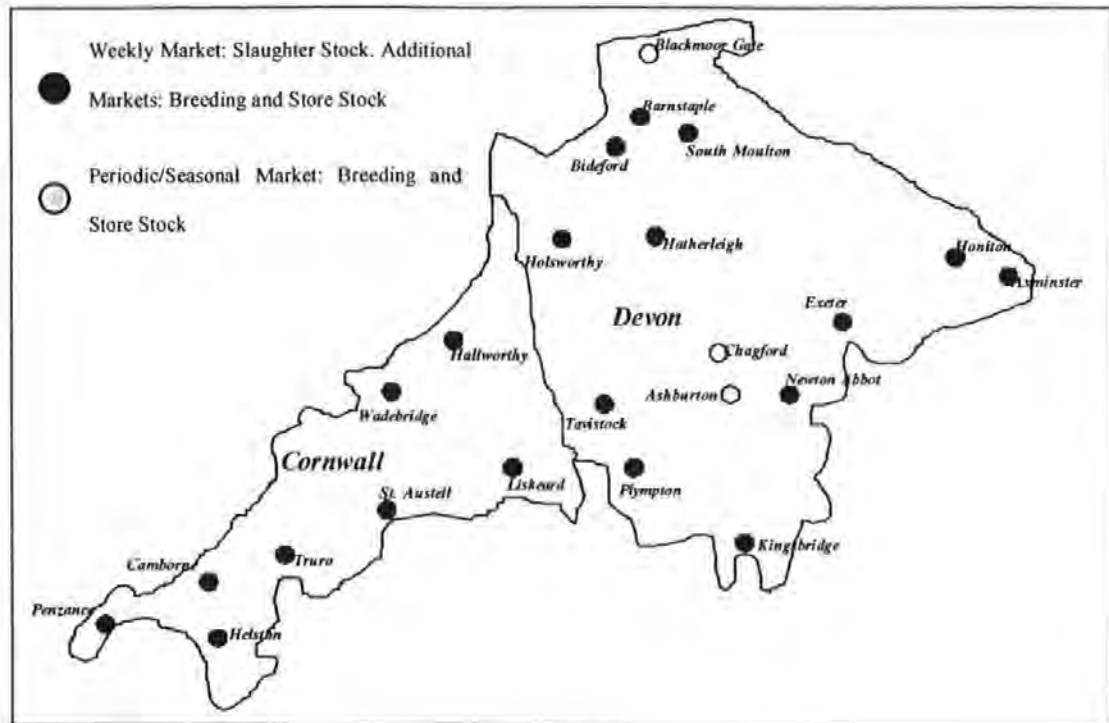
Source: Livestock Auctioneers' Association 1998, MAFF 1998a

In 1997, the ratio of livestock area ('000ha) to livestock markets in Cornwall and Devon was 27:1 and 25:1, respectively, providing a higher concentration of markets than both the South West regional and National averages but lower than those of the West Midlands and Yorkshire & the Humber.

¹² Area of grassland, sole right rough grazing and crops grown for livestock.

Rosenthal (1981) reports that in 1980 there were 30 livestock auction markets in Cornwall and Devon. By 1997 the number had declined to 23; 8 in Cornwall and 15 in Devon, 3 of which were used for periodic or seasonal sales of breeding and/or store stock only (Figure 2.2).

Figure 2.2 Livestock Auction Markets in Devon and Cornwall in 1997



Source: Livestock Auctioneers' Association 1998

In 1997, the frequency of live auction sales at markets in England ranged from a single annual event to four per week, providing over 209 weekly market auctions, 16 fortnightly, 13 monthly and 67 seasonal, periodic or annual sales, the latter predominantly for breeding and store stock. Weekly marketing opportunities were highest for prime¹³ sheep followed by prime cattle and were lowest for prime pigs in England (Table 2.3). Whilst marketing

¹³ Animals destined for slaughter and subsequent human consumption.

opportunities do not give any indication of throughputs, a higher percentage of sheep were sold via livestock auction markets in the UK 1997, followed by cattle and then pigs (see Table 2.1). Regional weekly marketing opportunities were highest within the South West.

Table 2.3 Weekly Marketing Opportunities for Prime Cattle, Sheep and Pigs at Livestock Auction Markets in the England Regions 1997

	Prime Cattle	Prime Sheep	Prime Pigs
East Midlands	11	13	12
Eastern	4	4	4
North East	5	6	5
North West	18	21	13
South East	10	10	9
South West	31	29	18
West Midlands	17	21	16
Yorkshire and the Humber	19	19	19
England Total	115	123	96

Source: Livestock Auctioneers' Association 1998

The number of livestock markets is in long term decline but, whilst their demise has been predicted (Bullen 1984), Jones and Steele (1995) report that rationalisation resulted in the closure of smaller inefficient markets and the establishment of larger more efficient markets on greenfield sites. The authors (citing Brown 1994 and Smith 1994) further report that estimates of the percentage of cattle and sheep sold through the livestock market sector increased between 1980 and 1993 (Table 2.4). However, this was not the case between 1993 and 1997 (see Table 2.1) with the percentage of cattle sold via livestock markets declining by almost 13% and sheep by almost 6%. By 1997, sales of both ruminant species were below estimates for 1980.

Table 2.4 Estimates of the Percentage of Cattle and Sheep Sold via Livestock Auction Markets 1980 and 1993

	Cattle	Sheep
Percentage Sold via Livestock Markets 1980 (Smith 1994)	52	68
Percentage Sold via Livestock Markets 1993 (Brown 1994)	57	72

Source: Jones and Steele 1995

The notable decline in cattle sales via livestock auction markets between 1995 and 1997 was exacerbated by the impact of the BSE ‘crisis’¹⁴ in 1996. Jones (1997) reports that the introductory price mechanisms of the Over Thirty Months Slaughter scheme (OTMS) was initially biased in favour of deadweight sales, *viz.* sales direct to abattoir, and is reported to have diverted trade for both prime and OTMS cattle, away from livestock auction markets in their favour. Whilst Jones (1997) reports that monthly livestock auction market throughputs recovered in 1996 once the distortion in the price mechanism was rectified, the percentage of slaughter cattle sold via this channel continued to decline during 1997 (see Table 2.1).

The Calf Processing Aid scheme (CPAS), introduced to counteract the anticipated supply surplus following the export ban of cattle from the UK, exceeded targets and resulted in a reduction in supply of prime cattle after October 1997 (MLC 1997 *personal communication*). As Jones (1997) points out, some of these animals may have been sold both as stores and finished cattle in livestock auction markets, further reducing throughputs.

¹⁴ Bovine Spongiform Encephalopathy ‘crisis’. For a chronology of events, see MAFF 2000a.

The pressures on livestock markets extend beyond the BSE 'crisis' and include the recent changes in the abattoir sector (see section 2.2), the introduction of electronic auctions (see section 2.3), the introduction of legislation relating to the transport of animals in 1997 (see section 2.4.1.), and changes in the nature of meat demand and the retail sector (see sections 2.4.2 and 2.4.3).

It is clear that the number of livestock markets and their market share of slaughter stock is in decline and it is, therefore, inevitable that livestock distribution patterns from farm to abattoir will change as a result.

2.2 Direct Farm to Abattoir Sales and the Abattoir Sector

Direct sales from farm to abattoir are indicative of both vertical and horizontal linkages between producers, processors and retailers and heretofore have been more prevalent in the pig and poultry sectors than in either ruminant sector (Gunthorpe, Ingham and Palmer 1995). There is now evidence that these linkages are developing in both the beef and sheep sectors with the emergence of producer clubs, assurance schemes and co-ordinated marketing groups (McEachern and Tregear 2000) as food retailers recognise the importance of providing consumers with quality assurances to reduce the levels of uncertainty within the supply chain (Loader and Hobbs 1996). This has largely been driven by the requirements of the Food Safety Act 1990 (UK Parliament 1990), under which retailers are obliged to demonstrate 'due diligence' in their procurement of livestock necessitating full traceability and quality assurance from farm to consumer.

The following concerns have been voiced by the UK retail sector:

'...auction markets are in danger of being declared a "no buy" areas by powerful supermarket companies as they prepare to meet supply chain audits... Supermarket buyers say auction markets have a poor welfare image - but their biggest objection is the way

animals sold under the hammer lose their identity' (Agra Europe 1991).

One supermarket buyer was quoted as saying:

'This means we have to know where our animals have come from and how they were managed. This cannot be done through the auction system. As soon as we can establish a network of three cornered quality assurance partnerships with farm-groups, abattoirs and ourselves, we will refuse to handle any auction animals' (Agra Europe 1991).

The factors influencing this shift towards direct sales from farm to abattoir are intricately associated with changes in the nature of meat demand and changes within the retail sector and are discussed further in Sections 2.4.2 and 2.4.3. There have also been changes in the structure of the abattoir sector in recent years, which have impacted on the distribution of livestock from farm to abattoir.

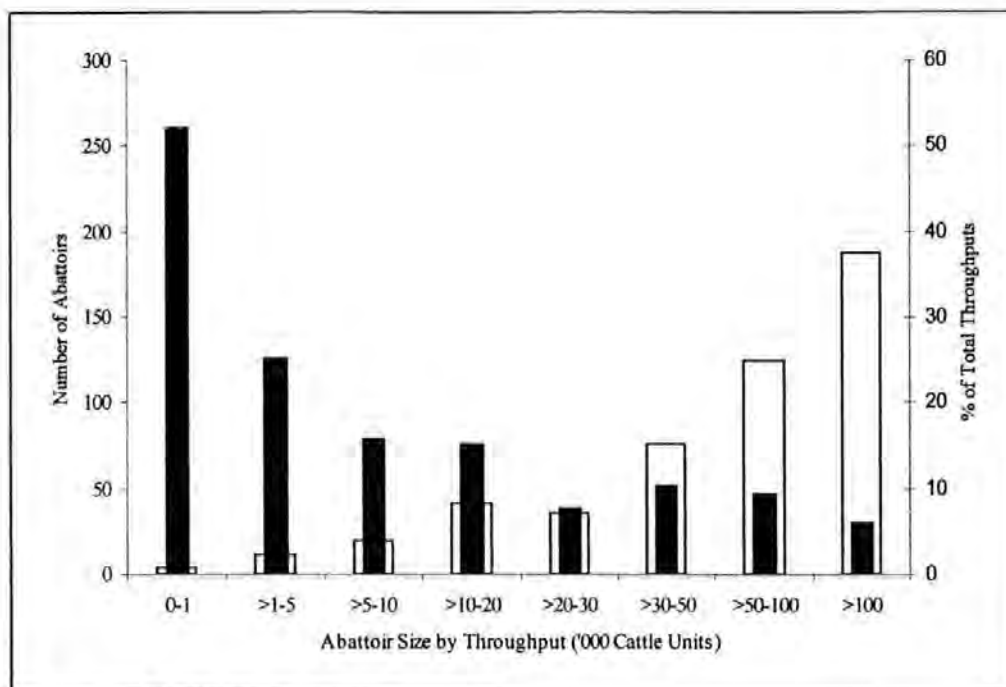
Abattoir numbers have fallen substantially in recent years and, by 1997, 458 remained in Great Britain - approximately 24% of the number in 1972 (MAFF 1997a, Meat Hygiene Service 1998, MLC 1999a, Scottish Office Agriculture, Environment and Fisheries Department 1998, Welsh Office Agriculture Department 1998). The MLC (1999a) reports that average abattoir throughputs increased from 6,600 to 29,002 cattle units¹⁵ within the same period, illustrating increasing concentration within the industry, with the closure of a high number of small plants. Recent concentration is evidenced by Key Note (1998) who report that between 1994 and 1996 the percentage of abattoir businesses with a turnover of £1m increased from 43% to 50.6%.

In Great Britain in 1992, 129 abattoirs (those with throughputs greater than 30,000 Cattle Units pa; less than 11% of the total number) accounted for over 62% of total slaughterings of cattle, sheep and pigs. The larger number of smaller abattoirs (387; 54% of the total),

¹⁵ 1 Cattle Unit = 1 bovine animal, or 5 sheep or 2 pigs. These data are illustrative only and not comparable with European Livestock Units (ELU).

with an annual throughput of less than 5,000 Cattle Units, accounted for 3% of slaughterings (MLC 1994a; Figure 2.3).

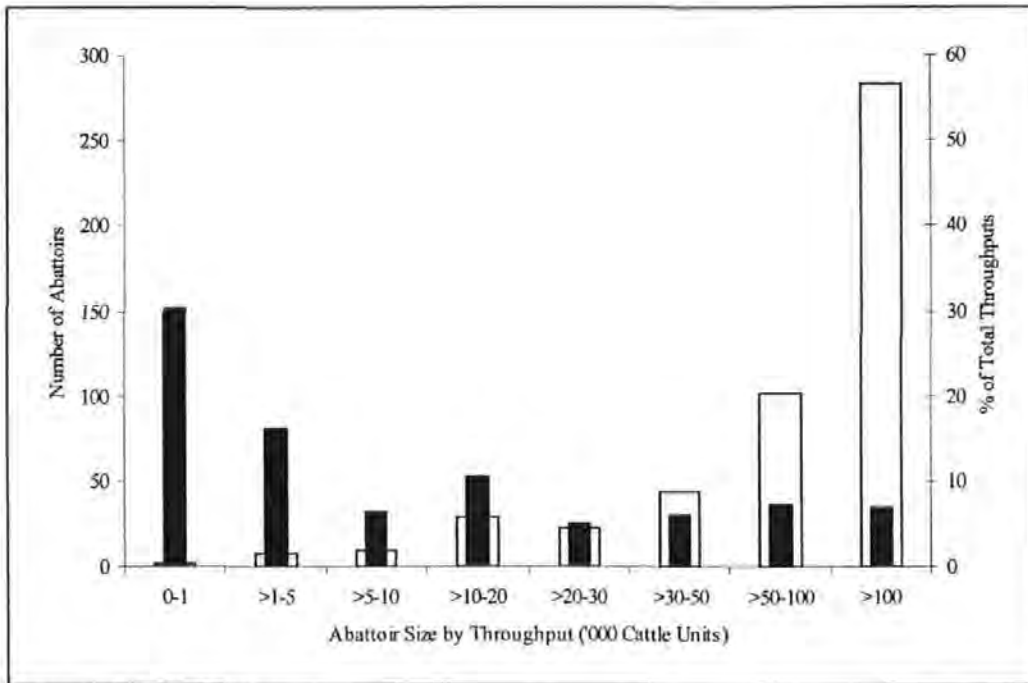
Figure 2.3 Abattoir Numbers (■) and Percentage Throughput (□) in England in 1992 by Size of Abattoir



Source: MLC 1994a

By 1997/8, the number of abattoirs with throughputs of over 30,000 Cattle Units pa had declined to 102. However, these accounted for almost 86% of total slaughterings. Small abattoirs with throughputs of less than 5,000 Cattle Units pa had also declined numerically to 232 by 1997/8 and these accounted for less than 2% of total slaughterings (MLC 1999a; Figure 2.4).

Figure 2.4 Abattoir Numbers (■) and Percentage Throughput (□) in England in 1997/8 by Size of Abattoir

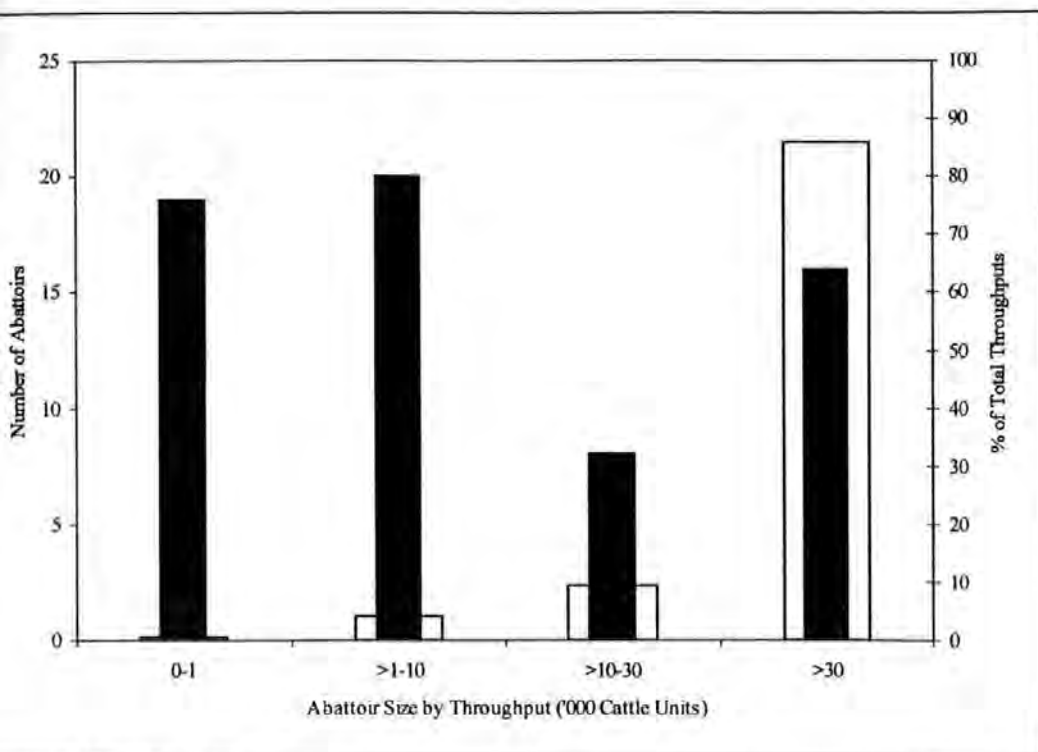


Source: MLC 1999a

In the South West in 1997/8, abattoirs with throughputs greater than 30,000 Cattle Units (25% of the total) accounted for 86% of total throughput, whilst small and medium sized plants (62% of the total number), with throughputs of less than 10,000 Cattle Units pa, accounted for just 4.6% of throughputs. (Figure 2.5). In all regions in England small abattoirs were numerically dominant but accounted for a small percentage of aggregate throughput (MLC 1999a).

Figure 2.5 Abattoir Numbers (■) and Percentage Throughput (□) in the South

West in 1997/8 by Size of Abattoir



Source: MLC 1999a

The process of concentration within the abattoir sector has been evident since the mid 1950s and the MLC (1999a) report that until the early 1990s, this was largely driven by market forces. However, the introduction of the Single European Market on 1st January 1993 was accompanied by EU wide legislation governing abattoirs, which harmonised inspection, hygiene and structural standards throughout the European Union.

Legislative controls and the costs associated with compliance now exerted a strong influence on the structure of the abattoir sector. The legislation was applied in Great Britain by the Fresh Meat (Hygiene and Inspection) Regulations 1992 (UK Parliament 1992) and later replaced by the Fresh Meat (Hygiene and Inspection) Regulations 1995 (UK Parliament 1995). The deadline for compliance, under temporary derogations, was set

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remained under temporary derogation, pending Full Throughput approval (MAFF 1997a and MAFF 1997 *personal communication*).

The number of Full and Low Throughput abattoirs in the England regions in 1997 is given in Table 2.5 and the regional distribution of abattoirs slaughtering cattle, sheep and pigs is given in Table 2.6. Three hundred and twenty eight abattoirs were licensed to slaughter more than one species of livestock, whilst 47 were specialist single species plants. The MLC (1999a) reports that, in association with the decline in abattoir numbers, there has been a shift towards specialist single species plants, defined as plants licensed to slaughter only one species. In 1997 there were 21 specialist pig abattoirs, 16 specialist cattle abattoirs and 10 specialist sheep abattoirs (MAFF 1997a). Regional distribution of specialist abattoirs by species in England identifies that specialist ruminant abattoirs were largely located within the north and west of the country and specialist pig abattoirs in the south and east (Table 2.7).

Table 2.5 Regional Distribution of Full and Low Throughput Approved Abattoirs in England - 1997.

	Full Throughput ¹⁷	Low Throughput
East Midlands	21	42
Eastern	23	17
North East	10	13
North West	36	19
South East	13	6
South West	36	25
West Midlands	35	23
Yorkshire and the Humber	31	25
England Total	205	170

Source: MAFF 1997a and MAFF 1997 *personal communication*

¹⁷ Includes 1 plant under temporary derogation.

Table 2.6 Regional Distribution of Full and Low Throughput Abattoirs Slaughtering Cattle, Sheep and Pigs – 1997

	Full Throughput ¹⁸			Low Throughput		
	Cattle	Sheep	Pigs	Cattle	Sheep	Pigs
East Midlands	17	15	15	42	40	19
Eastern	16	13	20	16	17	15
North East	9	9	9	13	13	8
North West	34	30	25	18	19	7
South East	11	12	9	6	6	5
South West	32	29	25	25	25	19
West Midlands	30	32	22	23	22	18
Yorkshire and the Humber	25	25	23	22	23	18
England Total	174	165	148	165	165	109

Source: MAFF 1997a and MAFF 1997 *personal communication*

Table 2.7 Regional Distribution of Specialist Abattoirs by Species in England - 1997

	Specialist Cattle Abattoirs	Specialist Sheep Abattoirs	Specialist Pig Abattoirs
East Midlands	4	1	3
Eastern	1	0	7
North East	0	0	1
North West	3	1	2
South East	0	1	1
South West	4	1	3
West Midlands	2	5	0
Yorkshire and the Humber	2	1	4

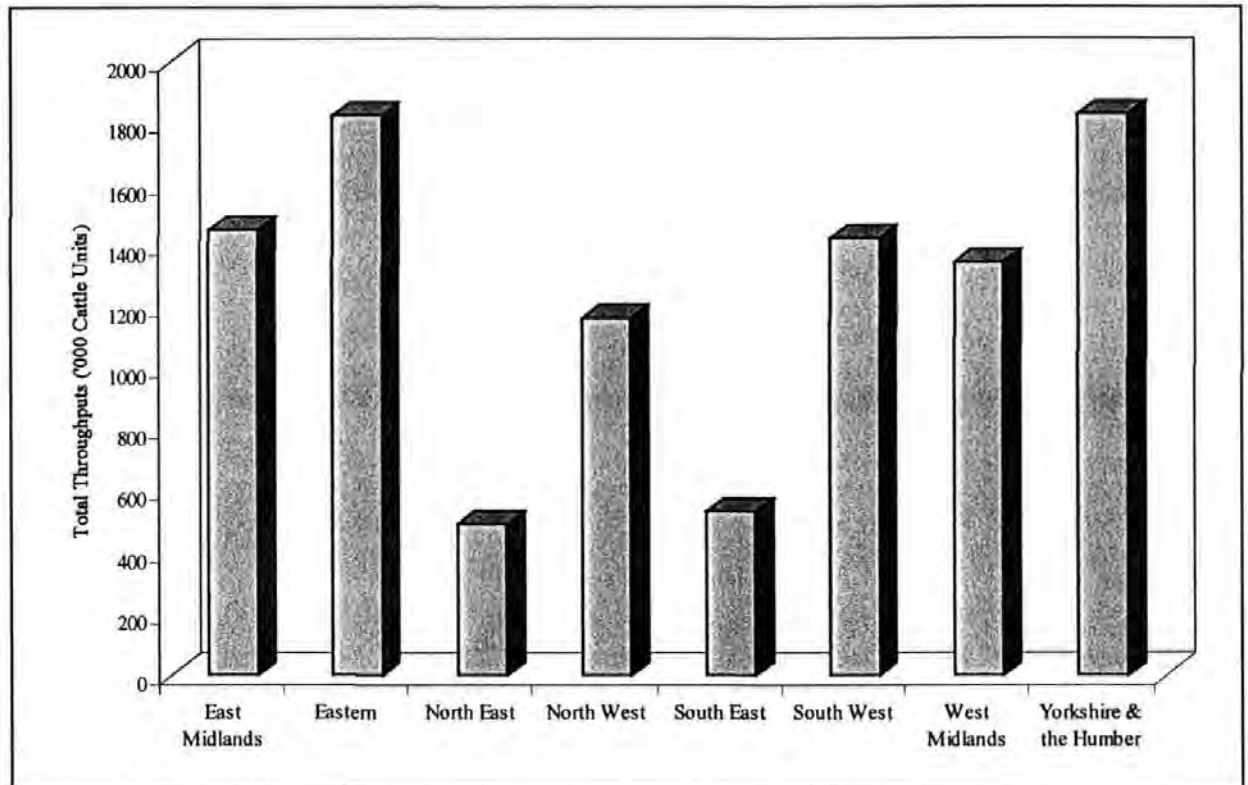
Source MAFF 1997a

Numerically, provision was lowest within the South East and the North East and highest within the East Midlands and the South West (Table 2.5). Provision, in terms of total throughputs, was also lowest in the South East and North East in 1997 with 532,820 Cattle Units (see footnote number 15) and 489,960 Cattle Units, respectively (Figure 2.6).

¹⁸ Includes 1 plant under temporary derogation.

However, highest total throughputs were in Yorkshire and the Humber and the Eastern region with 1,829,450 Cattle Units 1,821,150 Cattle Units, respectively (Figure 2.6).

Figure 2.6 Total Regional Abattoir Throughputs (Cattle Units) -1997



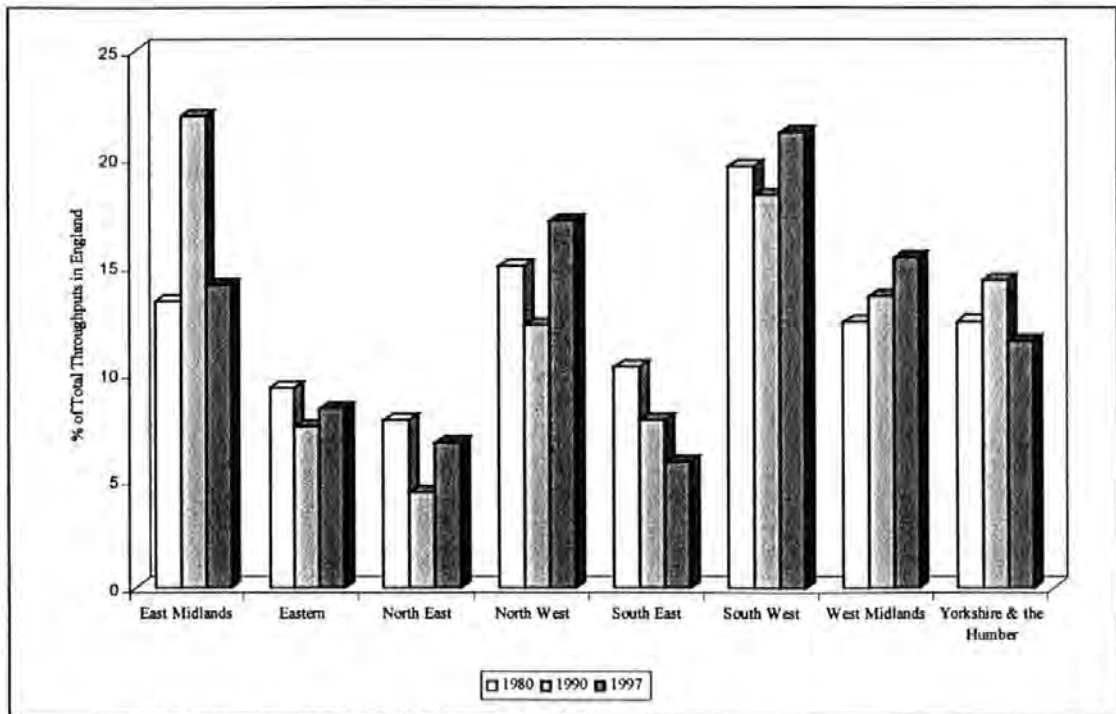
Source: MAFF 1998b

The process of concentration resulted in shifts in the regional distribution of slaughter provision. Regional data are presented as a percentage of the total slaughterings ('000 head) for each red meat species in England in 1980, 1990 and 1997 (Figures 2.7, 2.8 and 2.9).

In the cattle sector, between 1980 and 1990, the percentage slaughtered in the West Midlands, Yorkshire and the Humber and, more notably the East Midlands, increased at the expense of all other regions (Figure 2.7). By 1997, the dominance of the East Midlands region had declined and, over the 27 year period illustrated, net gains were made in the

North West, the South West, West Midlands and East Midlands. By 1997, the South West accounted for 21% of the total cattle slaughterings in England. Table 1.3 identified that in the same year, breeding herds for dairy and beef accounted for 35% and 25%, respectively, of the national herds. Therefore, the region was a net exporter of cattle before slaughter.

Figure 2.7 Regional Cattle Throughputs as a Percentage of Total Cattle Throughputs in England – 1980, 1990 and 1997

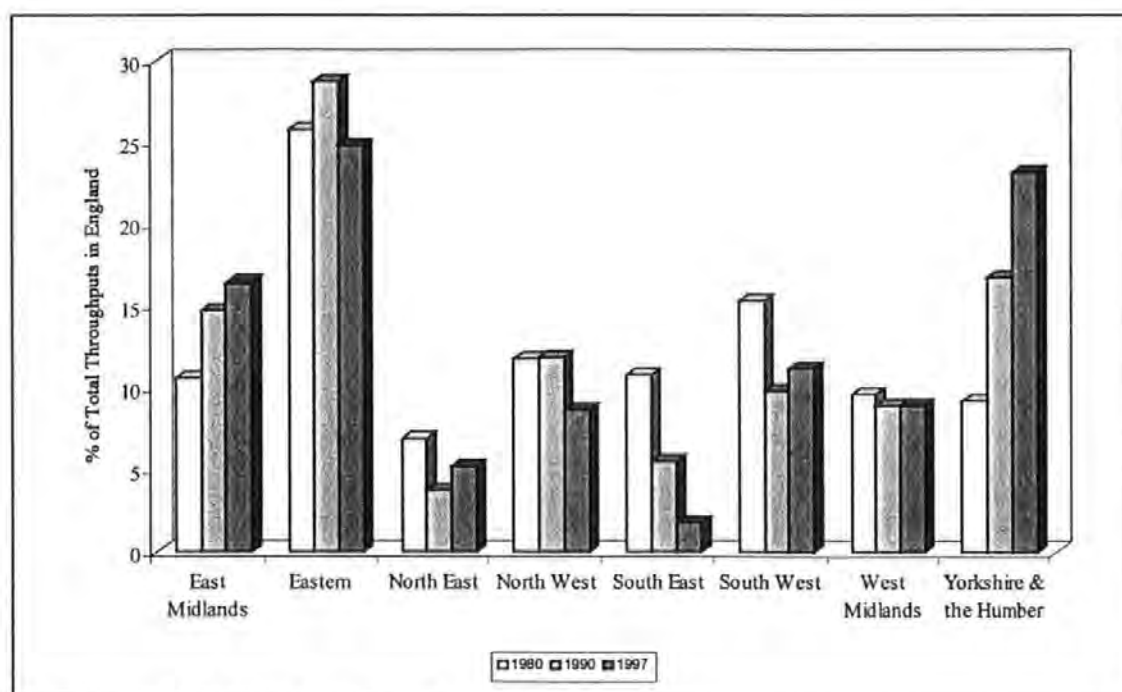


Sources: MLC 1981 and 1991, MAFF 1998b

In the pig sector, between 1980 and 1990, the percentage of animals slaughtered increased in the East Midlands, the Eastern region and in Yorkshire and the Humber (Figure 2.8). By 1997, whilst the percentage slaughtered in the Eastern region declined, over 48% of all pig slaughterings occurred in Yorkshire and the Humber and the Eastern region, identifying the source of their dominance in terms of total slaughterings of all the red meat species (Figure 2.6). By 1997, the South West accounted for 11% of the total pig slaughterings in

England. Table 1.3 identified that in the same year, the pig breeding herd accounted for over 13% of the national herd. Therefore, the region was a net exporter of pigs before slaughter.

Figure 2.8 Regional Pig Throughputs as a Percentage of Total Pig Throughputs in England – 1980, 1990 and 1997



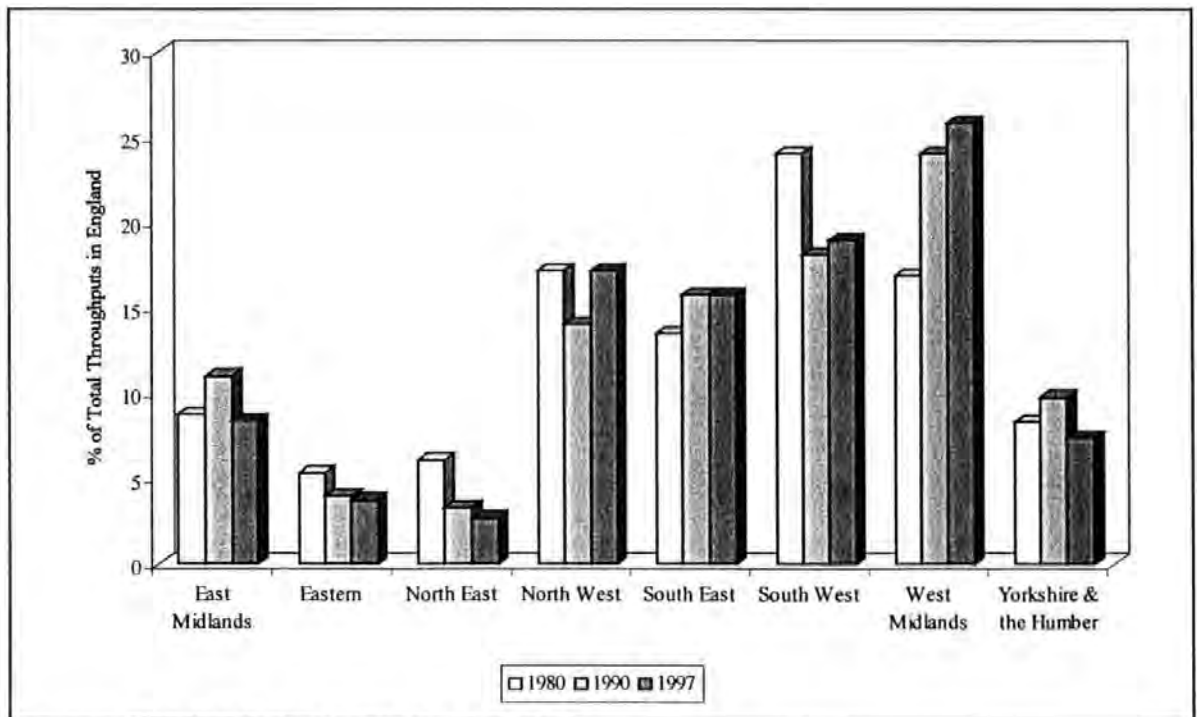
Sources: MLC 1981 and 1991, MAFF 1998b

In the sheep sector, between 1980 and 1990, the percentage of animals slaughtered increased in the East Midlands, the South East, the West Midlands and Yorkshire and the Humber. By 1997, the West Midlands further increased its share of national slaughterings and was the only region to show a net gain over the 27 year period. By 1997, the South West accounted for 19% of the total sheep slaughterings in England. Table 1.3 identified that in the same year, the sheep breeding flock accounted for over 21% of the national

flock. Therefore, the region was a net exporter of sheep before slaughter.

The process of concentration has affected the regional distribution of slaughter provision in recent years. The MLC (1999a) report that concentration is particularly evident in the pig sector and this is confirmed by the dominance of the Eastern region and Yorkshire and the Humber, which have more than half of all specialist pig abattoirs in the country (Table 2.5).

Figure 2.9 Regional Sheep Throughputs as a percentage of Total Sheep Throughputs in England – 1980, 1990 and 1997

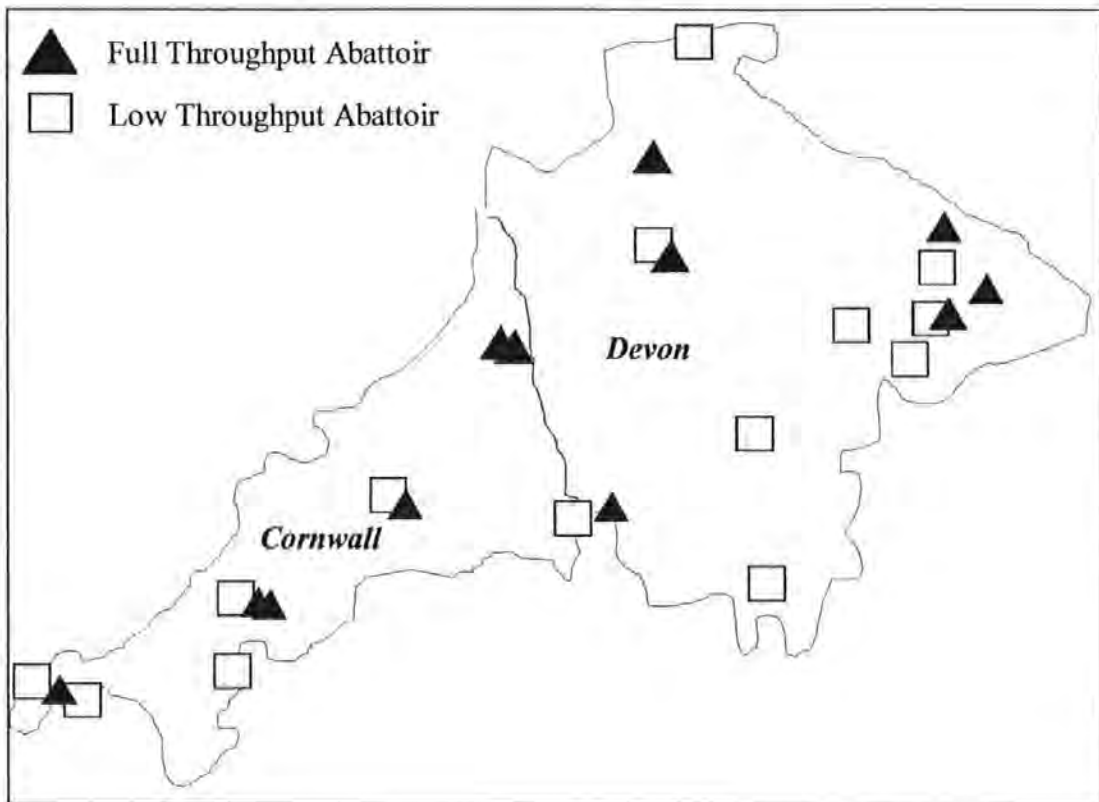


Sources: MLC 1981 and 1991, MAFF 1998b

In 1997, the South West region accounted for a lower percentage of total slaughterings in England in all three red meat species than would have been expected, using breeding livestock numbers as the benchmark.

In Cornwall and Devon, of the 26 abattoirs remaining in 1997, 12 were Full Throughput and 14 Low Throughput (Figure 2.10). Three abattoirs in Cornwall were specialist single species plants; one sheep and two cattle, whilst all abattoirs in Devon were licensed to slaughter more than one species (MAFF 1997a). One abattoir in Devon, however, was identified by the MLC (1999a) as a major sheep abattoir in the country; two were identified as major cattle abattoirs and one a major pig abattoir. The number of abattoirs in the two counties declined from 31 in 1980 (Rosenthal 1981).

Figure 2.10 Abattoirs in Cornwall and Devon – 1997

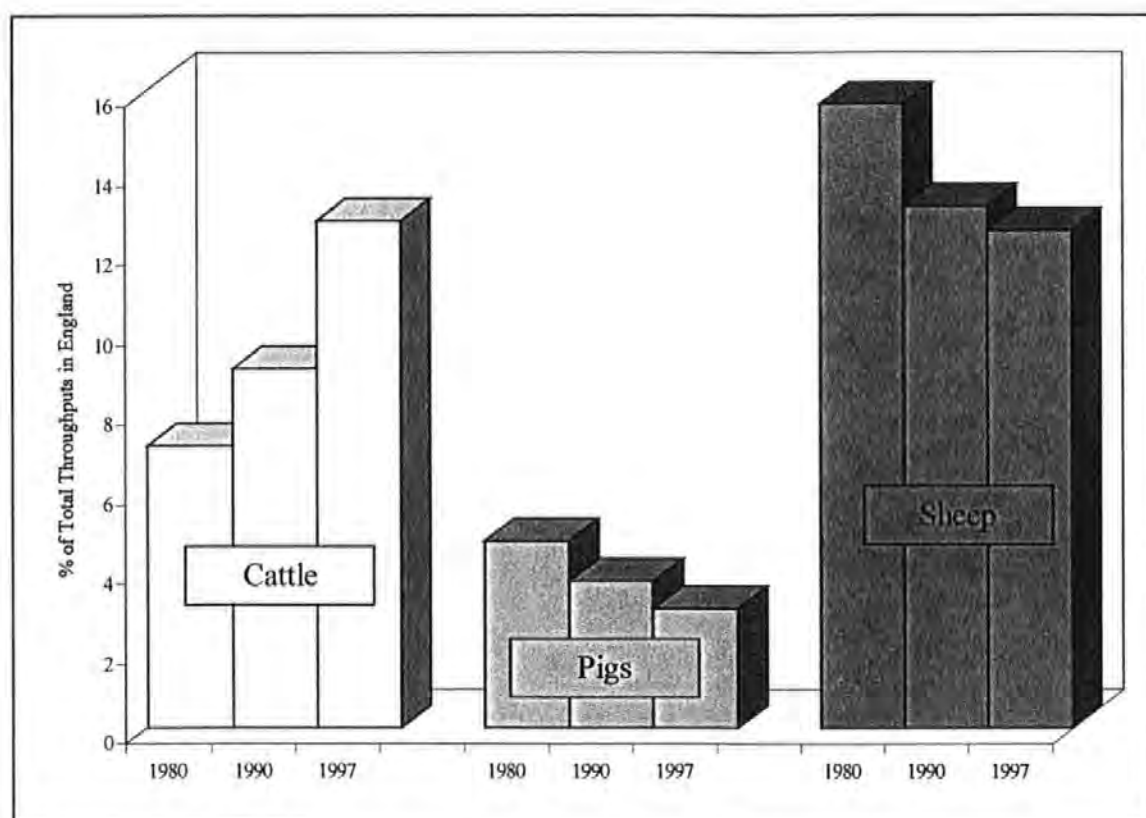


Source: MAFF 1997a and MAFF 1997b *personal communication*

Aggregate cattle throughputs for the two counties, expressed as a percentage of the total in England, increased between 1980 and 1997 from 7% to almost 13% whilst those for pigs

and sheep both declined from approximately 5% to 3% and over 15% to 12%, respectively (Figure 2.11). Once again, using breeding livestock populations as the benchmark (see Table 1.3), Cornwall and Devon were net exporters of all three red meat species in 1997.

Figure 2.11 Aggregate Slaughter Throughputs of Cattle, Pigs and Sheep ('000 head) in Cornwall and Devon – 1980, 1990 and 1997



Source: MAFF 1998b

The slaughtering industry is characterised by low margins and high volume (Key Note 1995). Moreover, the MLC (1994a and 1999a) have reported significant over capacity since the 1980s, which was exacerbated by abattoirs increasing capacity in the process of upgrading to meet EU wide legislative requirements. In January 1996, the MLC (1996 *personal communication*) suggested a managed programme of rationalisation designed to

remove 1.8 million ELU of capacity by voluntary, compensated closures financed by levies paid by remaining abattoirs. However, the slaughter programmes introduced as a result of the BSE 'crisis', including the OTMS, CPAS and the Selective cull, provided some reprieve for the industry and no further action was taken.

The abattoir sector has become increasingly concentrated in recent years, a phenomenon exacerbated by the legislative requirements of the Single European Market. The dominance of the large Full Throughput plants, which accounted for 86% of all slaughterings in 1997/8 (see Figure 2.4), and shifts in the levels of slaughter provision within the country (see Figures 2.7, 2.8 and 2.9) inevitably means that livestock distribution patterns from farm to slaughter have been affected.

The reduction in the number of abattoirs throughout the country has effectively reduced the number of livestock buyers, thus increasing the oligopsonistic¹⁹ nature of meat procurement and impinging on the marketing of livestock through markets and electronic auctions.

2.3 Electronic Livestock Marketing

Marketing channels for slaughter livestock now include electronic auction systems, introduced into the UK in 1989 (Grega and Ray 1992), in addition to livestock auction markets and direct sales to abattoirs. They were introduced by a farmers' co-operative

¹⁹ An oligopsony is a market in which there are few buyers and many sellers (Black 1997).

(Aberdeen Northern Marts Ltd) which also owned a livestock auction market in Aberdeenshire, in response to the increase in direct farm to abattoir sales (Grega and Ray 1992).

The co-operative bought the UK rights for a Canadian system which allowed real-time auctioning of sequential lots of animals (Graham 1997). Subsequently, a network of 11 franchises, operated by livestock auctioneers and known as EASE (Electronic Auction Systems Europe), was established to provide nationwide coverage (Grega and Ray 1992). By 1997, four organisations were participating in the UK electronic auctioneering market. These included EASE, LEAN (Lysis Electronic Auction Network), Direct, and Agvision, (Graham 1997).

Electronic auctions may employ a variety of technological mechanisms to link purchasers and vendors, and Henderson (1984) defines electronic marketing as:

' simultaneous trade negotiations among spatially separated buyers and sellers channelled into an interactive central market through electronic communications. Product movement occurs later. Neither traders nor products are physically assembled at a common location; products are sold by description rather than personal inspection by the buyer. '

The author identified five characteristics of electronic auctions: organised trading, centralised, competitive price negotiations, remote access through technological mechanisms, description selling and post sale product delivery. These characteristics are not all evident in livestock auction market transactions or direct sales from farm to abattoir.

Studies examining electronic livestock auction systems in the United States (Schrader 1984; Sporleder 1984; Rhodus, Baldwin and Henderson 1989; Bailey, Peterson and Brorsen 1991) and the UK (Grega and Ray 1992) have identified the following factors

influencing their adoption and sustainability:

- There must be disadvantages or limitations in existing marketing systems. In the case of the UK, livestock auction markets were experiencing competition from direct farm to abattoir sales and electronic systems were adopted by livestock auctioneers to secure market share. Grega and Ray (1992) indicate that electronic auctions would attract more sellers from the livestock auction system than direct farm to abattoir sales and as Graham (1997) points out, this would put further pressure on livestock auction market throughputs.
- Electronic auctions increase the number of buyers. The number of buyers within an electronic auction system is higher than both the other systems (Grega and Ray 1992) attracting both regular and occasional buyers.
- An increased number of buyers increases competition, thus reducing the extent to which a limited number of buyers can dominate a market.
- Through increased competition, prices are increased. Purchasers either bid on a deadweight basis or liveweight and grade assessment with premia and deductions on slaughter. Price comparisons between direct farm to abattoir sales, live auction markets and electronic auctions are, therefore, confounded because published prices from electronic auctions may only identify the bid price and not the price paid. Grega and Ray (1992), however, report that there was only a small price advantage in selling stock via electronic auction as opposed to direct to the abattoir. The studies in the

power of the major abattoirs and multiple retailers is reduced.

Graham (1997) suggests a number of reasons for poor penetration. The entry of additional competing organisations into the market increased the costs of the system because each maintains a network of fieldsmen. The size of each market is also reduced and the low profits inhibit investment in system updating and development. The operational similarity between organisations enabled auctioneers and fieldsmen to transfer allegiance taking their suppliers with them. This resulted in volatile swings in market share between organisations and reduced confidence of both sellers and buyers. For sellers, the social interaction at livestock auction markets does not take place with the electronic auction system and buyers would be unlikely to relinquish established supply chain relationships with producers.

Austin (1993) reports that results of a survey commissioned by the *Farmers Weekly* indicated that lack of knowledge about electronic marketing systems, the effect on farmers' social lives and transport problems because of sourcing over greater distances were all factors inhibiting the adoption of electronic marketing by some sellers.

Electronic marketing of cattle eroded the market share of direct farm to abattoir sales between 1991 and 1993 (Table 2.1), as did sales via livestock auction markets. However, after 1993 cattle sales via electronic auctions declined and fell below 1991 levels by 1997. Electronic sheep sales increased between 1991 and 1995 reaching over 1 million head in that year. By 1997, however, these had also declined to below 1991 levels, in absolute

terms. The electronic auction system introduced a new dimension in the transport of livestock from farm to abattoir and patterns of distribution will have been affected as a result.

Other factors influencing the use of electronic auction systems include the changes in the structure of the abattoir sector, effectively reducing the number of buyers for livestock (see Section 2.2), the introduction of legislation relating to the transport of animals (see section 2.4.1), and changes in meat demand and the retail sector (see sections 2.4.2 and 2.4.3.).

2.4 Factors Affecting Distribution Channel Utilisation

The previous three sections of this chapter have provided an overview of the main distribution channels from farm to abattoir used in this country, including discussion of those factors affecting their use which are germane to specific channels. The following sections discuss the effect of three holistic influences: the introduction of legislation relating to the transport of animals (Section 2.4.1), the demand for meat (Section 2.4.2) and the retail sector (Section 2.4.3).

2.4.1 The Welfare of Animals (Transport) Order 1997

The Welfare of Animals (Transport) Order 1997 (UK Parliament 1997) came into force on 1st July 1997, enacting EU-wide legislation on animal welfare during transit. This order revoked and re-enacted The Welfare of Animals during Transport Order 1994 (UK Parliament 1994), as amended by The Welfare of Animals during Transport (Amendment) Order 1995 (UK Parliament 1995b).

New arrangements were introduced relating to vehicle standards; maximum species-specific, journey times and space allowances for farm livestock; feeding watering and rest periods; the authorisation of transporters; and competence and assessment requirements. An overview of those elements of the order that directly impact on domestic road journeys and, therefore, distribution channel utilisation of cattle sheep and pigs, *viz.* vehicle standards and permissible journey times, follows.

2.4.1.1 Vehicle Standards

Arrangements for vehicle standards introduced the concept of ‘basic’ and additional ‘higher’ standards and are linked to maximum permissible journey times. All vehicles used to transport animals are required to comply with the ‘basic’ standards. For cattle, sheep and pigs, these are set out in Schedules 1 and 2 and the ‘higher’ standards in Schedule 7 of the Order. Those relevant to road transport are reproduced in Appendix 2, for information.

2.4.1.2 Journey Times

Under The Welfare of Animals during Transport Order 1994, as amended (UK Parliament 1994 and 1995b), the permissible journey time for all classes of cattle, sheep and pigs was 15hrs, before the provision of water, food and rest was required. The rest period was not prescribed. Under The Welfare of Animals (Transport) Order 1997 (UK Parliament 1997), journeys for cattle sheep and pigs, transported on ‘basic’ standard vehicles are limited to a maximum of 8 hours (Table 2.8) and unless livestock are delivered for immediate slaughter, transportation must be followed by 24hrs rest.

Journeys on ‘higher’ standard vehicles are age and species specific. For unweaned calves, lambs and pigs, journeys are limited to a maximum transport period of 9 hours (‘1st

leg'), a rest period of at least 1hr followed by a further maximum transport period of 9 hours ('2nd leg'). For all other cattle and sheep, journeys are limited to a maximum period of 14 hours ('1st leg'), a rest period of at least 1hr followed by a further maximum transport period of 14 hours ('2nd leg'). Rest periods must be of sufficient duration to allow all animals to be watered and, if necessary, fed. For all other pigs, journeys are limited to a maximum of 24 hours with continuous access to liquid. The '2nd leg' of journeys, or for pigs the single journey, on 'higher' standard vehicles may be extended by 2 hours depending on the proximity of the final destination (Table 2.8). As for journeys on 'basic' vehicles, unless livestock are delivered for immediate slaughter, transportation must be followed by 24hrs rest.

Table 2.8 Maximum Journey Times (hrs), Minimum Rest Periods (hrs) and Total Transit Time (hrs) for Cattle, Sheep and Pigs

		Maximum Journey Time (hrs) '1st leg'	Minimum Rest Period (hrs)	Maximum Journey Time (hrs) '2nd leg'	Total Transit Time (hrs)
'Basic' Standard Vehicle	All Species	8	na	na	8
'Higher' Standard Vehicle	Unweaned calves, lambs and pigs	9	1	9 (+2)	21
	Other cattle and sheep	14	1	14 (+2)	31
	Other pigs	24 (+2)	na	na	26

na = not applicable; +2 = permitted extension to journey time (hrs) depending on proximity of final destination. Source: UK Parliament 1997

For domestic journeys, all animals must be accompanied by documentation in the form of an Animal Transport Certificate (ATC) or any other readily identifiable means (Appendix 3).

For livestock sold via livestock auction markets or held at collection centres (also known as lairages, assembly points or staging posts), total permissible journey times are affected by the age and species of the animals, the status of the vehicles used into and out of market, the duration and the distance of the inward journey, the provision of water and, if necessary, food whilst held, accompanying documentation and the status of the market or collection centre. The status relates to EU approval as a collection centre under Council Directives 64/432/EEC²⁰, for cattle and pigs and 91/68/EEC²¹ for sheep and goats.

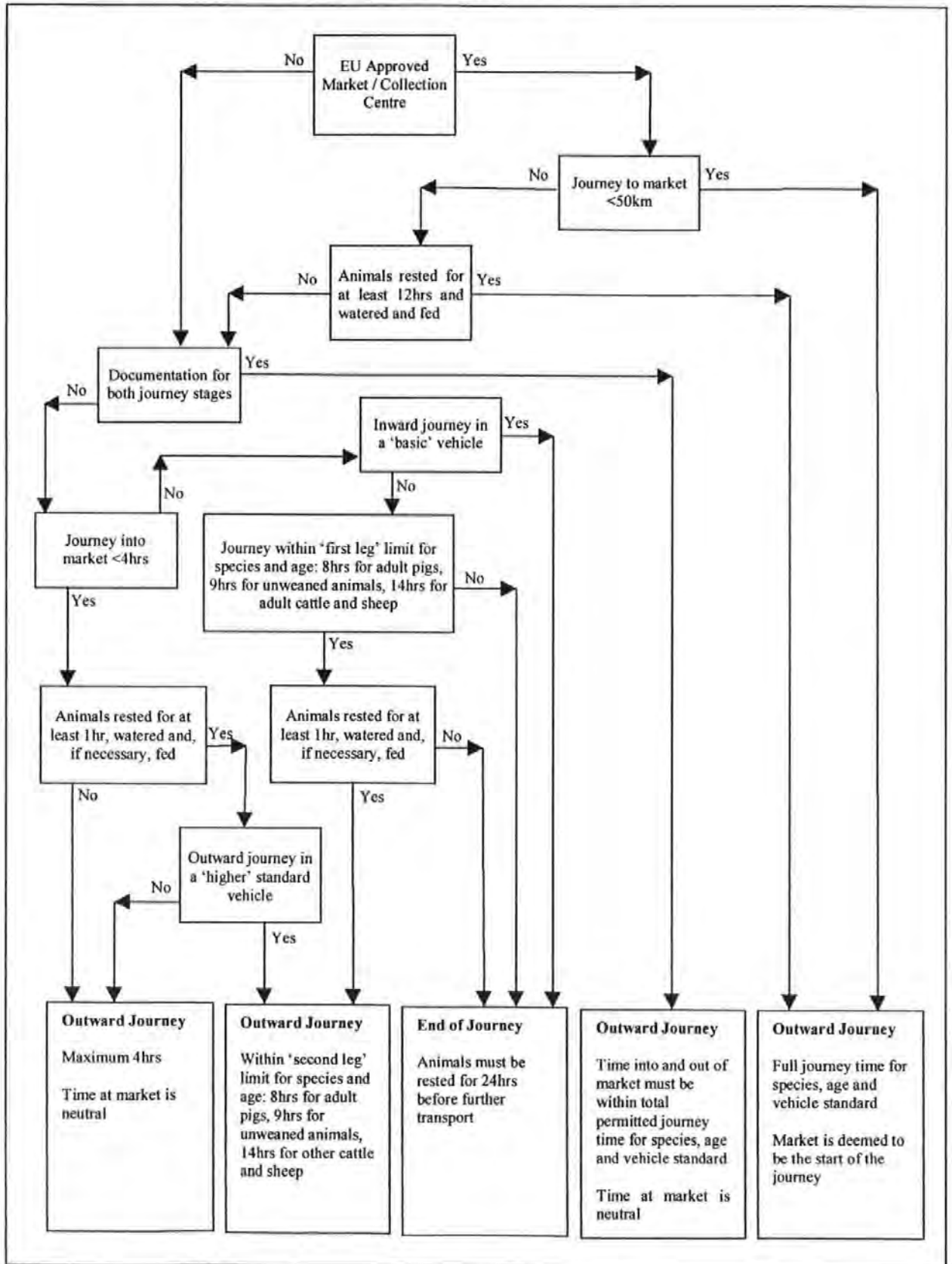
EU approved markets or collection centres may be regarded as the start of the journey for the purposes of the Order if the journey into market or collection centre is less than 50km or when animals have been rested for 12hrs, watered and fed. In these cases, the full journey times for the age, species and standard of vehicle apply (Table 2.8). A schematic illustrating permissible journey times for livestock sold via livestock auction markets or held at collection centres is given in Figure 2.12.

²⁰ On animal health problems affecting intra-Community trade affecting bovine animals and swine. OJ No. L121, 29.7.64 (Special Edition 1963-64, p. 164) as last amended by Council Directive 95/25/EC, OJ No. L148, 30.6.95, p. 52 (UK Parliament 1997).

²¹ On animal health conditions affecting intra-Community trade affecting ovine and caprine animals. OJ No. L46, 19.2.91 p. 19 as last amended by Council Decision OJ No. L1, 1.1.95, p. 1 (UK Parliament 1997).

Under some circumstances (shown in Figure 2.12), adult pigs may only be transported for 8hrs from a market if the journey into market was not more than 4hrs hours on a 'basic' standard vehicle or 8hrs on a 'higher' standard vehicle. For all other classes of livestock, journey times are those given in Table 2.8, modified by the status of the vehicles used into and out of market, the duration and the distance of the inward journey, the provision of water and, if necessary, food whilst held, accompanying documentation and the status of the market or collection centre.

Figure 2.12 Schematic Illustrating Permissible Journey Times for Animals Sold via Livestock Auction Markets and Held at Collection Centres



Source: MAFF 1998c

The introduction of dual vehicle standards, and their interaction with age and species specific permissible journey times and prescribed rest periods, will undoubtedly have an impact on all three main livestock distribution channels. For example, the Road Haulage Association (1997 *personal communication*) indicated that whilst there were approximately 3,000 livestock hauliers in Great Britain in 1997, few vehicles would meet the 'higher' vehicle standards prescribed in The Welfare of Animals (Transport) Order 1997 (UK Parliament 1997). However, no further quantification was available.

The Order may militate against livestock auction market throughputs more than sales direct from farm to slaughter, whilst the effect on electronic auction systems is unclear. For example, EU approved markets or collection centres are deemed to be the start of a journey for livestock if the inward journey is less than 50km, or when animals have been rested for 12hrs, watered and fed (Figure 2.12). Markets and collection centres that are not so approved cannot be deemed to be the start of journeys. In 1997, of the 146 livestock auction markets in England, 67 were approved as EU collection centres. Within Cornwall, 6 markets were EU approved in 1997, but none in Devon. A further 29 premises were approved as EU collection centres in England, but no additional premises were so approved in Cornwall and Devon.

In a survey of journey times of over 124,000 slaughter sheep arriving at two abattoirs in the south of England, Warriss, Beavis and Young (1990) found that over 90% of animals arriving at both plants had journeys of not more than 10hrs, whilst over 50% travelled for 5 hours or less. The maximum journey duration recorded was 16hrs. However, the authors estimated that approximately 70% of the animals came via livestock auction markets and the times recorded were only for journeys from the markets to the abattoir. Thus the total transit times would have been substantially longer than indicated by the survey. Jarvis and

Cockram (1994) recorded journeys of up to 8hrs in a study of lambs arriving direct from farms to an abattoir.

In an earlier survey of nearly 50,000 slaughter pigs killed in 5 abattoirs in England, Warriss and Beavis (1986) identified that over 57% travelled for 2hrs or less and that 96% travelled for 7hrs or less. The maximum recorded journey duration was 11hrs, which the authors noted was exceptional. Guise (1996) reports that maximum pig journey time from farm to slaughter in one survey was 8 hours 30 minutes.

No surveys describing the temporal characteristics of domestic road journeys experienced by cattle have been identified.

The evidence in the literature suggests that commercial transport times of slaughter sheep may be longer than those of pigs. However, no studies have identified total journey times for any of the red meat species sold via livestock auction markets or electronic auction systems. The Welfare of Animals (Transport) Order 1997 (UK Parliament 1997) introduced new arrangements for vehicle standards, which, in association with age and species specific limits on journey times and rest periods, will impact upon the journeys experienced by animals within all three distribution channels. It is suggested that the arrangements for journeys of animals sold via livestock auction markets will put further pressure on market throughputs, particularly those not approved as EU collection centres.

Two further factors will affect the distribution of livestock and channel utilisation levels. It is suggested that the demand for meat and changes within the retail sector have an holistic influence. These factors are inter-related and this chapter continues with an examination of the demand for meat; the changes within the retail sector are discussed in Section 2.4.3.

2.4.2 Changes in the Demand for Meat

The demand for meat *per se*, and the nature of that demand, has been undergoing change in this country since the 1950s (Mark 1989) and this section commences with an overview of those changes in recent years. A discussion of the factors effecting change and their influence on livestock distribution channels follows.

Between 1973 and 1997, total meat consumption in the UK rose from 3.8 million tonnes to 4.3 million tonnes, an increase of 13% (MLC 1988, 1992 and 1998b; Table 2.9). However, there were marked differences in consumption trends between meat types. Consumption of beef and veal, mutton and lamb, bacon and offal all declined and lost market share in favour of pork and, more particularly, poultry. Consumption of beef and veal declined by almost 24% in the period considered, and market share fell from approximately 30% of the total market to 20%. The effect of the BSE crisis reduced beef and veal consumption to 739,000 tonnes in 1996 from 901,000 tonnes in 1995 (not shown in Table 2.9) but, by 1997, this had recovered to 843,000 tonnes. Consumption of mutton and lamb declined by 26% and market share from 13% to 8%.

Table 2.9 UK Meat Consumption Trends ('000 tonnes) and Percentage Change in Market Share of Different Meat Types 1973 –1997 (Selected Years)

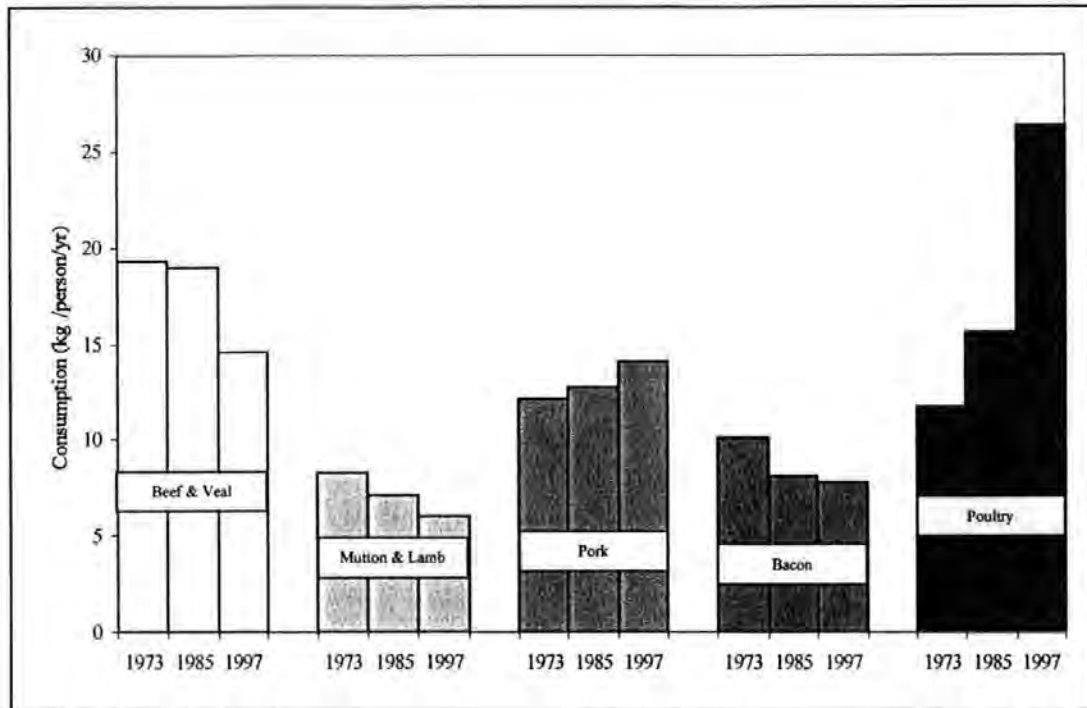
	1973	1977	1981	1985	1989	1993	1997	% Change in Market Share '69 –'97
Beef & Veal	1,107	1,205	1,131	1,125	1,063	1,066	843	-10%
Mutton & Lamb	473	401	391	412	411	382	351	-5%
Pork	686	651	719	721	759	808	844	+2%
Bacon	571	496	495	462	448	415	460	-4%
Poultry	661	681	771	909	1,061	1,157	1,614	+20%
Offal	221	259	265	273	233	214	165	-2%
Total	3,719	3,693	3,772	3,902	3,975	4,042	4,277	

Sources: MLC 1988, 1992 and 1998b

The consumption of pork increased by 23% with market share increasing by 2%. The most notable change in demand in the period considered was for poultry. Total consumption increased by 144% and market share by 20%.

Per capita consumption of total meat also increased between 1973 and 1997 from 61.5kg to 68.6kg, respectively (MLC 2000b). As would be expected from the data presented in Table 2.9, there were differences in consumption trends between meat types with that of beef and veal, mutton and lamb and bacon declining in favour of pork and poultry (Figure 2.13).

Figure 2.13 Per Capita Consumption of Beef & Veal, Mutton & Lamb, Pork, Bacon and Poultry (kg/person/year) in the UK – 1973, 1985 and 1997



Source: MLC 2000b

Domestic meat production expressed as a percentage of consumption²² gives a broad indication of the levels of self-sufficiency and, therefore, the potential to meet demand. In all the red meat sectors, self-sufficiency increased between 1973 and 1997 (MLC 1988, 1992 and 1998b; Table 2.10). However, there were differences between meat types. Beef and veal production increased from 77% of consumption in 1973 to 102% in 1985, falling back to 82% in 1997. In 1995, prior to the BSE 'crisis', production of 974,000 tonnes exceeded 108% of consumption (not shown in Table 2.10).

²² After adjustments for imports, exports and stocks. No adjustments for live exports

Table 2.10 UK Meat Production ('000 tonnes) and self-sufficiency (in parentheses)**1973 - 1997.**

	Beef & Veal	Mutton & Lamb	Pork	Bacon
1973	854 (77%)	234 (49%)	682 (99%)	252 (44%)
1977	1,002 (83%)	223 (56%)	650 (100%)	219 (44%)
1981	965 (91%)	259 (66%)	697 (97%)	199 (40%)
1985	1,148 (102%)	304 (74%)	754 (103%)	203 (44%)
1989	978 (92%)	366 (89%)	725 (96%)	193 (43%)
1993	859 (95%)	348 (103%)	801 (99%)	181 (45%)
1997	694 (82%)	322 (92%)	880 (104%)	238 (52%)

Sources: MLC 1988, 1992 and 1998b

Mutton and lamb production increased from 49% of consumption in 1973 to 103% in 1993, falling back to 92% in 1997. Domestic production during this period increased from 234,000 tonnes in 1973 to 385,000 tonnes in 1991 declining to 322,000 tonnes in 1997. Production in both ruminant sectors is modified not only by market forces, but also by the regimes within the Common Agricultural Policy. For example, beef and veal production peaked at 1,152,000 tonnes in 1984 (not shown), when milk quotas were introduced. In 1992, quota restrictions were imposed on both the beef and sheep livestock sectors, similarly limiting production. Quotas had the effect of reducing supplies of beef and veal and limiting them thereafter.

Domestic pork production increased from 682,000 tonnes in 1973 to 880,000 tonnes in 1997. Production as a percentage of consumption was maintained at between 96% and 104% throughout. However, production of bacon was consistently below 50% of

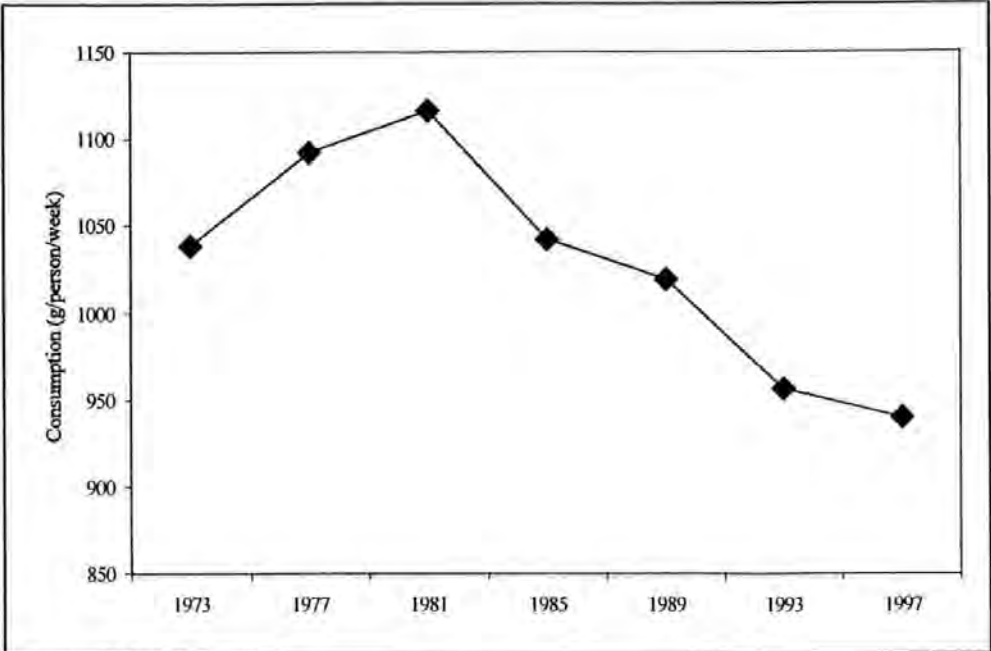
consumption until 1997 when it increased to 52%. The pig sector remains less protected by agricultural policy regimes than either ruminant sector and thus more exposed to market forces.

In summary, total meat consumption and *per capita* consumption in the UK increased in the twenty-four years from 1973 and 1997. There were differences between meat types and consumption of beef and veal and mutton and lamb both declined during the period considered, whilst that of pork, and more, particularly poultry increased. Self-sufficiency, despite the effects of the BSE 'crisis' and agricultural policy regimes, increased and remained high in 1997 in all sectors except bacon.

The demand for meat in this country may be further characterised as household consumption, *viz.* all food consumed within the home and that in the catering sector, *viz.* all food consumed outside the home. The catering sector includes, for example, hotels, restaurants, cafés, fast food outlets, school meals, and so on.

Household consumption of all meats in Great Britain increased between 1973 and 1981 from 1,038 g/person/week to 1,116g/person/week, thereafter declining to 912g/person/week in 1997 (MAFF 2000b; Figure 2.14). There were differences in trends in consumption between different meat types. After initial increases in the period considered, household consumption of all red meats, including bacon, declined whilst that of poultry increased despite falling back in 1985 (Table 2.11).

Figure 2.14 Household Consumption of all Meats (g/person/week) in Great Britain 1973 - 1997



Source: MAFF 2000b

Table 2.11 Household consumption of different meat types (g/person/week) in Great Britain 1973 -1997

	Beef & Veal	Mutton & Lamb	Pork	Bacon	Poultry	Other Meat & Meat Products
1973	179	126	85	151	173	325
1977	233	113	94	152	174	326
1981	198	121	108	150	207	332
1985	185	93	98	137	195	334
1989	171	85	89	130	220	324
1993	133	66	80	112	238	327
1997	110	56	75	113	254	332

Source: MAFF 2000b

Meat consumed in the catering sector is an important component of the total demand for meat. This sector has expanded in recent years and the MLC (1994b and 1999b) indicates

that between 1983 and 1997, there was an 31% increase in catering consumption of red meat and that the volume of mutton and lamb, pork and bacon sold to the catering sector increased (Table 2.12). The volume of mutton and lamb increased by 83%, whilst that of pork and bacon both increased by 40% or over. Beef consumption, after increasing by 14% between 1983 and 1993, declined to below 1983 levels as a direct result of the BSE 'crisis'. In 1983, the catering sector accounted for approximately 23% of total demand for red meat (excluding offal) and by 1997 this had increased to 32% (MLC 1992, 1994b and 1999b). The growth in this sector contrasts with the decline in household meat consumption and more particularly with that of red meat.

Table 2.12 Estimated Consumption of Red Meat in the UK Catering Sector ('000 tonnes) 1983 - 1997

	1983	1993	1997	% change 1983 - 1997
Beef & Veal	217	247	216	<-0.5%
Mutton & Lamb	58	78	106	83%
Pork	210	254	300	43%
Bacon	125	139	175	40%
Total Red Meat	610	718	797	31%

Data Source: MLC 1992; 1994b and 1999b

Meat demand and its nature have undergone change. Whilst total demand and *per capita* demand for meat *per se* have increased, demand for beef and veal and mutton and lamb is in long term decline, particularly in household consumption. Demand in the catering sector, in contrast, has shown increases for mutton and lamb and pork and bacon and growth in overall market share.

Household purchases, which, in 1997, accounted for approximately 69% of all red meat purchases are made from the retail sector. This sector has also undergone substantial

change in recent years, impacting upon the demand for meat, the distribution of livestock and distribution channel use. These changes are now described.

2.4.3 The Retail Sector

Changes within the retail sector, with increasing dominance of the multiples, have undoubtedly affected both distribution channel utilisation and the demand for meat. During the 1960s there were approximately 33,000 retail butchers in the UK. By 1997, the number had fallen to approximately 10,500 (MLC 1998c *personal communication*; National Federation of Meat and Food Retailers 1998 *personal communication*). Household purchases of meat have increasingly been made from supermarkets, following the trend away from traditional meat cuts to convenience products. Between 1993 and 1997 the supermarkets' share of household purchases increased from 55.3% to 69.9% at the expense of all other outlets (Key Note 1995; MLC 1995; MLC 1998b; Table 2.13).

Gunthorpe *et al.* (1995) indicate that this trend has been in evidence since the 1970s, and indicators suggest that it will continue. The MLC (1996c), for example, suggest that if this rate of growth is sustained, the multiple retailers will command 75% of market share by 2000.

Table 2.13 Household Purchases of All Fresh and Frozen Meat by Volume (Percentage) by Source of Purchase 1993 - 1997

	1993	1995	1997
Butchers	24.5	18.9	16.2
Co-ops	3.4	2.5	2.2
Supermarkets	55.3	65.1	69.9
Independent Grocers	2.2	1.4	1.0
Freezer Centres	6.7	5.7	5.2
Others	7.9	6.4	5.5

Sources: Key Note 1995; MLC 1995 and 1998b

There are differences in household sources of purchase between meat types. In 1997, sales via butchers shops accounted for a larger percentage of beef, lamb and pork purchases than the average for all meat types (MLC 2000c; Table 2.14). Bacon and poultry purchases via the multiple retailers were, however, greater than the average for all meat types. Data presented by the MLC (1998b and 2000c) indicate that, whilst there are differences between meat types, the trend for all is increasing purchases made from multiple retailers.

Table 2.14 Household Purchases of Fresh and Frozen Meat Types by Volume (Percentage) by Source of Purchase 1997

	Beef	Lamb	Pork	Bacon	Poultry
Butchers	23.7	30.9	23.1	9.6	8.9
Co-ops	1.5	1.1	0.7	2.6	3.1
Supermarkets	67.4	55.9	67.8	77.4	72.5
Independent Grocers	0.7	0.7	0.7	1.9	1
Freezer Centres	2.4	4.9	2.7	3.4	8.3
Others	4.3	6.3	4.7	5.3	6.3

Values may not add to 100 due to rounding. Source: MLC 2000c

Three way partnerships between multiple retailers, abattoirs and farms have emerged with the aim of integrating supply chain control to reduce livestock procurement transaction costs (Barry, Sonka and Lajili 1992; Sporleder 1992). This will reduce livestock market and electronic auction throughputs in favour of direct farm to abattoir sales. Additionally, the major retail multiples have introduced producer club schemes to ensure a greater continuity of supply, quality assurance and traceability.

Livestock producers joining such schemes are required to adhere to prescriptions which cover all aspects of production, for example, animal welfare, feeding regimes, housing conditions and carcass attributes. Retail multiples require that producers are members of farm assured schemes and many have gone a step further by implementing their own

welfare codes and practices. Table 2.15 shows examples of production prescriptions in producer club schemes introduced by major retail multiples to reduce livestock procurement costs.

Table 2.15 Examples of Production Prescriptions for Retail Producer Club Schemes for Lamb in 1997

Production Characteristics	Example Prescriptions
Carcass Specification	Weight: 18-20kg Conformation and fat classification: E1-R3H (See Figure 2.15)
Banned Feeds	No growth promoters or enhancers
Farm Assurance	Farm Assured British Beef and Lamb In-house schemes (multiple retailers) RSPCA Freedom Food
Audits/Inspection	Inspection by processors Inspection by retail fieldsman Random inspection by ADAS
Traceability	Database of all scheme producers All animals traced back to farm of origin Tagging schemes
Financial Bonuses/Penalties	Based on weight, conformation and fat classification (See Figure 2.15)

Source: adapted from McEachern and Tregear 2000

As outlined previously, the emergence of these three way partnerships and their associated producer schemes have largely been driven by the requirements of the Food Safety Act 1990 (UK Parliament 1990). Retailers are obliged to demonstrate ‘due diligence’ in their procurement of livestock necessitating full traceability and quality assurance from farm to

consumer. Transfer of information upstream from consumers to producers via retailers, processors and abattoirs is imperative in such partnerships. The livestock auction market sector has been a poor transmitter of reliable information. Few producers using this channel know the final destination of livestock sold, and Bullen (1984) suggests that fewer still take an active interest in the comparison between grade, quality and price of their carcasses on the hook. The electronic marketing system and, more particularly, direct farm to abattoir sales, do provide the mechanisms for good transmission of information.

The changes in the retail sector in recent years, with purchases for household consumption increasingly being made from the major multiple retailers, associated with the emergence of alliances between producers, abattoirs and retailers, have undoubtedly affected livestock distribution in this country. During the 1990s, particularly since 1995, livestock marketing channel use has also changed with shifts from both livestock auction markets and the electronic auction system, in favour of direct farm to abattoir sales (see Table 2.1). The evidence presented suggests that this trend will continue.

Changes in meat demand and the nature of that demand have inevitably been influenced by the growth of the catering sector and changes in the retail sector. Other factors, inter-related with those previously described, are also influential. Implicitly, these also impinge on livestock distribution and are now discussed.

2.4.4 Factors Affecting Meat Demand

The post war incentive of greater national food self sufficiency provided the agricultural industry with the criteria for success, namely increased productivity. Demand was production driven, with few penalties for poor quality and few premia for enhanced quality

products. The increased productivity, associated with government policy for cheap food, moved agricultural production from the satisfaction of nutritional needs to satisfaction of wants in terms of quality characteristics and degree of processing and presentation (Street 1990), changing the market characteristics to one which is now consumer led.

Meat quality characteristics have, however, long been recognised. For example, Forshaw and Bergstrom (1980) relate that butchers caught selling 'bad' meat in the middle ages were put in the stocks and the meat burned under their noses. During the nineteenth century, drovers were paid a percentage of carcass profits to maintain meat quality by ensuring animals were watered, fed and were not injured (Gregory 1984). In more recent times, it was observed that sheep deteriorate in quality if transported more than 100 miles by rail to the slaughterhouse and that a 'large' quantity of lamb was killed in Devon and then sent to London (Anon 1930). A proposal to grade and mark carcasses at slaughter to provide traceability "*enabling the housewife to obtain uniformity in her purchases*" was made by the Ministry of Agriculture in the early 1930s and a similar scheme for marking of beef carcasses was piloted in London and Birmingham for six months during 1930 (Anon 1930). It is interesting to note that traceability remains an aim within the industry.

The ability of the meat industry to respond to changes in demand is particularly well illustrated by the poultry and pig sectors. The increased concentration of, and vertical integration within, the poultry industry since the 1950s has permitted improved productivity gains and the development of a product with the more consistent quality characteristics demanded by the consumer. In the pig sector, the breeding programmes to improve conformation and increase the carcass lean meat percentage, along with horizontal linkages have similarly led to the production of a commodity of consistent quality. Gunthorpe, *et al.* (1995) report that between 1990 and 1993 the percentage of classified pig

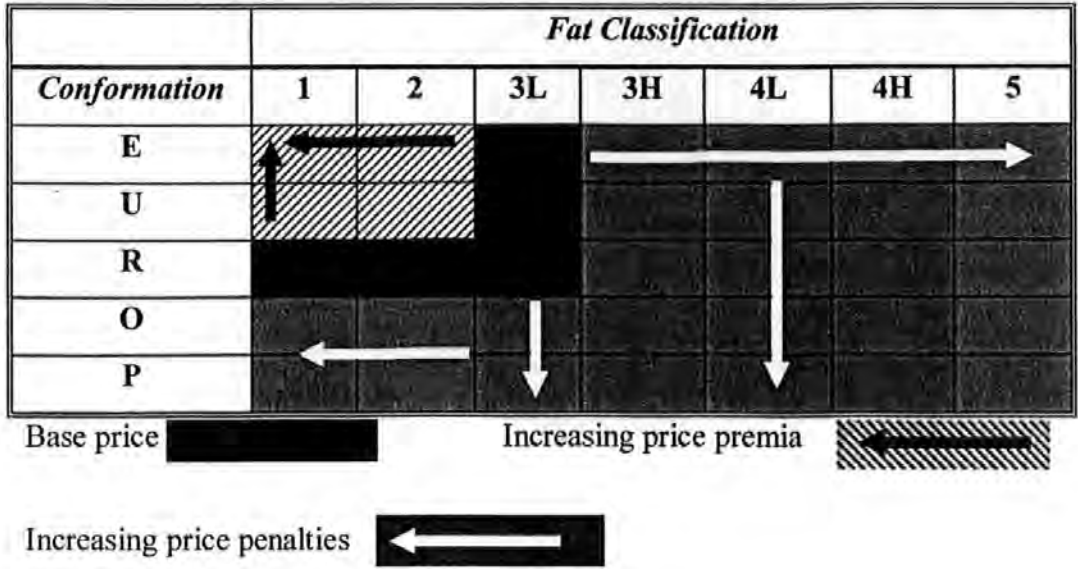
carcasses achieving the top two grades for lean meat percentage (above 55% lean meat) increased from 78.8% to 86%. The ability of these sectors of the industry to influence demand by introducing added value products and effective marketing strategies have also contributed to their success in recent years (Bansback 1995).

In contrast, the beef and sheep sectors have not responded as effectively to changes in the nature of demand. The historical dichotomy within the beef industry, with over half UK beef originating from the dairy herd (Gunthorpe *et al.* 1995) may in part explain difficulties in attaining conformation standards required. The authors reported that in 1993 over 50% of clean cattle²³ were of below standard conformation and 23% had unacceptably high fat levels. The removal of much of the dairy sector contribution to beef supplies from March 1996 may result in improved conformation characteristics in the future.

Within the sheep sector, the MLC (1998d) reports that over 25% of all lambs classified in England in 1997 were of adequate conformation but too fat and that consumers regard the fatness of lamb as a major negative factor of eating quality. In the same year, over 16% of lambs were of poor conformation (MLC 1998d). In a study of 2,327 lambs arriving at one abattoir in Devon in 1994, Murray, Eddison, Cullinane, Brooks and Kirk (1996) report that, whilst 57% of lambs were of acceptable conformation and fat classification, 29% were of poor conformation and 14% were too fat. An example carcass conformation (scale EUROP, where E is excellent and P is poor) and fat classification (scale 1-5, where 1 is leanest and 5 is fattest) grid for lamb illustrates the pricing structure which provides a base price for lambs with R conformation and 3L fat classification (Figure 2.15).

²³ Not cull livestock

Figure 2.15 Sample Conformation and Fat Classification Pricing Grid for Lamb



Whilst such grids are widely operated throughout the ruminant meat industry, specific criteria vary according to market requirements. Price premia are paid for higher quality and price penalties imposed for lower quality. An upper carcass weight limit may be set to discourage production of large stock. The grid for clean cattle is broadly similar with O and P classes further subdivided into plus (+) and minus (-). Fat classification of 4L or leaner and R conformation generally provide the base price for cattle, although market requirements differ. Such pricing structures have had an effect in reducing carcass fat levels and in improving conformation but may need to be more rigorous to encourage success. For example, it is understood from discussions with producers that the price penalties imposed for lamb with fat classification of 3H and 4L are outweighed by the price advantage of producing heavier carcasses.

There remains less evidence of horizontal and vertical linkages in the beef and sheep sectors than in the pig industry, although there is a call for more co-ordinated production and marketing, particularly from the multiple retailers, to provide more consistent quality,

traceability and assurance for the consumer, as stated above. For example, traceability has become more urgent since the BSE 'crisis' of 1996, in both the beef and sheep sectors. There are now a plethora of 'farm assurance' schemes and evidence of an increase in vertical alliances between producers, abattoirs, processors and retailers (McEachern and Tregear 2000).

The shift to meat purchases from the supermarkets has inevitably brought meat into closer competition with substitute products, including pre-prepared meals containing meat as a minority ingredient (Bansback 1995). The effect is likely to reduce aggregate demand even further and to influence demand of different meat types.

Bansback (1995) suggests that price and income factors may have explained some of the changes in consumption in recent years, but that others have become increasingly important. Demographic and social changes, including an increase in the number of one person households, increases in the number of working women and the decline in traditional family meals have influenced the growth in demand of convenience and versatile foods (Key Note 1995).

Concerns about food safety have an important effect on demand. The problems associated with BSE resulted in a decline in demand for beef and veal in 1989, driving an increase in demand for poultry. A further and more dramatic reduction in domestic demand for beef and veal followed the 1996 announcement of a possible connection between BSE in cattle and Creutzfeldt Jacob Disease in humans. Initially, demand fell by 70% but returned to approximately 80% of the pre-announcement levels in 1997, equivalent to an annual national consumption of 105,000 tonnes (MLC 1997 *personal communication*).

During 1991, the poultry industry experienced reduced demand as a result of publicity about *Salmonella* in the national flock (MAFF 2000b), and consumer concerns about the use of growth promoting hormones in meat production precipitated EU legislation banning their use (Gunthorpe *et al.* 1995). Dietary advice promoting white meat and advocating a reduction in intake of animal fats has also been influential in the decline in demand for red meat (Gunthorpe *et al.* 1995).

Animal welfare issues have become increasingly important (Eastwood 1995; Hughes 1995), and it has been recognised that poor animal welfare is a source of disutility to consumers (Bennett 1995, 1996 and 1997; McInerney 1991). Consumer concerns about production methods, transportation systems and slaughtering operations have affected demand and dictated change within the livestock and meat production industries. For example, under the Welfare of Pigs Regulations 1991 (UK Parliament 1991), stall and tether systems for pregnant sows were banned in the UK from January 1999. EU wide legislation will be imposed in 2006, suggesting that animal welfare issues may be of greater importance in the UK than in some other member states. As mentioned previously, legislation was introduced in 1997 relating to the welfare of animals during transport (Section 2.4.1; UK Parliament 1997) and relating to hygiene and structural standards within the slaughtering industry in 1992 and 1995 (UK Parliament 1992 and 1995; Section 2.2).

The factors affecting the demand for meat are numerous, diverse and interactive; and Bansback (1995) suggests that a multi-disciplinary approach to analysis is required for the industry to be able to respond effectively.

The three main distribution channels for slaughter livestock in this country are: sales via livestock auction markets, direct farm to abattoir sales and those via electronic auction systems. This chapter has identified that there are differences in utilisation levels between cattle, sheep and pigs and that there have been shifts in use over time. Between 1991 and 1997 the overall effect of these shifts has been in favour of direct farm to abattoir sales at the expense of both other channels (MLC 1996a and 2000a *personal communication*).

Structural changes within the livestock and meat producing industries, driven by legislative controls, technological advances and social and economic pressures, have resulted in altered supply chain relationships which impinge on the distribution of livestock both within and between channels. It is inevitable that the journeys experienced by livestock from farm to slaughter will also be undergoing change. This chapter continues with an overview of the domestic road journeys animals may experience.

2.5 The Distribution of Livestock from Farm to Abattoir

Evidence in the literature of the durations of domestic road journeys experienced by sheep and pigs has previously been described (See Section 2.4.1.2), whilst those for cattle have not been identified.

Journeys involving international transportation may extend to several days when the complete process is considered. For example, Knowles, Warriss, Brown, Kestin, Rhind, Edwards, Anil and Dolan (1993) reported that two groups of lambs exported to France were gathered from livestock auction markets and held at export lairage at pasture for at least five days before a final journey of 18 hours or 24 hours. The importance of considering the whole journey, which in this case was in excess of six days, is suggested

by the authors' indication that the lambs were in a catabolic state, utilising body reserves for energy, before the final leg of the journey began.

The distance travelled is also an important characteristic of journeys from farm to abattoir.

Warriss *et al.* (1990) report a maximum distance of 945km travelled by lambs to one slaughter plant in the south of England and mean distances travelled to the two plants in the study were both over 200km. Knowles, Maunder, Warriss and Jones (1994), examining the factors affecting the mortality of lambs in transit to, or in lairage at, a slaughterhouse, report that the average distance travelled by lambs arriving from farms was 62.4 miles (approximately 100km) whereas lambs from livestock markets travelled an average of 199 miles (approximately 320km) from market. Distance travelled into market and, therefore, total distance travelled was not available.

Jarvis, Cockram and McGilp (1995), examining the effect of source and distance travelled on bruising and blood chemistry of lambs at slaughter, recorded lambs travelling from distant markets (>500km), local markets (<400km) and direct from local farms (<350km). The study excluded journeys from farm of origin into livestock auction markets and it is likely, therefore, that total distances travelled were somewhat greater than those reported.

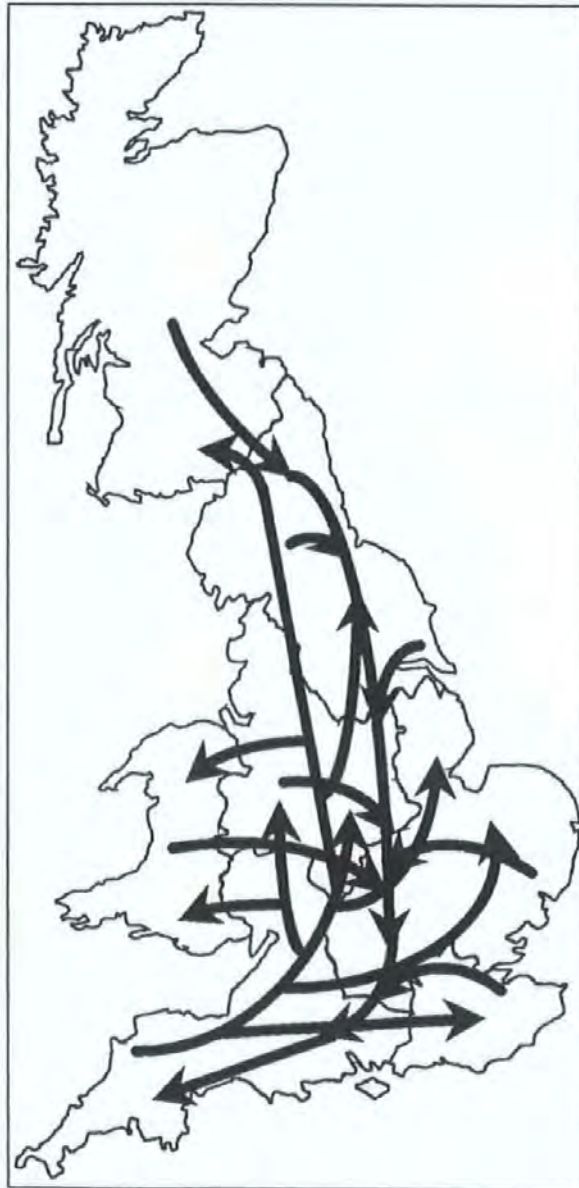
McNally and Warriss (1997) report distances travelled by cattle from market to abattoir of up to 464km. Once again, the distances into market were not available.

Warriss and Beavis (1986), in a study of transport and lairage times of almost 50,000 pigs arriving at 5 plants, report that the maximum distance recorded was 380 miles (approximately 612km), which together with one of 360 miles (approximately 579km) was exceptional. Over 60% of the pigs travelled 40 miles (approximately 64km) or less from

farm to abattoir.

It is clear that livestock may travel large distances from farm to the abattoir. Figure 2.16 is a simplified illustration of transport distances livestock may experience from farm to abattoir based on the evidence from the studies described above and anecdotal industry information.

Figure 2.16 Simplified Illustration of Transport Distances Livestock May Experience from Farm to Abattoir



There is a perception that animals sold via livestock auction markets experience a greater number of handling operations and more complex transportation processes than animals sold direct from farm to abattoir or via electronic auction systems, and that as a result welfare is reduced (Anon 1991; Baskerville 1996). For example, welfare standards under the RSPCA Freedom Foods assurance scheme precludes animals sold via livestock auction markets (RSPCA 1998a; 1998b; 1998c). Whilst it is implicit that such journeys must necessarily involve a minimum of two periods of transport and their associated handling operations, no evidence has been found in the literature of investigations of actual journey structure from farm to slaughter. Nor is there any evidence in the literature of any study that considers either the welfare of animals sold via electronic auctions or the transportation processes and patterns involved in that distribution channel.

Discussions with representatives of the production, haulage, livestock market, electronic auction and abattoir sectors reveal that journey structures range from one single component: a direct and uninterrupted journey from farm to slaughter, to highly complex, multi component, patterns incorporating:

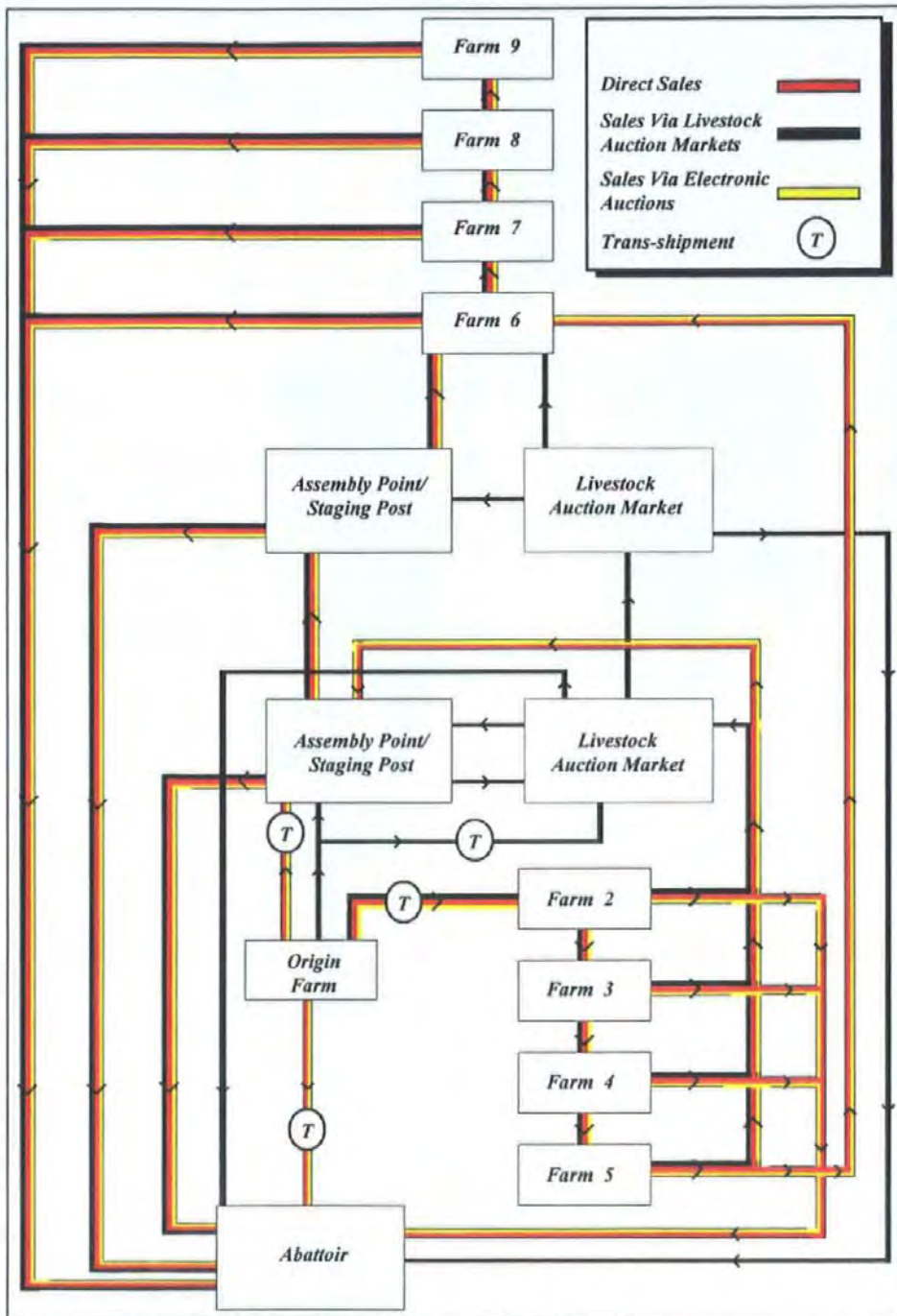
- an initial period of transport,
- trans-shipping, where animals are transferred from one vehicle to another,
- multiple pick ups from a number of farms,
- a period in an assembly point or market,
- second period of transport,
- a second period in an assembly point or market,

- a third period of transport,
- multiple pick ups from a number of farms, assembly points or markets,

before delivery to the slaughterhouse.

Figure 2.17 is a schematic systems model illustrating the diversity and complexity of journey structures that livestock may experience in domestic road transport from farm to abattoir in direct farm to abattoir sales, those via livestock auction markets and electronic auction systems.

Figure 2.17 Distribution Patterns of Livestock Sold Direct from Farm to Slaughter, Via Electronic Auction and Via Livestock Auction Markets.



N.B. Trans-shipment may also occur at other points in distribution chains.

Animals sold direct from farm and via electronic auction systems may experience similar distribution processes, including a single component journey.

In 1997, there were 69,849 holdings with cattle and calves in England and 174 Full Throughput approved abattoirs and 165 Low Throughput abattoirs licensed to slaughter cattle. In the same year, there were 45,003 holdings with sheep and 165 Full Throughput abattoirs and 165 Low Throughout abattoirs licensed to slaughter sheep and in the pig sector, there were 10,246 holdings with pigs and 147 Full Throughput abattoirs and 109 Low Throughput abattoirs licensed to slaughter pigs (MAFF 1997a and 1998a). It is suggested, therefore, that many livestock may experience multi-component journeys. For example, discussions with producers using electronic auction systems indicate that in some areas, livestock from a number of different holdings are gathered at an assembly point before sale to provide purchasers with the opportunity to acquire larger lots of animals and to facilitate more straightforward transportation to slaughter. Other anecdotal evidence suggests that assembly points are used after sale or that hauliers travel from holding to holding for multiple pick ups.

Direct farm to abattoir sales may also incorporate such multi-component journeys. The increasing concentration within the abattoir sector means that the hinterland from which animals are sourced may now be very extensive. For example, there is anecdotal evidence that animals are sourced from Cornwall and transported to Scotland and that such journeys may incorporate multiple pickups and a period in lairage *en route*. It is clear that a variety of handling and transportation processes are involved in each of the three main distribution channels for livestock in this country. The nature and structure of transportation processes may have a greater impact on animal welfare than the marketing channel *per se*.

2.6 Focal Species Selection

Aggregate distribution channel utilisation levels differs between species (Table 2.1) with little evidence of slaughter pigs being sold via electronic auctions and only 5% sold via livestock auction markets in 1997. A greater percentage of slaughter sheep are sold via livestock auction markets and electronic auctions than cattle. The distribution within channels may also differ between species. For example, Guise (1996) reports that maximum pig journey time from farm to slaughter in one survey was 8 hours 30 minutes (mean 2.8hrs), whereas Warriss *et al.* (1990) report a maximum journey time for sheep of 16 hours (mean 4.7hrs) which may have excluded the time travelling from farm to market. There is potential for increased complexity within longer journeys. Warriss *et al.* (1990) further report that in 1988, whilst only 16% of national lamb production occurred in the South of England, 24% of slaughterings took place in this region.

However, as previously stated, no studies have been identified which characterise the journey structures of cattle, sheep or pigs from farm to slaughter within or between marketing channels. Because of shifts in channel utilisation levels in recent years (Table 2.1), the decline in the number of markets (Section 2.1) and abattoirs (Section 2.2) and the introduction of electronic auction systems (Section 2.3), it is important that journey structures are identified. With a greater percentage of slaughter sheep sold via livestock markets and electronic auctions than cattle or pigs, they provide the focus for a survey of complete journey structure from farm to abattoir. Sheep production is important within Cornwall and Devon, which together accounted over 13% of the national breeding flock in 1997, and these two counties provide the geographical focus for the survey.

A number of studies have indicated that the welfare of livestock sold via live auction markets may be poorer than those sold direct from farm to abattoir (for example; Evans, Sains, Corlett and Kilkenny 1987; Cockram and Lee 1991; Kim, Jackson, Gordon and Cockram 1994; Knowles, Maunder and Warriss 1994; Knowles *et al.* 1994; Jarvis and Cockram 1995a; Jarvis, Cockram and McGilp 1995; and McNally and Warriss 1996 and 1997). Differences have been identified between markets (Jarvis and Cockram 1995b; McNally and Warriss 1997) and between farms (Jarvis and Cockram 1994; Murray, Eddison, Cullinane, Brooks and Kirk 1996).

Both electronic auction systems and direct sales to abattoirs use procedures for the selection of stock. This may involve prior inspection by fieldsmen employed by the auction company or abattoir, or producer selection for known quality requirements. This may result in an increased proportion of less fit animals presented at livestock auction markets, particularly when prices are high and buyers have less choice (Knowles *et al.* 1994). The welfare of animals in any distribution system is affected not only by the characteristics of the system, but also the nature of their responses to the environmental challenges. The welfare of less fit animals may be compromised to a greater extent than others before any handling procedures, transportation or marketing begins. Monitoring the quality of livestock sold via livestock auction markets may be less rigorous than that in the other two channels and may be improved by instituting greater communication between abattoirs, markets and producers.

Feedback mechanisms, to inform producers of quality characteristics, are apparent in direct sales and those via electronic auctions. This includes information about weight, carcass conformation and fat classification and also levels of bruising and any pre-slaughter pathological conditions. Such communication is almost absent between producers and

abattoirs when animals are sold via livestock auction markets and, if in place, could alert markets and producers to any shortfall in quality standards. Authors who have identified higher bruising levels of animals sold via livestock auction markets have attributed the bruising to the additional handling and the markets themselves (Cockram and Lee 1991; Jarvis and Cockram 1994; Jarvis, Cockram and McGilp 1995; Knowles, Maunder and Warriss 1994; McNally and Warriss 1996 and 1997). However, handling and loading practices on farms have not been examined and these could be a potential source of injury. Without adequate feedback from abattoir to farm any quality deficiencies may not be identified.

The following chapter provides, for the first time, information about the complete journey structures of slaughterweight lambs sold via livestock auction markets, direct from farm to abattoir and via electronic auction systems.

Chapter 3 Processes and Patterns of Lamb Distribution from Farm to Abattoir²⁴

3.1 Introduction

From the evidence in the literature, it is clear that major changes are taking place in all sectors of the meat producing industries. These changes could affect channel utilisation levels and the processes and patterns of livestock distribution from farm to slaughter. Significant pressures are directed towards livestock auction markets, not the least of which emanates from the perception that the welfare of animals sold via this channel is worse than that of animals sold direct from farm to slaughter. The welfare of animals sold via electronic auctions has not been investigated.

No studies have investigated journey nature and structure in any channel. Preliminary enquiries identify that these are diverse and range in complexity within all channels (see Figure 2.17). Increasing concentration is evident in both the livestock auction market and abattoir sectors and this phenomenon alone means that some animals will experience increased journey distances and durations. Whilst this was noted by Knowles *et al.* (1993) and Knowles, Brown, Warriss, Phillips, Dolan, Hunt, Ford, Edwards and Watkins (1995) with respect to abattoir provision, such changes within both sectors may be important. A secondary consequence may be increased journey complexity because of more multiple

²⁴ This chapter incorporates information published in: Murray, K.C., Davies, D.H., Cullinane, S.L., Eddison, J.C. and Kirk, J.A. 2000. Taking lambs to the slaughter: marketing channels, journey structures and possible consequences for welfare. *Animal Welfare*. 9, 111-122. Listed on page xxv of this thesis.

collections of lambs from a number of farms within an area or the use of collection points, or both. Superimposed upon possible changes in journey types resulting from sector concentration are those which may occur because of reported reduction in livestock auction market throughputs, increases in sales direct from farm to abattoir and the introduction of electronic auction systems (MLC 1996a and 2000 *personal communication*). It is suggested that such shifts in marketing channel utilisation levels do not necessarily mean that transportation complexity is reduced.

Identification of the structure of journeys from farm to slaughter in all three distribution channels is clearly an important precursor to a study of the relationship between channels and animal welfare. A survey was conducted to investigate the temporal and physical characteristics of journeys experienced by slaughterweight lambs from farm to abattoir. Attention focused on three livestock auction markets, three Full Throughput abattoirs and four haulage companies transporting animals bought through electronic auction systems. It was intended that three Low Throughput abattoirs would also be included in the study for comparative purposes. However, the main aim was to identify the range of transportation process and patterns within and across channels, which could be achieved by focusing on Full Throughput abattoirs. Because of the sensitive nature of the data collected, assurance of confidentiality was given and data presentation precludes identification of any participating organisation.

3.2 Materials and Methods

Of the 20 weekly livestock auction markets selling slaughter livestock in Cornwall and Devon in 1997, 18 were known to conduct regular sales of slaughterweight lambs. Four were randomly selected as foci for this investigation, following sale day allocation. The

auctioneers at three of the markets agreed to permit data collection on market premises. Auctioneers at the fourth declined on the grounds that questions about transport would not be well received by farmers bringing stock into market.

Ten Full Throughput abattoirs slaughtering sheep remained in Cornwall and Devon in 1997. Three were randomly selected as foci and the management at all three agreed to permit data collection on abattoir premises.

Two of the three electronic auction companies known to operate in Cornwall and Devon in 1997 agreed to participate, via the hauliers, during the planning phase. However, one ceased computer sales before data collection commenced. Whilst the purchasing and transportation infrastructure continued to be used, sales were conducted on a direct farm to abattoir basis with no bidding. This adds another dimension to changes to marketing channel utilisation levels and in distribution patterns. Ultimately, four haulage companies transporting lambs sold via electronic auction systems provided data: two hauled lambs from Cornwall and Devon to abattoirs outside the region, one transported lambs into the region from other areas and the fourth transported lambs wholly outside the region.

Data were collected between mid-April and early July by personal interview of producers or hauliers bringing lambs into abattoirs and livestock auction markets, hauliers, buyers and recipient abattoirs of lambs leaving livestock auction markets and by telephone with hauliers transporting lambs sold via electronic auction companies with cross checks made. The data collection timetable is shown in Table 3.1.

Table 3.1 Data Collection Timetable in Livestock Auction Markets, Abattoirs and Electronic Auction Systems

Week	Livestock Auction Markets	Abattoirs	Electronic Systems
1	√		
2 & 3	Data entry and preliminary analysis		
4		√	
5	√		
6		√	√
7	√		
8	Data entry		
9		√	√
10		√	
11	Data entry		
12			√

Each livestock auction market was visited on three occasions, necessarily on the same day each week, between mid-April and the end of May. In the intervening weeks, excluding time spent on computer data entry and preliminary analysis, each abattoir was visited on four occasions between early May and mid-June. A visit day was randomly allocated to each abattoir with no abattoir visited twice on the same weekday. It was decided to attend on different weekdays because discussions with abattoir personnel indicated that throughputs vary from day to day and that journey structures may also vary.

Data from within the electronic auction system were collected between mid-May and early July.

Data were not collected on consecutive weeks within channels to avoid possible distortions of journey types imposed by regional production characteristics. For example, the

beneficial climate in Cornwall and Devon means that lamb production occurs earlier in the year than in many other parts of the country. At such times, animals sold direct from farm to slaughter may experience journeys of limited distance and duration. It is, however, known that direct farm to abattoir sales do involve transportation out of the region. Those animals sold via livestock auction markets may experience journeys of increased distance and duration because of the attendance of buyers from other regions of the country. Conversely, as local supply becomes more restricted, and as production of lambs with characteristics for specific specialist markets occurs in other areas (for example, in the Scottish and Welsh hills and uplands), the sourcing hinterland for direct farm to abattoir sales may be extended and journey distances and durations increased. Discussions with auctioneers suggest that during such periods, when supply may not be restricted in other areas, lambs may experience outward journeys from markets of reduced distance and duration because of the prevalence of local buyers. In all cases, journey complexity may also change with distance and duration. Possible variations within electronic auction systems are not known.

Week One comprised the pilot survey to evaluate data collection methods and quality and was conducted in a livestock auction market using specially designed proformas (Appendices 4 and 5).

Following the pilot survey, preliminary analysis indicated that the questionnaires were appropriate to provide information relating to the nature and structure of journeys experienced by slaughterweight lambs sold direct from farm to slaughter, via livestock auction markets and electronic auction systems from farm to abattoir. Pilot survey data were incorporated in the final analyses.

All distances and vehicle dimensions were given in imperial measurements and have been converted to metric equivalents. Journey time is defined as the time from departure from the farm to time of arrival at the abattoir.

During the course of the survey it was found that groups of lambs could be split during a journey and other groups formed as a result. It was therefore concluded that individual lambs were the appropriate sampling unit. Kruskal-Wallis non-parametric analysis of variance (Zar 1996) was used to compare the three distribution channels with respect to duration and distance and also to analyse the complexity of journeys across all distribution channels. The relationship between the complexity of journey structure and distance was explored by relating the number of lambs transported within each structure to the distance travelled between farm and slaughter using contingency table chi-square analysis (Zar 1996). Data were collated in Microsoft Excel 97 (Microsoft Corporation 1997) and statistical analysis was conducted using Minitab Release 12.1 (Minitab Inc. 1998).

3.3 Results

During the data collection period a total of 19,726 lambs were transported within the marketing systems surveyed and the complete journey structures from farm to abattoir were identified for 18,393 slaughterweight lambs. Because of data collection limitations within the livestock auction market system, data relating to inward journeys were obtained for 9,060 lambs: three drivers declined to participate (78 lambs) and data for 873 lambs were not recorded because of time constraints. Details of the complete outward journeys of 63 lambs were not obtainable and 319 lambs were not sold for slaughter. Thus, the complete journey structures of 8,678 lambs were identified within the livestock market

system (Table 3.2). The following analyses incorporate only data relating to those animals for which complete journey structure was identified.

Considering only those animals for which complete journey structures were identified, there were differences between the distribution channels in terms of the numbers of lambs sold, with electronic auction systems accounting for 11% of the total (Table 3.2).

Table 3.2 Number of Animals Sold Directly from Farm to Slaughter, via livestock Auction Markets and via Electronic Auction Systems

	Total Number of Lambs Transported	Complete Journey Structures Identified (Number of Lambs)
Direct Farm to Abattoir	7,647	7,647
Livestock Auction Markets	10,011	8,678
Electronic Auction Systems	2,068	2,068
Total	19,726	18,393

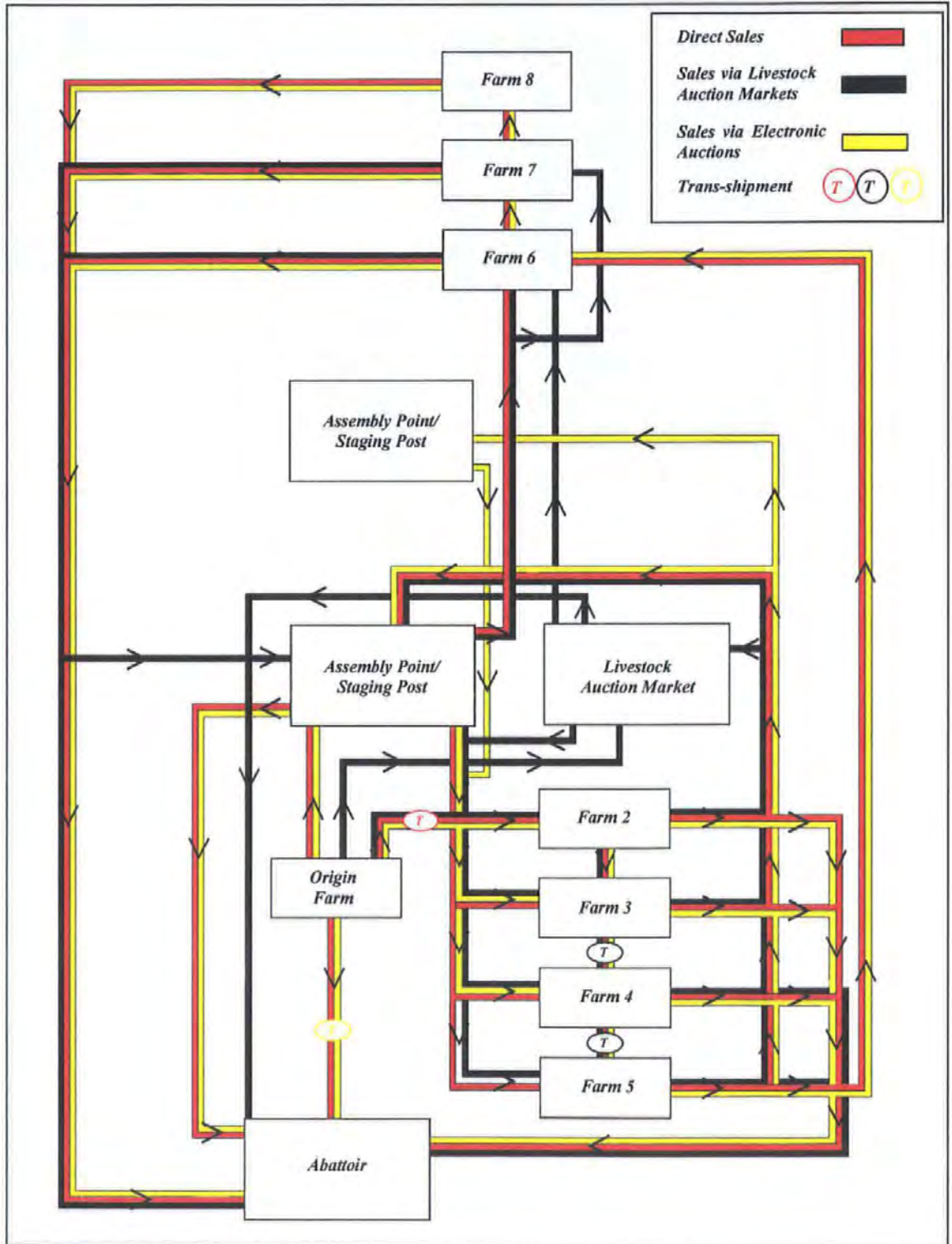
Within all three marketing distribution channels, journeys were diverse in nature and complexity. Journeys from the farm to abattoir contained combinations of the following components: periods of transport; trans-shipping (when animals were transferred from one vehicle to another); multiple pickups from a number of farms; and periods of holding at either assembly points, staging posts or auction markets. The journeys ranged from direct and uninterrupted transfer from farm to abattoir ($n=4,888$) to highly complex itineraries including up to three periods of transportation interspersed with two holding periods at assembly points, staging posts or auction markets ($n=1,034$). Journeys also included those with between 2 and 8 pickups *en route* ($n=2,369$), and those involving holding at assembly points, staging posts or livestock auction markets before transfer to abattoir ($n=10,102$).

Figure 3.1 is a schematic of all journey types identified within channels. There were minor departures from the systems model developed in advance of the survey (see Figure 2.17).

In all, a total of 26 different journey structures were identified: 18 in direct farm to abattoir sales, 9 in sales via livestock auction markets and 13 within the electronic systems.

Appendices 6 to 8 show the structures identified within channels.

Figure 3.1 Schematic of Distribution Patterns Identified in the Survey of Lambs Sold Direct from Farm to Abattoir, via Livestock Auction Markets and via Electronic Auction Systems



Comparison of the three channels with respect to journey duration and distance showed that all the channels differed from each other significantly (duration: $H= 10375.11$; $P<0.001$; distance: $H= 7292.61$; $P < 0.001$; Table 3.3) with median duration and distance being lower in direct farm to abattoir sales than the other two channels.

Table 3.3 Median Journey Duration(hrs) and Distance (km) from Farm to Abattoir

	Median Time Farm to Abattoir (hrs)	Median Distance Farm to Abattoir (km)
Farm to Abattoir	1.08	45.1
Livestock Markets	7.83	120.7
Electronic Auctions	7.50	349.2

Column values differ at $P<0.001$ in all cases

Median transit time for lambs sold through livestock auction markets was significantly greater than for those lambs sold through electronic auctions, but distance travelled was greatest for lambs sold through electronic auctions. However, considerable within-channel variation in both journey duration and distance was also found (Figures 3.2 and 3.3).

Figure 3.2 Frequency Distributions of Journey Durations (hrs) Experienced by Lambs from Farm to Slaughter: (a) Direct Sales; (b) Livestock Auction Markets; (c) Electronic Auctions

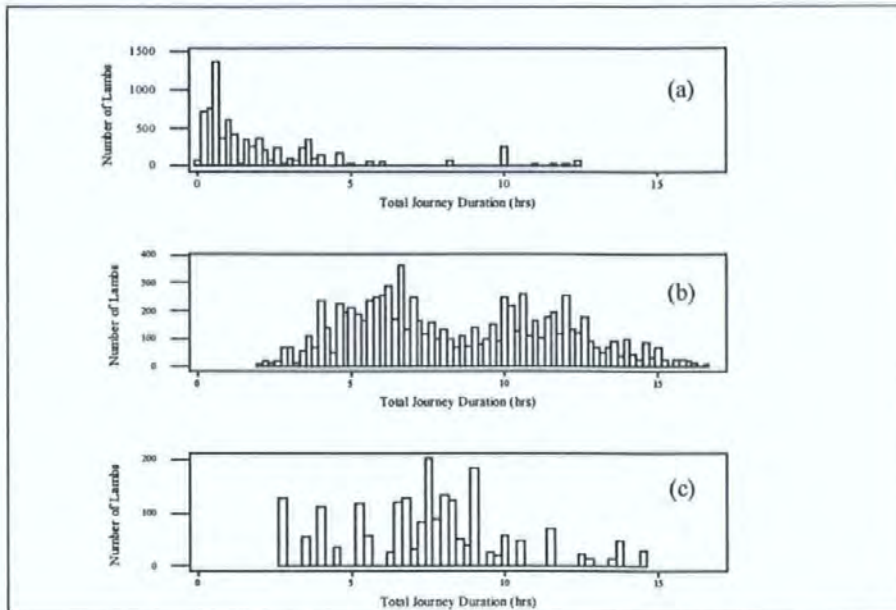
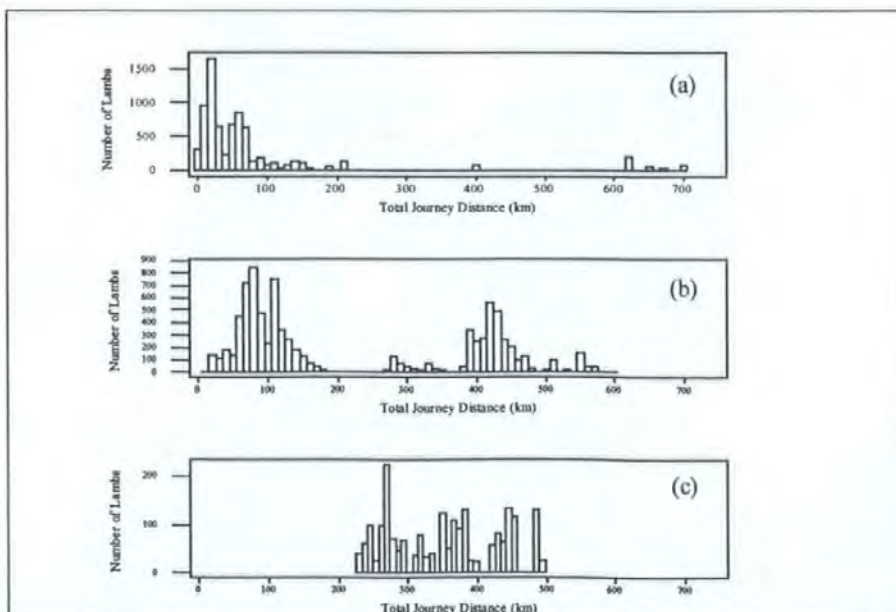


Figure 3.3 Frequency Distributions of Journey Distances (km) Travelled by Lambs from Farm to Slaughter: (a) Direct Sales; (b) Livestock Auction Markets; (c) Electronic Auctions



Analysis of journey complexity across all distribution channels revealed that journeys involving between 1 and 3 pickups *en route* to the abattoir had the lowest journey time and distance compared with itineraries involving two discrete journeys (*i.e.* holding at a livestock auction market or lairage), those involving between 4 and 8 pickups *en route*, and those involving 3 discrete journeys (*i.e.* holding at a livestock auction market or lairage, transfer to a second holding location and then transfer to abattoir). Differences in time and distance travelled between these journey structures were significant in all cases (journey duration: $H= 11887.93$; $P < 0.001$; distance: $H= 8993.85$; $P < 0.001$; Table 3.4).

Table 3.4 Median Journey Duration(hrs) and Distance(km) from Farm to Abattoir within Different Journey Structures

	Median Time Farm to Abattoir (hrs)	Median Distance Farm to Abattoir (km)
1-3 Pickups	0.75	24.1
2 Discrete Journeys	6.90	112.7
4-8 Pickups	7.50	349.2
3 Discrete Journeys	13.58	437.7

Column values differ $P<0.001$ in all cases

The relationship between the complexity of journey structure and distance was explored further by relating the number of lambs transported within each structure with the distance travelled between farm and slaughter and this showed that within each channel more animals than expected experienced journeys of increasing complexity as distance increased. Table 3.5 presents aggregate results across all channels. Results for each channel are presented in Appendices 9 to 11.

Table 3.5 The Relationship between Journey Complexity and Distance from Farm to Slaughter (number of lambs)

	<50km	>50 - 100km	>100 - 250km	>250 - 400km	>400km
1-3 Pickups	4145	984	357	333	14
2 Discrete Journeys	560	3746	2204	1333	2259
4-8 Pickups	0	112	362	524	426
3 Discrete Journeys	0	0	0	50	984

$\chi^2 = 13965; df = 12; P < 0.001$

Lambs sold via livestock auction markets or transferred via collection centres, assembly points or staging posts in the direct farm to abattoir and electronic auction systems experienced a period of holding between transport elements. Median holding time for lambs across all channels was 4.25hrs. Significant differences in holding time between channels were identified ($H = 4164.18, df = 2; P < 0.001$; Table 3.6).

Table 3.6 Median Holding Time (hrs) at Livestock Auction Markets and Assembly Points or Staging Posts in the Direct Farm to Abattoir and Electronic Auction Systems

	Median Holding Time (hrs)
Direct Farm to Abattoir	1.75
Livestock Auction Markets	4.92
Electronic Auctions	1.5

Column values with differ $P < 0.001$ in all cases

Median holding time was significantly greater in the livestock auction market system than in the direct farm to abattoir and electronic auction systems (4.92hrs, 1.75hrs and 1.5hrs, respectively; $P < 0.001$ in both cases) and significantly greater in the farm to abattoir system than in the electronic auction systems ($P < 0.001$; Table 3.6).

Vehicle types used to transport lambs included commercial livestock haulage vehicles and a range of farm vehicles (listed in Appendix 12). Plates 3.1 and 3.2 show examples of a commercial livestock haulage vehicle and a farm trailer, the most commonly used type of farm vehicle.

Plate 3.1 Example of a Commercial Livestock Haulage Vehicle Used to Transport Lambs



Plate 3.2 Example of A Farm Trailer used to Transport Lambs



There were 978 discrete loads of lambs transported during the course of the survey. With farm vehicles examined collectively, there were significant differences in median load size between commercial and farm vehicles (Mann-Whitney *U*-Test; $P < 0.001$) but not in stocking density ($P > 0.05$, Table 3.7). The data refer to discrete loads of lambs and, for composite loads, to the final load size and stocking density. The data include those for lambs for which inward journey details to markets were not identified where appropriate.

Table 3.7 Median Load Size (No. Lambs) and Vehicle Stocking Density ($m^2/lamb$) of Discrete Loads of Lambs Transported in Commercial Haulage Livestock Vehicles and Farm Vehicles

	Median Load Size (No. Lambs)	Median Vehicle Stocking Density ($m^2/lamb$)
Commercial Livestock Haulage Vehicles	67 ^a	0.32
Farm Vehicles	11 ^a	0.33

column values with similar superscripts differ $P < 0.001$

Commercial livestock haulage vehicles were used to transport larger loads of lambs than farm vehicles (median 67 lambs and 11 lambs, respectively; $P < 0.001$; Table 3.7). There were no significant differences in stocking density of lambs transported in either vehicle type.

Farm vehicles were associated with single component loads transporting discrete groups of lambs direct to abattoir or into market or lairage, and commercial vehicles with composite loads incorporating multiple pickups of different groups of lambs from different locations (Table 3.8).

Table 3.8 The Relationship Between Vehicle Type and Single and Multiple Component Loads

	Single Component Loads (No.)	Multiple Component Loads (No.)
Commercial Vehicles	82	125
Farm Vehicles	760	11

$\chi^2 = 473.831; df = 1; P < 0.001$

In consideration of composite loads, median distance between pickups of groups of lambs was 12.87km and median duration was 0.67hrs. Differences between channels for both parameters were non significant (distance: $H=2.71, df = 2$; duration: $H=1.64, df = 2, P>0.05$ in both cases; Table 3.9).

Table 3.9 Median Distance (km) and Duration (hrs) of Transport Between Pickups for Composite Loads in Direct Farm to Abattoir Sales and those via Livestock Auction Markets and Electronic Auction Systems

	Median Distance (km)	Median Duration (hrs)
Direct Farm to Abattoir (n = 43)	12.87	0.50
Livestock Auction Markets (n = 15)	19.31	0.67
Electronic Auctions (n = 26)	14.48	0.67

values within columns do not differ; $P>0.05$ in all cases

Whilst this survey was substantially completed before the introduction of The Welfare of Animals (Transport) Order 1997 (UK Parliament 1997), examination of the possible effect on livestock distribution shows that of those lambs that experienced direct and uninterrupted journeys from farm to abattoir ($n = 7,257$), 6,664 were transported in less than 8hrs and, therefore, would be within the limits set for journey duration if transported on either ‘basic’ and ‘higher’ standard vehicles (see Table 2.8). There were 623 lambs

transported for longer than 8hrs, which would have exceeded the limit if transported on 'basic' standard vehicles. Thirty of those lambs were transported for more than 14hrs; thus, if transported on a 'higher' standard vehicle, would also have exceeded the limit for the '1st leg' of a journey. Table 3.10 identifies the number of lambs sold direct from farm to abattoir and via electronic auction systems transported for less than 8hrs, between 8hrs and 14hrs and greater than 14hrs.

There were significantly more lambs sold direct from farm to abattoir that experienced journey times of less than 8hrs than would be expected by chance and significantly less that experienced journeys of between 8 and 14hrs or greater than 14hrs. Conversely, within the electronic system, significantly fewer animals than would be expected experienced journeys of less than 8hrs and more experienced journeys of between 8 and 14hrs or greater than 14hrs ($\chi^2 = 1947.64$; $df = 2$; $P < 0.001$; Table 3.10).

Table 3.10 The Relationship Between Distribution Channels and Journey Times Associated with The Welfare of Animals (Transport) Order 1997

	Journey Times <8hrs (no. lambs)	Journey Times between 8hrs and 14hrs (no. lambs)	Journey Times >14hrs (no. lambs)
Direct Farm to Abattoir	5,763	80	0
Electronic Auctions	901	513	30

$\chi^2 = 1947.64$; $df = 2$; $P < 0.001$

For those animals that were sold via livestock auction markets or experienced holding at a collection centre and two discrete journeys ($n = 9,958$), the inward journey of 9,233 lambs

was less than 50km (excludes all trans-shipped animals²⁵; see Figure 2.12 and Table 2.8). Therefore, for EU approved markets or collection centres, the market is deemed to be the start of the journey and the full journey durations prescribed in the legislation apply. All outward journeys of those lambs experiencing two discrete journeys were less than 8hrs and, therefore, within the permitted travelling time if transported on 'basic' or 'higher' standard vehicles.

For non-approved markets or collection centres or those animals that experienced an inward journey of greater than 50km to EU approved centres, the time into and out of the market or collection centre must be within the total permitted journey²⁶ time with the time held at market deemed as 'neutral'. The inward journeys of 725 lambs was greater than 50km and Table 3.11 shows the relationship between distribution channel and inward journeys of less than and greater than 50km. There were more lambs than would be expected sold via livestock auction markets that experienced inward journeys of less than 50km and less than would be expected that experienced inward journeys of more than 50km, whereas in the other two channels the converse was the case ($\chi^2 = 1441.074$; $df = 2$; $P < 0.001$; Table 3.11).

²⁵ The Welfare of Animals (Transport) Order (UK Parliament 1997) does not prescribe for animals that are trans-shipped. They have therefore been excluded from the analyses.

²⁶ Assuming animals had not been rested for at least 12hrs and watered and fed and that documentation for both journey stages was available (see Figure 2.12).

Table 3.11 The Relationship Between Distribution Channels and Journey Distance into Livestock Auction Markets or Collection Centres

	Inward Journeys <50k (no. lambs)	Inward Journeys >50km (no. lambs)
Direct Farm to Abattoir	1547	214
Livestock Auction Markets	7423	271
Electronic Auctions	263	240

$$\chi^2 = 1441.074; df = 2; P < 0.001$$

For those lambs travelling more than 50km into market or collection centre, within the direct farm to abattoir system, 109 lambs travelled for longer than the total permitted journey time if transported in a ‘basic’ standard vehicle but within the permitted journey time if transported on a ‘higher’ standard vehicle (83 lambs total travelling time = 10.75hrs; 17 lambs total travelling time = 10.25hrs). Within the livestock auction market system, 10 lambs travelled for longer than the permitted journey time if transported on a ‘basic’ standard vehicle. However, this was just 0.08hrs (5 minutes) longer than the permitted journey duration. No lambs within the electronic auction market system travelled for more than the permitted total journey time.

For those animals that were sold via livestock auction markets or experienced holding at a collection centre and a total of three discrete journeys (n = 833) outward journeys from the livestock market or collection centre may only be on ‘higher’ standard vehicles. If such vehicles were used, the inward journey to the first market or collection centre was less than 50km for 799 lambs. All outward journeys were within the permitted ‘1st leg’ journey times, all holding times at collection centres exceeded the minimum 1hr requirement, animals were reported to have been watered and fed at the second holding location and all ‘2nd leg’ journeys were within the permitted times. Thirty-four lambs experience an initial inward journey of greater than 50km and all subsequent components complied with the

legislative requirements. If transported on 'basic' standard vehicles, all the above journeys incorporating three discrete transport period would have ended at arrival at the second holding location where a minimum of 24hrs rest would be required.

It is important to note that maximum permitted journey durations apply to complete loads of animals. So, for example, for composite loads comprising multiple pickups, the maximum duration is that for the first lambs loaded. For loads compiled from animals sold via livestock auction markets or held at a collection centre the maximum outward journey duration is that for those animals whose maximum outward journey duration is the shortest. Clearly, for composite loads comprising multiple pickups and animals that have experienced holding at a livestock market or collection centre, the maximum journey duration remains limited to that of those animals closest to their permitted maximum.

3.4 Discussion

The results reported here demonstrate very clearly that the journeys experienced by lambs travelling from farm to slaughter vary very considerably from the very simple to the highly complex: 26 different journey structures being identified during the course of this investigation. Furthermore, the analysis of journey structures showed that the complexity of journeys is related to the distance travelled during the journey.

The comparison between marketing distribution channels, in which electronic auction markets have been examined for the first time, showed that lambs sold direct from farm to abattoir experience shorter journeys (in terms of both median duration and distance) than lambs sold through either of the other two channels. Lambs sold through electronic auctions, on average, travel longer distances but for shorter times than lambs sold through livestock auction markets. Although these results are broadly consistent with the common

perception of direct sale lambs experiencing simpler journeys than lambs passing through the other channels, they do not support this view unequivocally.

The journey distances and durations illustrated in Figures 3.2 and 3.3 demonstrate that, although the *median* journey durations and distances travelled by direct sold lambs are shorter than lambs sold through the other two channels, some lambs sold through direct sales actually experience very long journeys (more than 10h and over 400km). This analysis of journey structure, therefore, shows that there is not as clear a distinction between these three marketing channels as has previously been stated (Cockram & Lee 1991; Knowles, Maunder, Warriss & Jones 1994; Jarvis *et al.* 1995). Moreover, when viewed alongside the relationship between journey complexity increasing with distance travelled, some lambs may have experienced extremely complex journeys, irrespective of the marketing channel through which they had travelled to slaughter.

The introduction of The Welfare of Animals (Transport) Order 1997 (UK Parliament 1997) will impact upon the distribution of animals within all channels. The interaction of dual vehicle standards and livestock market or collection centre status will particularly impinge on those journeys comprising composite loads and/or those incorporating two discrete journeys. Journeys incorporating three discrete periods of transport can only occur on 'higher' standard vehicles. Local authorities are responsible for the enforcement of this legislation and it is not clear, given the complexity of the transportation processes involved, how this is to be achieved.

Animal welfare implications arising from this study are, broadly, twofold. First, available evidence suggests that journeys of increasing complexity may have an increasingly deleterious effect on animal welfare (Evans *et al.* 1987, Kenny and Tarrant 1987 and Murray *et al.* 1996). Therefore, it is essential to consider the journey structure, rather than

simply the marketing channel, when judging the impact of livestock transport and marketing on animal welfare.

Second, the structural changes within the livestock, marketing and meat processing sectors impact upon animal welfare: as the number of producers, livestock auction markets and abattoirs continues to decline, the distances from farm to slaughter that animals will have to travel will also increase. Therefore, since journey complexity increases with distance travelled, the net result of these changes in industrial concentration will be a reduction in the welfare of the animals being transported to slaughter across all channels.

As stated above, it is essential to consider the journey structure when judging the impact of livestock transport and marketing on animal welfare. No studies have been identified which examine the effect of different journey structures on animal welfare. An overview of concepts of farm animal welfare and a review of the literature relating to the welfare of lambs during handling, transportation and marketing is presented in the next chapter. This is followed by details of an investigation conducted to examine the effect of journey structure from farm to abattoir on the welfare of lambs.

Chapter 4 Animal Welfare

4.1 Farm Animal Welfare

The welfare of farm animals first received widespread public scrutiny following the publication of *Animal Machines* (Harrison 1964) which precipitated the appointment of a committee, led by Professor Brambell and subsequently known as The Brambell Committee, to enquire into the welfare of animals kept under intensive livestock systems (Brambell 1965).

The Committee rejected representations that productivity alone is the only objective measure of animal welfare and reported that '*welfare is a wide term that embraces both the physical and mental well-being of the animal*' and that '*animals show unmistakable signs of suffering from pain, exhaustion, fright, frustration and so forth*'. Whilst the transportation of farm livestock was outside the remit of the Brambell Report, the principles of farm animal welfare prevail for all production, handling, marketing and transportation operations.

Amongst the recommendations made by the Committee was the formation of a Farm Animal Welfare Standing Committee (FAWSC) to advise the Agriculture Minister on all matters relating to the welfare of farm livestock. The FAWSC has undergone several metamorphoses in the intervening years, and in 1979 the Farm Animal Welfare Council (FAWC) was formed. It developed the proposals contained in the Brambell Report and identified five basic freedoms which animals should be given:

- freedom from thirst, hunger and malnutrition;

- appropriate comfort and shelter;
- the prevention and rapid diagnosis and treatment of injury, disease or infestation;
- freedom from fear;
- freedom to display most normal patterns of behaviour.

These freedoms were subsequently amended in 1992 to:

- freedom from hunger and thirst - by ready access to fresh water and a diet to maintain full health and vigour;
- freedom from discomfort - by providing an appropriate environment including shelter and a comfortable resting area;
- freedom from pain, injury or disease - by prevention or rapid diagnosis and treatment;
- freedom to express normal behaviour - by providing sufficient space, proper facilities and company of the animal's own kind;
- freedom from fear and distress - by ensuring conditions and treatment which avoid mental suffering (FAWC 1992).

The FAWC emphasises that these freedoms are ideals to which all who are responsible for animals should aspire, and that they should exercise:

- caring and responsible planning and management
- skilled, knowledgeable and conscientious stockmanship;
- appropriate environmental design;
- considerate handling and transport;
- humane slaughter.

Whilst these recommendations are broad and open to diverse interpretation, they provide the basis for welfare provision which may be further adapted for different species, breeds and individuals and applied to all processes within animal production systems. A design strategy clearly identifying the '*needs*' of the animal is implicit to provide the appropriate focus. This identification of '*needs*', particularly behavioural '*needs*' is, however, fraught with difficulties (Jensen and Toates 1993) not the least of which is defining welfare (Brambell 1965; Duncan and Dawkins 1983; Broom and Johnson 1993; Mason and Mendl 1993; Waran 1995). The terms '*welfare*', '*well-being*', '*suffering*', '*stress*', and '*distress*', amongst others are used throughout the literature to describe the effects of the environment on an individual. Solipsism is rejected and many authors adopt what Kennedy (1992) defines as a neobehaviourist stance, perceiving that internal processes are involved in the causation of behaviour, and employ a combination of physical, physiological and behavioural measures in the assessment of an animal's physical, physiological and psychological condition.

Dawkins (1980, 1988, 1990, 1995) emphasises that welfare involves the '*subjective feelings of animals*' and that physical health and production performance, whilst important,

do not in themselves give any indication of the animal's perception of its situation. Whilst the animal's view is clearly very important, there may be procedures in the management of livestock which, if not conducted, may predispose the animal to discomfort, pain and even death. Shearing of sheep would be such an example which, if not conducted, may result in conditions which include discomfort during periods of high ambient temperature and an increased risk of pain and even death resulting from myiasis. So, 'welfare' becomes a question of balance: whilst the sheep may experience feelings of anxiety and even fear as a result of isolation from conspecifics and the discomfort of shearing, the immediate costs of the operation may be outweighed by the long term costs of not being sheared. This does not mean that all management practices which seek future protection of an animal are so balanced or that good welfare may be maintained as a result of their use. Those, like beak trimming of poultry and tail docking of piglets, may be imposed because of limitations of husbandry systems where welfare may be poor for reasons of production system design.

Broom (1986 and 1990) and Broom and Johnson (1993) define welfare as the '*state of an animal as regards its attempts to cope with its environment*' at the time under consideration and that it can be measured. Physical, physiological and behavioural measurements may provide a very good indication of welfare, and may in certain circumstances be conclusive, for example where disease or injury are present (Duncan and Dawkins 1983). However, injury alone may not be conclusive in the teleologic sense; for example, that incurred in the establishment of natural dominance order (Wiepkema and Koolhaas 1993) and some subjective assessment may be required of the animal's feelings in the interpretation of those data. Broom (1990) and Fraser and Broom (1997) additionally state that welfare is on a continuum from very good to very poor and is poor if an animal fails to cope with its environment and also if it succeeds in coping but has great difficulty in doing so. In the former case, failure to cope implies some adverse affect on fitness or in

the worst case, death, and up to that point welfare may be very poor. However, in the latter case, examination of the coping strategies may give an indication of whether or not welfare is reduced. For example, the non nutritional suckling needs of calves may be important to their sense of well being, and those that are bucket fed show an increased motivation for cross sucking on ingesting milk (de Passillé, Metz, Mekking and Wiepkema 1992; Lidfors 1993). Redirection of this behaviour to pen mates suggests that welfare is reduced. Motivation for cross sucking, however, is apparently reduced following weaning (Lidfors 1993), which suggests that the effect on welfare changes with time. But, there is no evidence in the literature of comparative studies of the behaviour and physiology of suckled and bucket fed calves beyond the weaning period.

A further example of coping strategies employed by animals which may give an indication of welfare are stereotypies, the causes of which may be multi factorial (for reviews see Lawrence and Rushen 1993). In tethered sows, these were found to be associated with endogenous opioid activity (Cronin, Wiepkema and van Ree 1985) and, whilst such behaviours may have the effect of improving the animal's sense of well being, their expression indicates poor welfare. If, on the other hand, the animal has employed strategies which have enabled it to cope and adapt then it may have experienced '*suffering*' or '*distress*' in the process of coping and adaptation, and experienced reduced welfare in the short term, but ultimately its welfare is not reduced. For example, anti-predator behaviour of a range of prey animals may be accompanied by feelings of fear, associated with bradycardia or tachycardia and elevated levels of catecholamines and glucocorticoids, amongst other things, but such responses have evolved as a means of avoiding danger and preserving fitness. Wiepkema and Koolhaas (1993) suggest that these are normal and desirable and welfare may indeed be enhanced as a result.

The welfare of an animal encompasses its physical, physiological and psychological states which are integrated and interactive, on a continuum of very good to very poor (Broom 1990, Fraser and Broom 1997) and may change with time. The welfare of an animal which has all the resources required to maintain good physical and mental health, indicative of *'living in harmony with its environment'* (Wiepkema and Koolhaas 1993), may be considered to be very good. The more those resources are limited, either in quantity or quality, or both, the further the animal's welfare will move along the continuum towards very poor. Physical, physiological and behavioural data may be used as indicators of welfare and interpretation may be dependent on the qualitative assessment of the animal's subjective feelings. As previously discussed, an animal may experience *'suffering'*, *'distress'* or a reduced sense of *'well being'* when confronted by some environmental challenges or management operations, and welfare in the short term may be reduced, but it is not always ultimately diminished as a result. Conversely, an animal may employ coping strategies which enhance the feeling of well-being in an adverse environment, but nonetheless welfare is poor.

The term *'stress'* is used by some authors to describe the external stimulus; that is, the change in the animal's environment which precipitates a physiological or behavioural response, or both, and by others, the animal's response to the change in environment. For example, Amoroso (1967), cited by Kilgour and de Langen (1970), suggested that the word *'stress'* may be used as an acronym for Situations That Release Emergency Signals necessary for Survival; Broom and Johnson (1993) define stress as 'an environmental effect on an individual which overtaxes its control systems and reduces its fitness or appears likely to do so' and Fraser, Ritchie and Fraser (1975) state that an animal is in a state of stress *'if it is required to make abnormal or extreme adjustments in its physiology*

or behaviour in order to cope with adverse aspects of its environment and management'.

Wiepkema and Koolhaas (1993) suggest that '*stress*' is '*a state...that can be recognised by the occurrence of stress responses evoked by one or more stressors*'. Any environmental change, whether internal or external, which elicits physiological or behavioural responses, or both, imposes a demand on the homeostatic mechanisms and the ability of the animal to adapt, at the individual level, to the change. Only when the stress, which may emanate from one or more stressors, reaches a critical point where homeostasis fails (Cannon 1935) or the animal is unable to adapt successfully would welfare be reduced.

4.2 The Welfare of Lambs During Handling, Transportation and Marketing

All handling processes initially disrupt an animal's *status quo*, stimulating responses to the changing environment in an attempt to maintain homeostasis. The maintenance of homeostasis by behavioural or physiological modifications, or both, is possible only within certain limits (Broom and Johnson 1993) which are genetically determined (McFarland 1993) and varied by physical, physiological and psychological status both at the time of and before challenge.

Knowles and Warriss (2000) and, in a review of the road transport of sheep, Knowles (1998) identify a range of physical, physiological and behavioural indicators used in the assessment of the welfare of livestock. These include:

- mortality

- bruising

calves under four weeks of age should not be marketed. Mortality rates of slaughter weight lambs arriving at one slaughterhouse were identified by Knowles *et al.* (1994) and, whilst overall levels were low at 0.0182%, it was more than four times higher in lambs bought via live auction markets than those direct from farms. The authors suggested that this was associated with higher market prices, when vendors may have presented animals of poorer quality and buyers had less choice, and with increased rates of carcass condemnations due to *ante mortem* pathologies. One can infer that the pricing structure may be responsible for drawing poorer quality animals to market, rather than the auction markets themselves being responsible for the higher level of mortality.

Bruising may occur for a variety of reasons including fighting, excessive use of sticks or other goads by handlers, over- and undercrowding on transporting vehicles, crowding during droving, slipping or falling and, in the case of sheep, wool pull, amongst others (Warriss, 1990). It is undoubtedly both a welfare problem and, because of the reduction in meat quality, an economic one and reports of levels apparent in livestock vary widely. The MLC (1974) estimated that 10% of all slaughter lambs were injured during handling, transportation and marketing and that bruising was a major cause. Reported levels of bruising in sheep carcasses are presented in (Table 4.1).

Table 4.1 Reported Levels of Bruising in Sheep Carcasses

Bruised Sheep Carcasses	Assessment Criteria	Source
0.08%	bruising resulting in partial or whole carcass condemnation	Evans and Pratt (1978)
1.25%	economically significant bruising	Knowles, Maunder and Warriss (1994)
10%	all bruising and injury	MLC (1974)
18%	all visible bruising	Evans <i>et al.</i> 1987
25%	all visible bruising	Jarvis and Cockram (1994)
33%	all visible bruising	Murray <i>et al.</i> (unpublished data)
69%	all visible bruising	Cockram and Lee (1991)

The reasons for the variation in the extent of bruising reported in sheep carcasses may emanate from the differences in assessment criteria used and may simply reflect the purpose for which the data were collected. If carcasses are partially or wholly condemned because of bruising then only the most severe levels may have been recorded. Similarly, economically significant bruising levels may include condemnations and levels sufficient to cause carcass downgrading, excluding more minor bruises. Differences in reported figures between those studies assessing all bruising may also emanate from differences in assessment techniques, but may also indicate differences between handling and transportation variables during the movement of the sheep from farm to slaughter. Nonetheless, in those studies where all visible bruising was recorded, levels were high and ranged from 18% to 69% of sheep carcasses. McNally and Warriss (1996) suggest that the annual cost of bruised meat to the beef industry in the UK could be £4.5m, and was estimated at \$36m in Australia in the late 1980s (Blackshaw, Blackshaw and Kusano 1987). The MLC estimated that bruising, abscesses and other forms of carcass damage,

cost the sheep industry £3m annually in the UK (cited in: Blackshaw. Blackshaw and Kusano 1987).

The effects of food deprivation and dehydration in sheep, providing an indication of metabolic stress, have been investigated in a number of transport studies (for example, Knowles *et al.* (1993); Knowles, Warriss, Brown and Kestin (1994); Knowles, Brown, Warriss, Phillips, Dolan, Hunt, Ford, Edwards and Watkins (1995); Cockram and Corlet (1991) and Jarvis, Cockram and McGilp (1995)). Jarvis, Cockram and McGilp (1995) found that lambs bought from distant markets (>500km) were more dehydrated than those from local farms or markets (<400km), but measures of food deprivation showed no significant differences. Knowles, Brown, Warriss, Phillips *et al.* (1995) indicated that, for transport periods of up to 24 hours, sheep did not become severely dehydrated and that the effects of food deprivation had largely been overcome within 24 hours of transport. Parrott, Lloyd and Goode (1996) held sheep for 48hrs at temperatures up to 35°C without food or water and found that the sheep remained within water balance. However, signs of dehydration were apparent if the sheep consumed food.

Broom, Goode, Hall, Lloyd and Parrott (1996) found no significant differences in liveweight loss between lambs transported for 15hrs (5.0%) and those which remained in stationary confinement for the same period (3.6%). Knowles *et al.* (1995) reported an 8% loss of liveweight after 24hrs of transport which occurred during the first 15hrs and was due to loss of gut fill. Knowles *et al.* (1993) found mean liveweight loss of 6.7% in animals transported for 14hrs compared to 1.5% for lambs held in a pen for the same period. Warriss, Brown, Beavis, Kestin and Young (1987) found that carcass weight losses of lambs deprived of food and water for 24hrs, 48hrs and 72hrs extended to 2.5%, 3.8% and 5.8%, respectively. In a later study, Warriss, Kestin, Young, Beavis and Brown (1990)

found that transport periods of 1hr, 3hrs or 6hrs had no effect on liveweight or carcass weight. Knowles (1998) reports that sheep are to some extent buffered from the effects of food and water deprivation as ruminants but the period of deprivation should probably not exceed 24hrs.

Knowles *et al.* (1995) found that loading and the initial stages of transport were the most stressful parts of a 14hr journey, eliciting increases in heart rate, plasma cortisol, glucose and creatine kinase which then declined almost to basal levels after 9hrs of transport. Broom *et al.* (1996) similarly found that loading and the initial stages of a 15hr journey produced increases in cortisol and prolactin concentrations, which gradually declined over the subsequent 3hrs. Cockram, Kent, Goddard, Waran, McGilp, Jackson, Muwanga and Prytherch (1996) found that loading followed by stationary confinement did not affect plasma cortisol concentrations. Increased plasma cortisol concentration and heart rate were identified in transported animals and were attributed to the '*novel psychological aspect*' of transport, for example, vibration, jolting and noise. This supports the findings of a study by Baldock and Sibly (1990) who found no increase in heart rate of sheep following loading and confinement on a stationary vehicle (see Table 4.2 and associated further discussion).

Studies of the behaviour of sheep during transport have identified that they ruminate and, given sufficient space, may lie down and are able to rest (Cockram *et al.* 1996; Knowles *et al.* 1993). Cockram *et al.* (1996) found that transported lambs at stocking densities of 0.22m² per lamb and 0.31m² per lamb ruminated less than those in stationary confinement during the first 6hrs of a 12hr experiment and that most ruminating occurred whilst the lambs were standing. During the last 6hrs lambs at 0.22m² per lamb ruminated less than those at all other stocking densities (0.22m², 0.27m², 0.31m² and 0.41m² per lamb). During a 24hr journey from the UK to France, Knowles, Warriss, Brown and Kestin (1994)

observed that lambs could be seen to ruminate and lie down (average stocking density 0.2m² per lamb), although these behaviours were not quantified. Cockram *et al.* (1996) found that a space allowance of 0.27m² per lamb was sufficient for most lambs (mean liveweight 35kg) to lie down during a 12hr journey and Buchenauer (1997) reports that for German Blackface lambs of 35kg – 40kg liveweight, a space allowance of 0.4m² per lamb was required for all animals to lie down.

Motion sickness has been observed in pigs (Bradshaw and Hall 1996) but not in cattle or sheep. However, Eiler, Lyke and Johnson (1981) investigated '*internal vomiting*' in sheep. They suggested that because of the '*multicompartmental anatomy of the ruminant stomach*', vomiting through the mouth may not be observed but abomasal contents may, nonetheless, be expelled into the rumen. The pH of ruminal contents of four sheep were found to decline following intravenous injection of apomorphine (an emetic for monogastric species) and the authors concluded that the acidic abomasal contents were expelled into the rumen and that sheep exhibit '*internal vomiting*'. In an earlier study of rumination in sheep, Bost, McCarthy, Colby, and Borison (1968) commented that area postrema, in the medulla oblongata, initiates vomiting in non-ruminant animals and inhibits rumination in sheep in response to the chemical stimulus of deslanoside. Austin (1996) suggests that inhibition of rumination during transport may indicate travel sickness.

Ante mortem handling, transportation and marketing are known to affect meat quality. Monin and Ouali (1991) indicate that diverse interpretations of the term 'meat quality' have resulted in there being no single recognised definition. For the purposes of this study, 'meat quality' refers to those parameters that are known to be affected by pre-slaughter handling operations, viz. water holding capacity, propensity to bacterial spoilage and organoleptic variation. Two important meat quality defects are attributable to pre-slaughter

stressors imposed on an animal. These are: dry, firm and dark (DFD) meat and pale, soft and exudative (PSE) meat.

That the quality of meat can be affected by environmental conditions experienced by the living animal has long been recognised. For example, Lawrie (1991) cites Daniel Defoe who, writing in the early eighteenth century, indicated that meat from hunted wild ox had poor keeping qualities. And, in 'The Mayor of Casterbridge', Hardy (1886) describes the practice of baiting oxen '*to make them tender before they were killed*'. This custom had evidently been common for a number of centuries because Gregory (1984) reports that in the early seventeenth century six butchers appeared before a local Assizes in the south of England accused of not baiting bulls before slaughter. Such practices are now, of course, illegal in this country. However, adverse experiences before slaughter are now known to influence *ante mortem* glucose metabolism which in turn affects *post mortem* glycolysis and associated proteolysis, the predominant processes in the conversion of muscle to meat.

Faustman (1994) identifies that whilst a precise definition is elusive, the establishment of *rigor mortis* is widely accepted as the point at which muscle becomes meat. The conversion results from a series of biochemical and biophysical changes, initiated at the death of the animal, which alter its *in vivo* characteristics (Gill 1982; Faustman 1994; Lawrie 1991, 1992; Moss, 1992; Monin and Ouali 1991). *In vivo*, muscle contraction results from shortening of the sarcomeres by the cyclical association and disassociation of the contractile proteins, actin and myosin. This is achieved by utilisation of energy derived from the hydrolysis of adenosine triphosphate (ATP) to adenosine diphosphate (ADP) and inorganic phosphate (P_i), catalysed by an adenosine triphosphatase which is activated by actin and associated with the myosin molecules (Bailey 1990; Cardinet 1989).

ATP is produced through metabolism of fats, carbohydrates and creatine phosphate stores. This is achieved aerobically through the oxidation of fatty acids, mobilised from fat stores in the muscle and fat depots, and glucose from liver and muscle stores. Anaerobic ATP production occurs through phosphorylation of adenosine diphosphate (ADP) from creatine phosphate (CP) and glycolysis utilising glucose from muscle glycogen stores (Cardinet 1989).

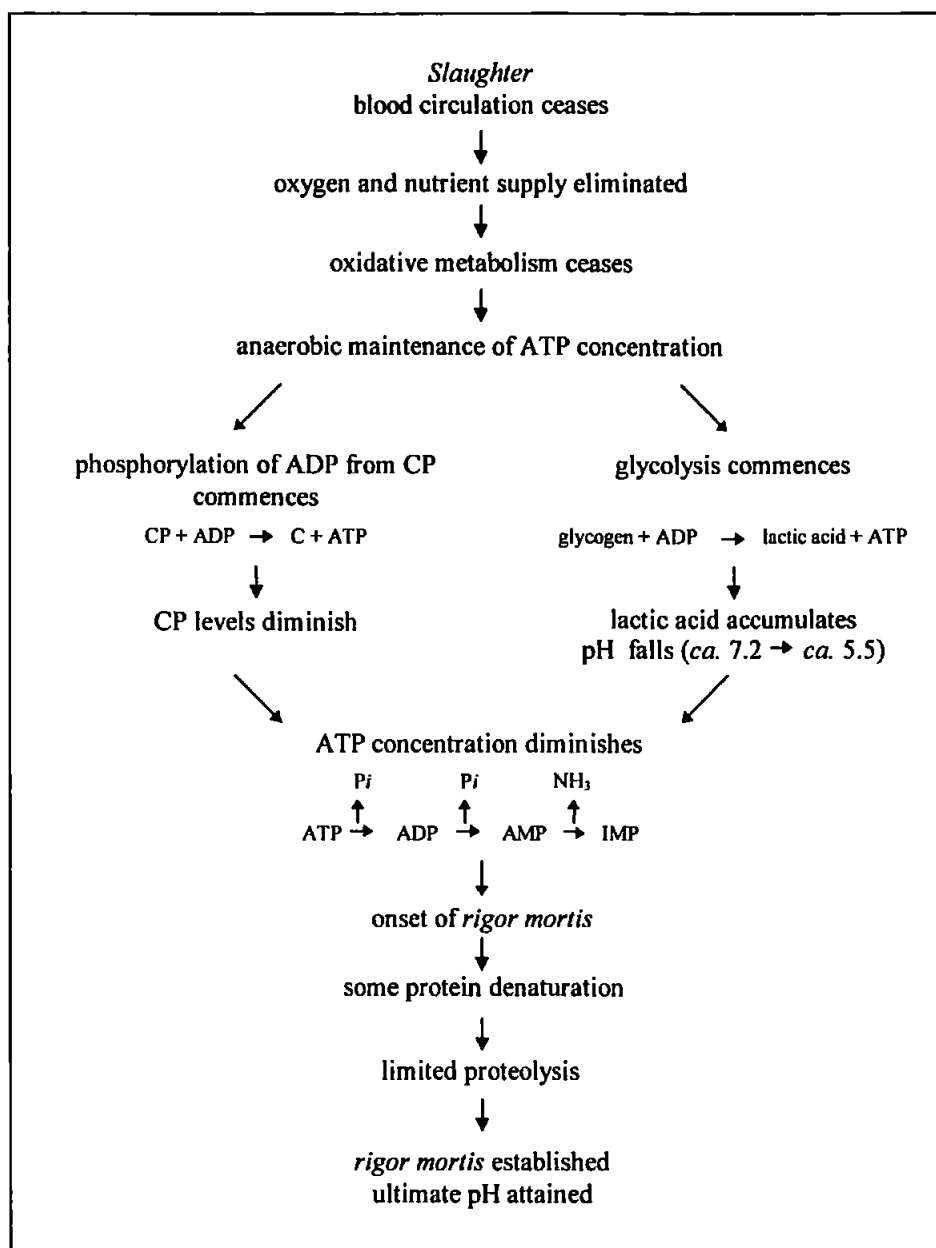
Post-mortem, oxidative metabolism rapidly ceases, but anaerobic ATP production continues and muscle remains alive until all energy sources are depleted or inhibited and *rigor mortis* is established (Lawrie 1991). At slaughter, the blood supply to muscle is terminated, eliminating both oxygen and nutrients. Initially, ATP levels are maintained by glycolysis and phosphorylation of ADP from CP. As reserves of CP and glycogen become depleted so resynthesis of ATP decreases. ADP is degraded to adenosine monophosphate (AMP) which is then deaminated to inosine monophosphate (IMP) and ammonia. Lactic acid accumulates as a result of glycolysis and muscle pH declines (Gill, 1982; Figure 4.1).

Rigor mortis is characterised by the formation of inextensible actomyosin from the irreversible association of actin and myosin when ATP levels are insufficient to maintain cyclical association and disassociation (Lawrie 1992). The production of lactic acid, which increases muscle acidity from its *in vivo* level of *ca.* pH 7.2 to *ca.* pH 5.5 (Gill 1982; Lawrie 1992) and the deamination of AMP inhibit glycolysis even if muscle glycogen stores are adequate. The increase in acidity inactivates enzymes involved in glycolysis, which at low pH are close to their isoelectric point; and AMP is a cofactor for enzymes which catalyse the rate determining reactions of glycolysis (Gill 1982; Lawrie 1992). Gill (1982) reports that, providing initial glycogen stores are adequate, pH 5.5 can be attained

before enzyme activity is inhibited and that residual glycogen is characteristic of normal meat.

Some protein becomes denatured because resynthesis is prevented in the absence of ATP, and proteolysis by endogenous proteolytic enzymes occurs. Proteolysis plays an important role in meat tenderisation (Dransfield 1994; Etherington 1984; Koomaraie, Whipple, Kretchmar, Crouse, and Mersmann 1991; Lawrie 1992; Wheeler 1994), and it commences before *post-mortem* glycolysis ends and continues for many days.

Figure 4.1 Biophysical and Biochemical Changes in the Conversion of Muscle to Meat



Adapted from Gill 1982

Establishment of *rigor mortis* is time and temperature dependent (Marsh 1954) and varies between muscles, animals and species. Lawrie (1992) reports that normal ultimate pH (pH_u) for pork, lamb and beef is in the range of 5.4 - 5.6, and Lister, Gregory and Warriss (1981) indicate that the time taken for pig, sheep and cattle muscle to achieve this is

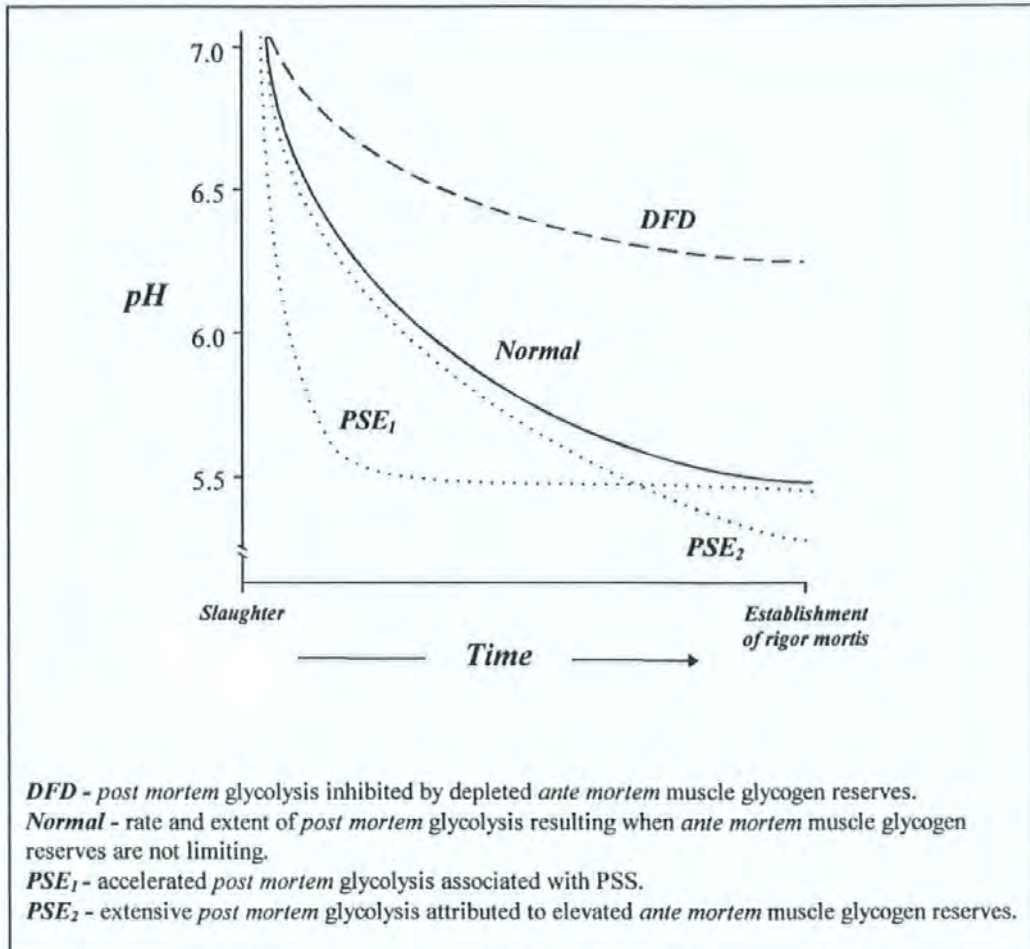
4 - 8hrs, 12 - 24hrs and 24 - 48hrs, respectively (diagrammatic representation for all species - Figure 4.2).

Pre-slaughter stressors imposed on an animal can influence both the rate and extent of *post mortem* glycolysis and give rise to meat which is PSE or DFD. PSE meat is most commonly witnessed in pork and is associated with two separate glycolytic phenomena. First, an accelerated rate of *post mortem* glycolysis reducing pH levels to *ca* 5.5 whilst temperatures remain at near *in vivo* values characterises what has become known as Porcine Stress Syndrome (PSS) and is prevalent in the Piétrain, Poland, China and some strains of the Landrace breed (Lawrie 1992; Lister, Gregory and Warriss 1981; Figure 4.2), although Faustman (1994) reports that it does occur in other breeds as well. Second, attainment of an unusually low pH_u , although the rate may not be abnormally rapid, is common in the Hampshire breed which rarely exhibits classical PSS and has been attributed to elevated *ante mortem* levels of muscle glycogen (Monin, Mejenes-Quijano, Talmant and Sellier 1987; Essen-Gustavsson and Fjelkner-Modig 1985; Figure 4.2). Faustman (1994) indicates that PSE meat quality defects vary over a wide range and Lister, Gregory and Warriss (1981) suggest that the pale colour and excessive exudate from PSE meat renders it unattractive to the consumer.

Depletion of muscle glycogen reserves, as a result of exhausting exercise, prolonged exposure to environmental conditions which an animal finds aversive, inanition or a combination of all three, inhibits the extent of *post-mortem* glycolysis (Figure 4.2). The consequence of limited *post mortem* glycolysis is dry firm and dark (DFD) meat which has a high ultimate pH, poor organoleptic qualities and is prone to bacterial spoilage (Lawrie 1992) and is known to occur in many meat species, for example; cattle (Warriss 1990), pigs (Guise and Penny 1989), rabbits (Jolley 1990), deer (Smith and Dobson 1990) and

duck (Chew, Lin and Lin 1990).

Figure 4.2 Rate and Extent of pH Decline with Time in the Conversion of Muscle to Meat



Adapted from: Bailey 1990; Lawrie 1992; Monin and Ouali 1991

DFD meat in lamb is less widely reported but is known to occur (Devine, Graafhuis, Muir and Crystall 1993; Gregory 1994; Manteca 1996a). It is prevalent in cattle and pigs and of significant economic importance to these two industries (Guise and Penny, 1989; Warriss, 1990). McNally and Warriss (1996; 1997) found that high levels of bruising in cattle resulted in higher ultimate pH and that animals from markets had more bruising than those from farms and dealers. Ultimate pH provides an indication of the welfare of animals

during handling, transportation and marketing.

The stratification of the sheep industry in the UK (diagrammatic representation in Appendix 13) and seasonality of production (Lynch, Hinch, and Adams 1992) results in animals which may show diverse responses to handling, transportation and marketing. For example, extensively reared animals from the hills and uplands may show a greater response to stressors imposed by handling (Manteca and Ruiz de la Torre 1996) than more intensively reared and more frequently handled animals (Fordham, Lincoln, Ssewanyana and Rodway 1989). The movement of store lambs from the hills and uplands for finishing in the lowlands (Carlyle 1972) means that such animals may have experienced a greater range of handling and movement operations before final transport to slaughter than lambs born and finished on a single holding. Hargreaves and Hutson (1990), for example, showed that in repeated exposure to handling procedures, stress responses of sheep diminished. Hall (1996a) reports that there may be breed differences in responses to transport stressors. In assessment of the effect of handling, transportation and marketing processes on animal welfare, breed, production systems and the previous experience of the animal are all factors for consideration.

Evidence of the impact of different practices within handling and transportation processes on animal welfare are well documented in the literature; for example:

- the use of dogs for collection (Kilgour and de Langen 1970; Baldock and Sibly 1990; Coppinger and Coppinger 1993),
- sensitivity of stockhandlers (Grandin 1993),
- design of handling facilities (Grandin 1990; Lapworth 1990; Tarrant 1990;

Warriss 1990),

- loading onto and unloading from vehicles (Kenny and Tarrant 1987; Lapworth 1990; Tarrant 1990; Trunkfield and Broom 1990; Cockram and Lee 1991; Jarvis and Cockram 1995a; Knowles *et al.* 1995; Broom *et al.* 1996; Cockram *et al.* 1996),
- vehicle stocking density (Randall 1993; Jarvis and Cockram 1994; Buchenauer 1997; Cockram *et al.* 1996; Hall 1996b),
- noise levels (Ames and Arehart 1972; Broom *et al.* 1996; Hall 1996b),
- periods of food and water deprivation (Kim *et al.* 1994; Knowles *et al.* 1995; Horton, Baldwin, Emanuele, Wohlt and McDowell 1996; Parrott, Lloyd and Goode 1996),
- mixing of unacquainted animals (Guise and Penny 1989; Parrott and Misson 1989; Baldock and Sibly 1990; Warriss 1990; Jarvis and Cockram 1995; Bradshaw, Parrott, Goode, Lloyd, Rodway and Broom 1996; Manteca 1996b),
- journey duration (Knowles *et al.* 1993; Knowles, Warriss, Brown and Kestin 1994; Jarvis *et al.* 1995; Knowles *et al.* 1995; Bradshaw, Hall and Broom 1996; Broom 1996; Broom *et al.* 1996).
- rest periods within a journey (Knowles *et al.* 1994; Cockram 1996),
- driving skill and road conditions (Buchenauer 1996; Hall 1996b; Manteca 1996a).

The importance of identifying the effects of individual components of handling and transportation processes on animal welfare is, of course, unequivocal and some authors have calibrated components in terms of the severity or magnitude of effect on the animal. For example, Baldock and Sibly (1990) measured heart rate changes in sheep for a range of handling and transportation procedures and found that, after accounting for activity, the approach of a man with a dog elicited the greatest response, and that a 20 minute period of transportation elicited a similar response to introduction to a new flock (30-120 minutes; Table 4.2).

Table 4.2 Sheep Heart Rate Responses (bpm) to Handling and Transportation Procedures

Treatment	Change in Heart Rate (bpm) (adjusted for activity)
Spatial Isolation	0
Confinement in a Stationary Trailer	0
Transportation (20mins duration)	+14
Introduction to a New Flock (30-120mins)	+14
Visual Isolation	+20
Introduction to a New Flock (0-30mins)	+30
Approach of a Man	+45
Approach of a Man with a Dog	+79

Source: Baldock and Sibly 1990

Other examples include a study of the effect of road types by Bradshaw, Hall and Broom (1996), who identified that both sheep and pigs found rough journeys more aversive than smooth journeys; and Knowles *et al.* (1993), who found no measurable differences in the welfare lambs transported for 9hrs or 14hrs. In an investigation of journey durations of 3hrs, 9hrs, 15hrs, 18hrs and 24hrs, Knowles *et al.* (1995) found that liveweight loss in

lambs increased with increasing journey durations.

These studies identify components within handling and transportation processes which may be demanding or aversive to animals, and where modifications may be made to improve animal welfare. However, when considering a complete transportation process, which may include many individual components, this reductionist approach may limit our understanding of the aggregate effects of handling and transportation and marketing processes on animal welfare. Three studies have gone some way towards examining the effects of complex journeys.

As stated previously, the effect of journey complexity on animal welfare has not been thoroughly explored, but Kenny and Tarrant (1987), Evans *et al.* (1987) and Murray *et al.* (1996) have identified that journeys of increasing complexity may have an increasingly deleterious effect on animal welfare.

First, Kenny and Tarrant (1987) investigated the effect of re-penning in a novel environment, confinement on a stationary vehicle, confinement on a moving vehicle and social re-grouping on 15 month old Friesian bulls and found that, as the complexity of treatment increased, the frequency of social interactions decreased. Plasma cortisol concentrations, levels of which may become elevated in response to environmental challenge, increased with increasing complexity of transport treatment.

Second, Evans *et al.* (1987) studied the effect of marketing route on liveweight loss in slaughterweight lambs. Lambs sent on a single direct journey from farm to slaughter lost 0.53kg liveweight (average time between farm weighing and abattoir weighing - 5 hours) and those sent via a livestock auction market lost 3.07kg liveweight (average time between farm weighing and abattoir weighing 26 hours). Difference in carcass weight loss between

the two routes was 0.47kg, which represented the additional carcass weight loss incurred by taking the longer, multi-component route through the livestock auction market. The authors suggested that lambs lost weight at a greater rate when being transported than when held at either the market or the abattoir lairage, and concluded that longer, more complex journey structures resulted in increased weight loss.

Third, an indication of the possible importance of journey structure was identified in a preliminary study of slaughter lambs arriving at an abattoir in Devon from 6 local live auction markets and 28 local farms (Murray *et al.* 1996). There were no significant differences in terms of bruising levels between marketing channels or ultimate carcass pH, which may provide an indication of the effects of pre-slaughter handling and transportation on animal welfare. However, there were fewer bruised carcasses and ultimate carcass pH was lower, indicating that pre-slaughter operations in those animals which experienced a single component journey to slaughter may have been less physically and psychologically demanding, or both, than those which experienced a multi component journey (Murray *et al.* 1996). This study was, however, limited by lack of data identifying complete journey structure of market lambs.

Some studies have taken a 'partialist' approach in examining the effects of marketing channel on animal welfare. Such an approach considers that each channel is discrete in terms of livestock distribution patterns and does not examine patterns within channels to identify complete journey structure. Cockram (1990), Cockram and Lee (1991), Jarvis and Cockram (1995), Kim *et al.* (1994), Knowles, Maunder, and Warriss (1994); Knowles, Maunder, Warriss, and Jones, (1994), McNally and Warriss (1996, 1997) and Warriss (1990) indicate that the welfare of livestock sold via live auction markets is worse than those sold direct from farm. None, however, identified complete journey structure of the

animals sold via either channel and our understanding of the relationship between marketing channel and animal welfare, therefore, may be limited. No studies have been identified which examine the welfare of animals sold via electronic auction systems.

As identified in the previous chapter, journeys experienced by slaughterweight lambs from farm to abattoir are diverse in nature and complexity in all three marketing distribution channels. There are indications that journeys of increasing complexity have an increasingly deleterious effect on animal welfare. However, complexity is characterised by multiple pickups of animals from different locations, unloading, holding at a livestock market or lairage, loading and further transportation and combinations of multiple pickups and discrete journeys. No studies have been identified which examine the effect of journey structure on the welfare of livestock. The following chapter describes an experiment to investigate the effect of three different journey types from farm to abattoir on the welfare of slaughterweight lambs.

Chapter 5 The Effect of Journey Structure on the Welfare of Slaughterweight Lambs

5.1 Introduction

Changes taking place within all sectors of the livestock and meat producing industries impinge on the journeys experienced by animals from farm to abattoir. The results of a survey conducted to trace the journey of slaughterweight lambs from farm to abattoir indicate that within the three main marketing distribution channels in this country (*viz.* direct farm to abattoir sales, those via livestock auction markets and those via electronic auction systems), journeys are diverse in nature and complexity.

As previously stated, some studies have indicated that the welfare of animals sold via livestock markets is worse than that of those sold via livestock auction markets (for example, Cockram 1990; Cockram and Lee 1991; Jarvis and Cockram 1995; Kim *et al.* 1994; Knowles, Maunder, and Warriss 1994; Knowles, Maunder, Warriss, and Jones 1994; McNally and Warriss 1996, 1997 and Warriss 1990). None identified the complete journey structure of the animals sold via either channel but in light of the results of the survey, it is essential to consider the journey structure rather than simply the marketing channel. No studies have been identified which examine the welfare of animals sold via electronic auction systems.

Three studies (Kenny and Tarrant 1987; Evans *et al.* 1987 and Murray *et al.* 1996) have identified that journeys of increasing complexity may have an increasingly deleterious effect on animal welfare. The 26 journey structures from farm to abattoir characterised in the survey contained combinations of the following components: periods of transport;

trans-shipment (when animals were transferred from one vehicle to another); multiple pickups from a number of farms; and periods of holding at either collection centres, staging posts, assembly points or auction markets. The dominant journey types were those involving two discrete journeys (10,102 lambs), direct and uninterrupted transfer from farm to abattoir (4,888 lambs) and those involving between two and eight pickups (2,369 lambs) *en route*. No studies have been identified that distinguish between the effects of direct and uninterrupted journeys to abattoir and those involving multiple pickups *en route* on animal welfare (both being classed as direct farm to abattoir transport) and thence, none that distinguish between journeys involving multiple pickups and those involving two discrete journeys.

An experiment was conducted to investigate the effect of three different journey types from farm to abattoir on the welfare of slaughterweight lambs: direct transfer from farm to abattoir, a journey involving 3 additional pickups *en route* and a journey involving holding at a livestock auction market.

5.2 Methodology

Variables measured included physical, behavioural and physiological indicators of the welfare of the lambs and incorporated: liveweight, weight of digestive tract (including digesta), lying and standing behaviours, jaw movements (ruminating, eating, idle and 'undetermined'; see Section 5.2.3) carcass weights and ultimate carcass pH (pH_u).

The manager of the Seale-Hayne farm kindly agreed that lambs from the farm's commercial flock could be used in the experiment on the proviso that no financial loss was incurred by the farm business. Financial constraints on expenditure for the experiment meant that the cost of purchasing lambs could not be borne. However, a local abattoir

agreed to purchase 90 lambs over a period of 9 weeks and to permit data collection on abattoir premises. The abattoir specified that on the same given day each week, lambs should arrive at the abattoir at 10am, with slaughter commencing immediately after unloading.

Examination of the farm records indicated that slaughterweight lambs would be available from early October to January. Thus, the framework for experiment was dictated by lamb availability and the willingness of the abattoir to purchase the lambs within a given time period. This inevitably imposed constraints on experimental design and resulted in there being 30 transported lambs in each treatment and a total of 45 control lambs. Two transported and two control animals were selected for behaviour recording within each replicate; a total of six per transport treatment and 18 controls. Where appropriate, results of data analyses comparing transported and control animals are presented prior to an examination of the effect of different journey types.

5.2.1 Treatments

One hundred and thirty five shorn Charollais x Mule lambs (90 transported and 45 non-transported controls) from the Seale-Hayne commercial flock were allocated to three treatments, replicated three times within a randomised block design.

The treatments were:

1. direct and uninterrupted transfer from farm to abattoir;
2. direct transfer from farm to abattoir incorporating three additional pickups *en route*;

3. transfer from farm to abattoir incorporating a holding period at a livestock auction market.

Journey duration, *i.e.* time from initial loading at the farm to final unloading at the abattoir, was four hours in each case. The survey of journeys experienced by slaughterweight lambs from farm to abattoir (Chapter 3) identified that journey complexity increased with distance travelled. However, the aim of this experiment was to investigate the effect of journey structure on the welfare of lambs. For this reason, journey duration was the same for each treatment thus controlling the effects of duration of inanition on the variables measured. Structural and temporal characteristics of each treatment are illustrated in Figure 5.1. Focal lambs were transported in the front pen on the lower deck of a two-deck commercial livestock lorry in treatments 1 and 2 and for the outward journey from market in treatment 3. For the inward journey to market in treatment 3, focal lambs were transported in a single deck livestock trailer.

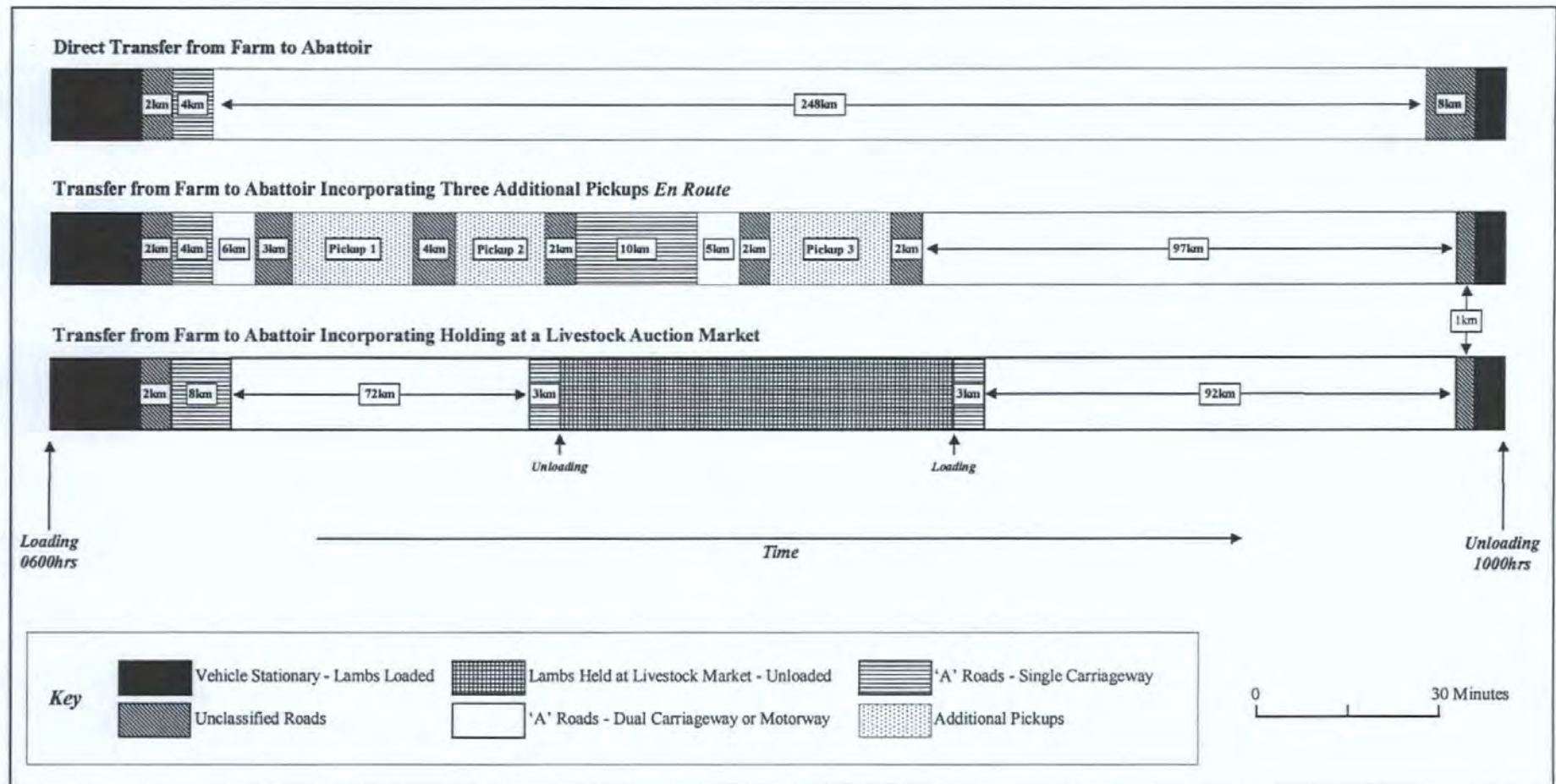
Treatment 1 comprised a total distance of 262km of which 10km was on local unclassified roads, 4km on 'A' classified single carriageway roads and 248km on 'A' classified dual carriageway roads.

Treatment 2 comprised a total distance of 138km of which 16km was on local unclassified roads, 14km on 'A' classified single carriageway roads, and 108km on 'A' classified dual carriageway roads. The distance from the farm to the first pickup was 15km; seven lambs were loaded into the adjacent pen and time from arrival to departure was 0.33hrs. The distance between pickups one and two was 4km; seven additional lambs were loaded and penned with lambs from pickup one and time from arrival to departure was 0.25hrs. The distance between pickups two and three was 19km; six additional lambs were loaded and penned with lambs from pickups one and two and time from arrival to departure was

0.33hrs. The distance travelled between the farm and pickup three was 40km and time to the completion of loading of all lambs was 2.33hrs. The distance travelled between pickup three and the abattoir was 100km, extending to 1.67hrs duration.

Treatment 3 comprised a total distance of 181km of which 3km was on local unclassified roads, 14km on 'A' classified single carriageway roads and 164km on 'A' classified dual carriageway roads or motorway. The distance from farm to market was 85km and lambs were unloaded immediately on arrival at 0725hrs, penned and held for 1hr before loading and departure at 0830hrs. Six additional lambs were loaded in the adjacent pen. The distance from market to abattoir was 96km.

Figure 5.1 Structural and Temporal Characteristics of Journeys from Farm to Abattoir

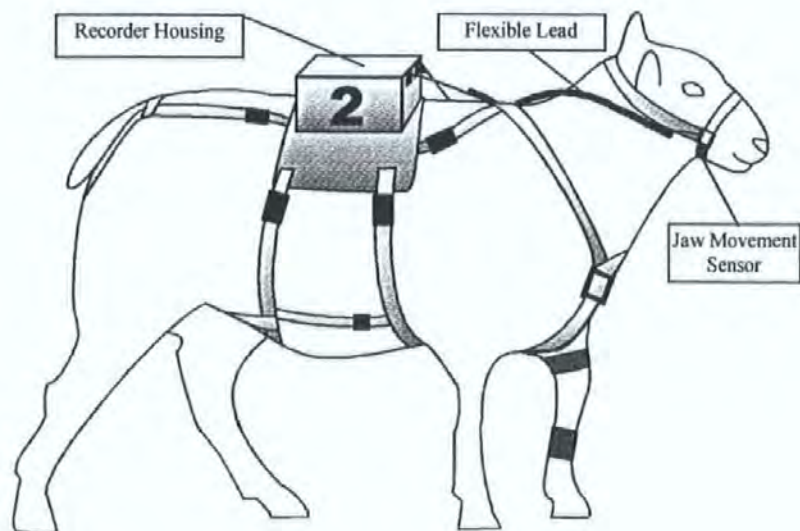


5.2.2 Handling and Transportation Operations

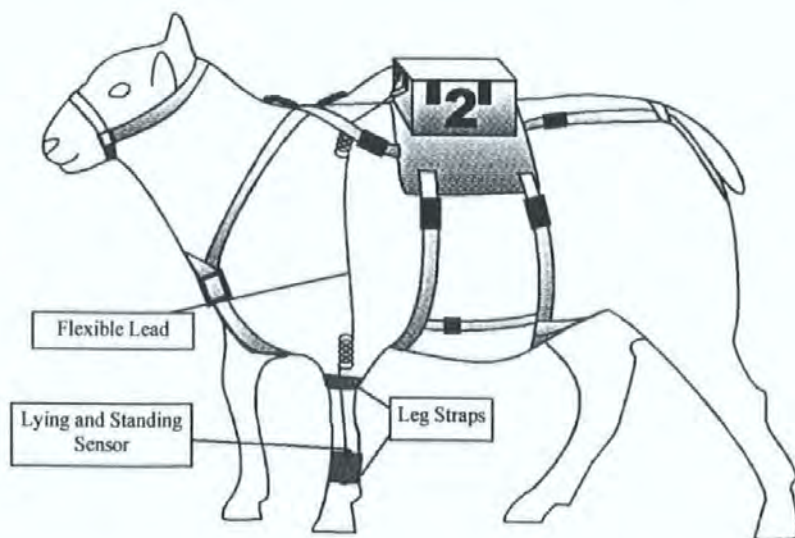
An automatic system for digital recording of jaw movements (to characterise and quantify ruminating, eating, idle and 'undetermined' behaviours) and lying and standing behaviours, operated by a data logging programme was used (*BehavRec* V1.0; Institute of Grassland and Environmental Research 1996). This system, developed by the Institute of Grassland and Environmental Research (IGER), North Wyke, had previously been employed to examine the behaviour of cattle and sheep at pasture (Champion, Rutter and Penning 1997; Champion, Rutter, Penning and Rook 1994; Rutter, Champion, and Penning 1997) and calves during transport (Rutter 1997 *personal communication*). The application of this technology provided a novel approach in the examination of the behaviour of lambs during transport. The equipment and associated operational training were provided by IGER.

Four lambs within each replicate (two transported and two non-transported control lambs) were randomly selected for behaviour recording. Recorders were housed in harnesses worn by the lambs and attached to leg and jaw movement sensors (Figure 5.2) and discussions with IGER indicated that a minimum period of 48hrs between fitting the harnesses and data collection were required to allow the lambs to habituate to the equipment.

Figure 5.2 Right and Left Lamb Profiles Identifying Sensor Locations, Harness Position and Adjustable Locating Straps



(a) Right lamb profile. Jaw movement sensor forming the lower muzzle section of the head collar and connected by a flexible lead extending from the right of the head collar to the recorder located in the recorder housing



(b) Left lamb profile. Lying and standing sensor attached to the lower left foreleg, held in position by adjustable 'velcro' straps above and below the knee and connected by a flexible lead to the recorder located in the recorder housing.

The management of, and data collection from, each replicate comprised 6 days of operations. In summary: on Day 1, fifteen focal lambs were randomly selected from those drafted from the Seale-Hayne commercial flock for slaughter (10 transported and 5 non-transported controls). Four of these lambs (2 transported and 2 non-transported controls) were randomly selected for behaviour recording and harnesses and behaviour recording equipment were fitted for habituation. Behaviour recording commenced on Day 3 and the lambs were maintained at pasture until Day 4 when they were housed. The principal reason that lambs were housed overnight prior to the transport period was to ensure that slaughter was not delayed by lambs being too dirty or too wet (or both) to comply with the Meat Hygiene Service Clean Livestock Policy (Meat Hygiene Service 1997).

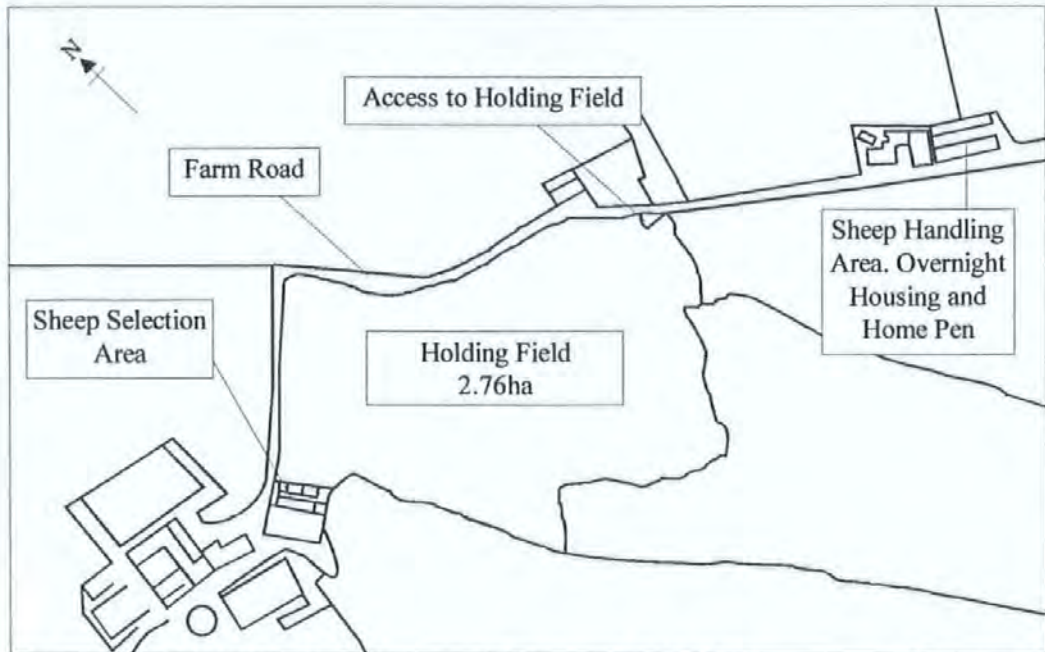
Transport and control groups were segregated at 0545hrs on Day 5. Transported animals were loaded onto the transporting vehicle at the farm at 0600hrs, departing at 0615hrs. Arrival at the abattoir occurred at 0955hrs with unloading at 1000hrs. Lambs were slaughtered within 30 minutes of arrival. Control animals remained in a home pen for the duration of the transport period and were subsequently returned to the farm flock for marketing the following day. On Day 6, carcasses were weighed and graded and muscle samples taken for subsequent pH measurement. A more comprehensive description of all handling and transportation operations is now given and a site plan (Figure 5.3) identifies locations for all on-farm procedures.

Day1: The Seale-Hayne lamb flock was gathered in the Sheep Selection Area (Figure 5.3), and those animals suitable for marketing were drafted using extant farm practices, which comprised grading and weighing. Grading extended to assessment of muscular development and fat deposition by tactile examination of the spinous and transverse processes of the lumbar vertebrae in the loin region, the eye muscle in the loin region and

the spinous processes in the shoulder region to determine suitability for marketing and overrode weight. Minimum criteria for selection included: a full eye muscle in the lumbar region, with the spinous and transverse processes felt with gentle pressure. Selected animals were drafted from the flock. Grading was subjective and weights were not recorded because individual animal identification was not possible. The fifteen focal lambs were randomly selected and drafted from the farm marketing flock, which was then returned to pasture. Henceforth, focal lambs remained segregated from the rest of the flock.

The focal lambs were transferred by foot to the Sheep Handling Area (approximately 600m; Figure 5.3). They were individually marked using a proprietary spray stock marker for identification purposes and weighed. Four lambs (2 transported and 2 non-transported controls) were randomly selected for behaviour recording and harnesses and recording equipment were fitted for habituation (Figure 5.2). The focal lambs were then transferred on foot to pasture in the Holding Field (approximately 200m Figure 5.3). All procedures were completed by 1700hrs on Day 1.

Figure 5.3 Plan of Part Scale-Hayne Farm Identifying Locations Used During Farm-Based Experimental Procedures



Adapted from: Farmade Management Systems Ltd. 1996

Not to scale

Day 2: Focal lambs remained at pasture in the Holding Field throughout Day 2 and were checked twice in line with normal husbandry routines.

Day 3: Focal lambs remained at pasture in the Holding Field until 1500hrs when they were transferred on foot to the Sheep Handling Area (Figure 5.3).

Behaviour recorders were activated (Figure 5.2) and the lambs returned on foot to pasture in the Holding Field. All operations were complete by 1700hrs.

Day 4: Lambs remained at pasture in the Holding Field until 1500hrs when they were once again transferred on foot to the Sheep Handling Area. Behaviour recorders were removed, data collected were downloaded to a laptop computer and all batteries were changed to enable further data collection. The lambs were weighed at 1630hrs and then penned for

overnight housing after recording equipment was replaced and reactivated. All operations were complete by 1700hrs. Hay and water was provided during overnight housing.

Day 5: Lambs were weighed at 0515hrs and Transport and Control lambs were segregated at 0545hrs. Control animals were penned in the home pen for the duration of the transport period. Transported animals were loaded at 0600hrs with departure at 0615hrs. On arrival at the abattoir, the lambs were unloaded and weighed. Slaughter commenced at 1020hrs and was complete by 1030hrs. Following dressing, hot carcass weights were recorded. Control lambs were weighed at 1000hrs to coincide with arrival time at the abattoir.

All operations were complete by 1330hrs.

Behavioural data were downloaded to a laptop computer.

Day 6: Recording of cold carcass weights commenced at 0730hrs. Approximately 3g of muscle was removed from the *semimembranosus* of each carcass and samples were packed in ice and returned to the laboratory where they were frozen. All operations were complete by 0900hrs.

5.2.3 Behaviour Recording

A total of 36 focal lambs (18 transported and 18 non-transported controls) were selected for behaviour recording, as described previously. The focal period for comparative analysis was the transport period: 0600hrs - 1000hrs on Day 5. Baseline data were collected whilst the lambs were at pasture on Days 3 and 4 and during overnight housing on Days 4 to 5.

In an experiment examining the temporal variation of grazing behaviour in sheep, Champion *et al.* (1994) found that grazing patterns were disrupted in the hour following

disturbances resulting from changing the behaviour recording equipment. Thus, in this experiment, because handling operations associated with changing the behaviour recording equipment were completed by 1700hrs on Days 3 and 4, behavioural data used for analysis commenced at 1800hrs. Comparative periods used for analysis from Day 3, when the lambs were at pasture, to the conclusion of the transport period on Day 5 are shown in Table 5.1.

Table 5.1 Time Periods Used in Analysis of Lamb Behaviour from Day 3 to Day 5

Time Period	Experiment Days	Lamb Location
1800hrs - 0500hrs	3 - 4	All lambs at pasture
0600hrs - 1000hrs	4	All lambs at pasture
1800hrs - 0500hrs	4 - 5	All lambs in Overnight Holding Pen
0600hrs - 1000hrs	5	Transport Group transported Control Group in Home Pen

The system (*BehavRec* V1.0; Institute of Grassland and Environmental Research 1996) was as described by Rutter, Champion and Penning (1997). It comprised an erasable programmable read only memory (EPROM) plugged into a microcomputer, a 2 Mb static random access memory (RAM) card and associated interface electronics mounted on a clear polycarbonate lid (120mm x 122mm x 15mm) which was attached to a polycarbonate base (120mm x 122mm x 70mm) containing a re-chargeable 7.2V; 1.7A h nickel-cadmium battery pack.

The recorders were set up using a slider switch located within the lid and connected to the battery pack. A liquid crystal display (LCD), visible through the lid, showed the recorder number, time and date. This information was subsequently stored on the data file for identification. A reed switch, activated by a magnet through the lid, was used to enable

detection of the RAM card and fully charged battery, to format the RAM card and show the status of and test the jaw movement and lying and standing sensors. Sensitivity adjustments could be made to the jaw movement sensor after examining the amplitude of the raw signal, which was displayed on the LCD, using a potentiometer on the interface board. These procedures were conducted before the equipment was fitted to the animals. Further steps to full activation of the recorders, prompted by commands on the LCD, were conducted after fitting. Following full activation, the LCD showed the amplitude of the signal from the jaw movement sensor, the number of bytes of jaw movement data which had been recorded, the status of the lying and standing sensor and the current time.

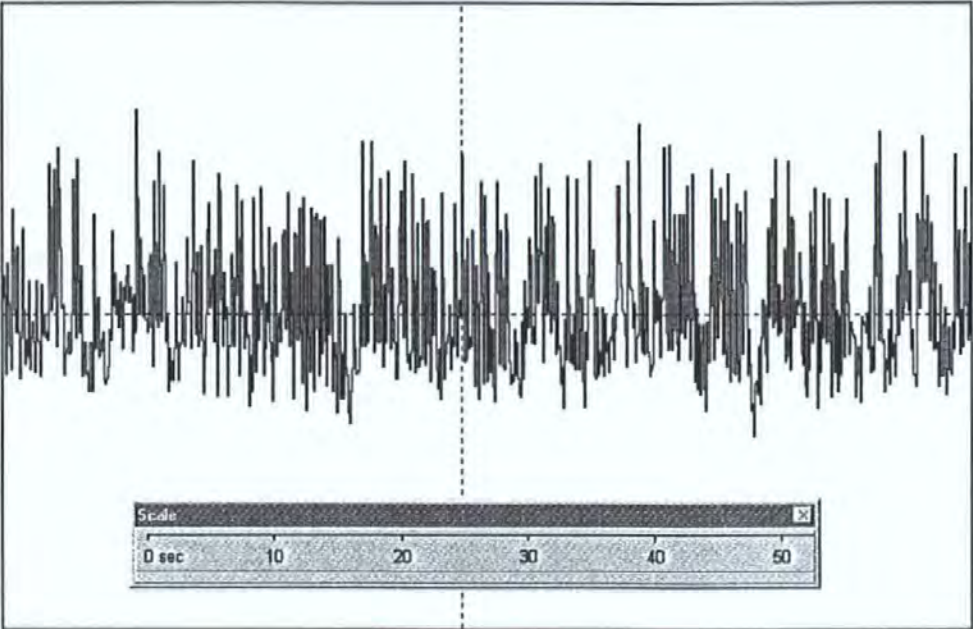
The amplitude of jaw movements was logged at 20Hz, and whether the animal was standing or lying was logged at 0.5Hz. Continuous data recording was limited to 25.5hrs by the capacity of the RAM cards and battery charge. Therefore, because the recording periods required in this experiment were greater than this, two recordings per animal were made: the first from 1700hrs Day 3 to 1500hrs on Day 4 and the second from 1700hrs on Day 4 to 1000hrs on Day 5.

Data files were downloaded from the RAM cards to a laptop computer fitted with a PCMCIA drive and subsequently processed using *Graze* software (Institute of Grassland and Environmental Research 1997). Within this programme, jaw movement data (*i.e.* the signal amplitude from the jaw movement sensor), is plotted against time and displayed as waveforms (Figure 5.4) which are then characterised to give time spent eating, ruminating, idling and 'undetermined'.

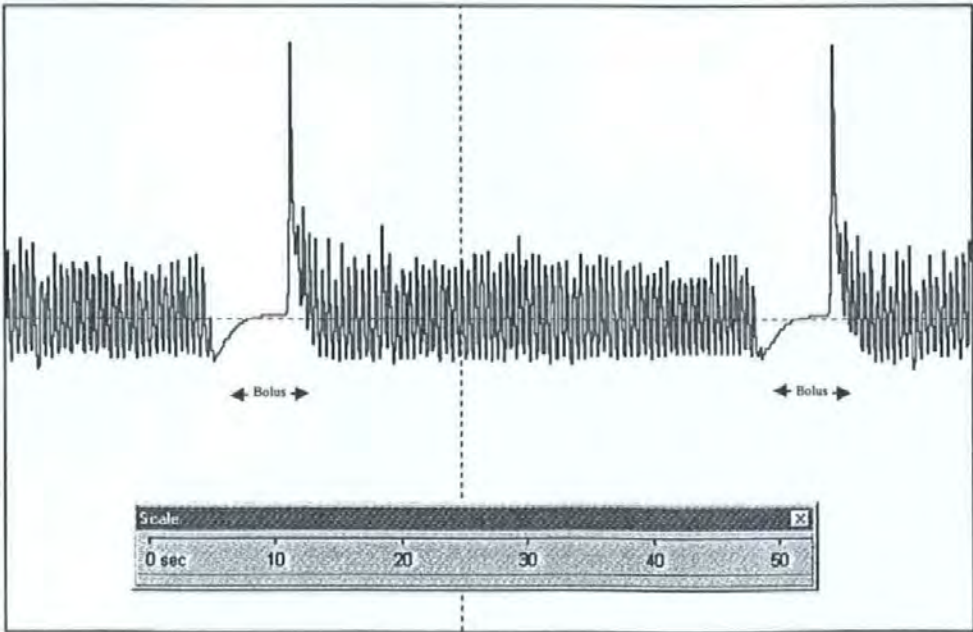
The irregular waveforms in Figure 5.4(a) show jaw movements characteristic of eating and those in Figure 5.4(b) show those characteristic of ruminating including bolus regurgitation. Figure 5.5 identifies those waveforms characteristic of idling, and

'undetermined' behaviours. 'Undetermined' behaviours are those that result in waveforms of a minimum of 10s duration (pre-set in the software), but are not characteristic of eating or ruminating. The reason for including such occurrences in the jaw movement behaviour profile is, for example, that sheep have been observed to wool-pull *i.e.* pull out the wool of conspecifics under conditions of close confinement (Fraser and Broom 1997; Lynch, Hinch, and Adams 1992) and to grind their teeth during penning and handling operations (*personal observation*). Whilst these behaviours have not been validated for *BehavRec*, the occurrence of 'undetermined' jaw movement behaviours during transportation may indicate an area for further study.

Figure 5.4 Jaw Movement Waveforms Characteristic of Eating (a) and Ruminating (b) Displayed by *Graze* Software

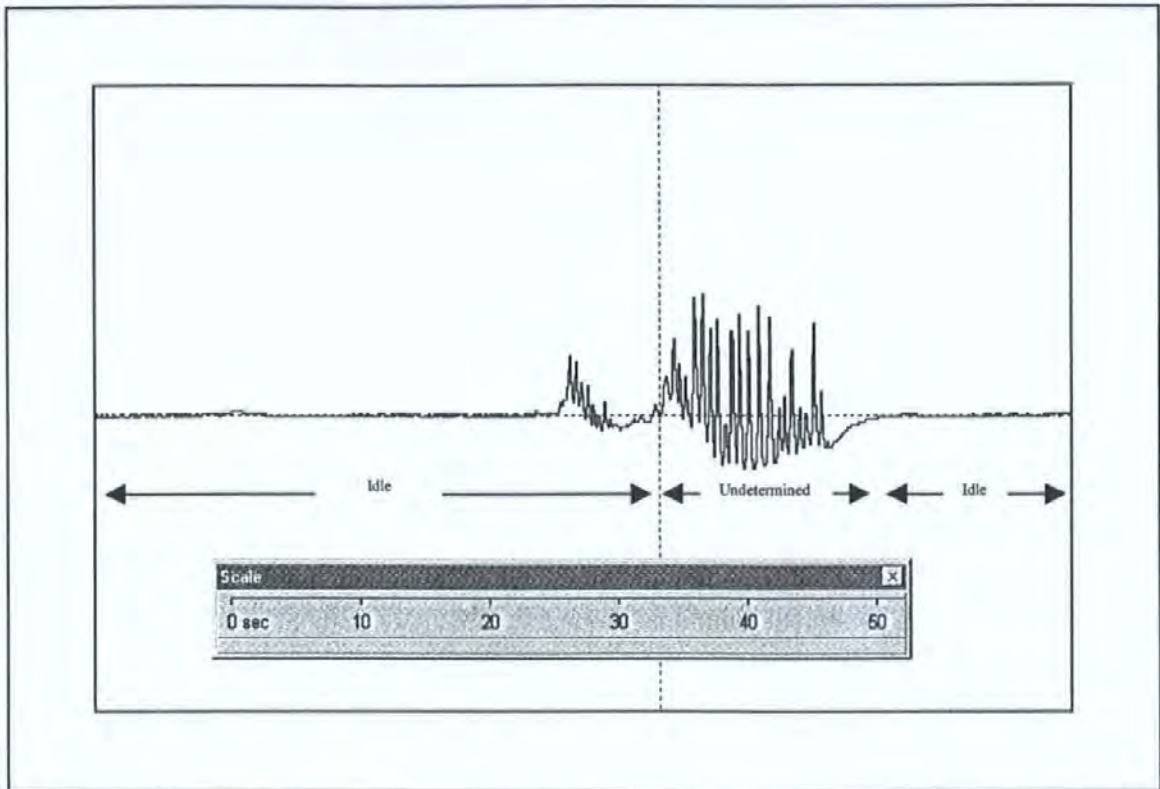


(a) Irregular waveforms characteristic of eating



(b) More regular waveforms characteristic of ruminating. Bolus regurgitation identified.

Figure 5.5 Jaw Movement Waveforms Characteristic of Idling and ‘Undetermined’ Behaviours Displayed by *Graze* Software



Sequential patterns of jaw movement behaviours, including time of occurrence and duration are identified. Presentation of lying and standing data by the software identifies times of transitions from standing to lying and *vice versa*, and thus, sequential patterns and durations may be calculated. All data were transferred to Microsoft Excel Version 7.0 (Microsoft Corporation 1997) for further processing.

5.2.4 Liveweight, Carcass Weight and Digestive Tract Weight Recording

For liveweight recording, two different lamb weighers incorporating electronic weigh heads (GHL Products, Crewe) were required to record the weights of transported and control animals within each replicate simultaneously. The weighers were calibrated before the experiment commenced and tested thereafter at weekly intervals. The weigher used at

the abattoir was delivered in Week 1 and remained there until completion in Week 9. Carcass weights were recorded on the abattoir scales. Hot carcass weights were recorded on conclusion of all dressing operations after slaughter and cold carcass weights were recorded after overnight hanging.

Digestive tract weights, including digesta, were recorded using a spring balance (Salter (UK) Ltd, West Bromwich). This was conducted to give an indication of the extent of gut fill.

5.2.5 Ultimate Carcass pH (pH_u) Measurement

pH_u measurement, in excised samples of the *semimembranosus*, was conducted in a single assay after conclusion of all replicates using a microprocessor bench-top pH meter (HI 8521, Hanna Instruments Ltd, Leighton Buzzard). Previously frozen samples were thawed and held at 5°C for 48hrs to ensure complete glycolysis before measurements were taken.

5.2.6 Sheep Handling Area, Overnight Holding Pen and Home Pen

Following focal lamb selection all handling and housing procedures were conducted under cover in the building identified in Figure 5.3.

The Sheep Handling Area comprised a temporary straw bedded pen (3.6m x 1.8m) constructed of sheep hurdles, providing a floor area of 6.48m² or 0.43m² per lamb, located within the Overnight Holding Pen. This provided a working environment for fitting behaviour recording equipment and weighing the lambs. The Sheep Handling Area was dismantled for overnight holding on Day 5 and re-erected for handling operations on Day 6.

The Overnight Holding Pen comprised a straw bedded pen (4.5m x 4.5m). Two water buckets, each containing 12 litres of water, attached to the pen superstructure, occupied an area of 0.29m²; thus a floor area of 19.96m² (1.33m² per lamb) was provided. Hay (5kg Fresh Weight) was offered in a purpose built hay rack (1.8m in length) attached to the pen superstructure providing rack space of 0.12m per lamb. Hay remaining after the completion of each replicate was weighed and a sample was oven dried at 80°C for 24hrs for dry weight consumption calculation.

The Home Pen, holding control lambs during the transport period, comprised a straw bedded pen (1.8m x 1.25m), constructed of sheep hurdles providing a floor area of 2.25m² (0.45m² per lamb). The Home Pen was located in the pen adjacent to the Overnight Holding Pen and was secured to the pen superstructure to prevent distortion during holding. No hay or water were offered during the transportation period.

5.2.7 Transporting Vehicles

A commercial two-deck livestock transporter was used for treatments 1 and 2 and for the outward journey from market in treatment 3. Focal lambs were transported in the front pen (2.28m x 1.98m) on the lower deck providing a total floor area of 4.5m² (0.45m² per lamb) and headroom of 1.03m. The gradient of the ramp on loading at the farm and at all additional pickup farms in treatment 2 was 27°. Raised loading/unloading bays at the market and abattoir reduced this to 20° and 22°, respectively. The haulage company had assured that the same driver would transport all replicates. However, the driver was unwell on two separate occasions, which resulted in another driver transporting treatment 1 lambs (direct farm to abattoir) in replicates 1 and 2.

A single deck, twin axle livestock trailer (Rice Richardson Ltd, Shipton-by-Beningbrough) was used to transport the focal lambs on the inward journey to market in treatment 3 providing a floor area of 4.63m² or 0.46m² per lamb and headroom of 2.48m. The gradient of the loading/unloading ramp was 12°. The raised loading/unloading bay at the market was not used when unloading.

Straw bedding was provided in all cases, to a depth sufficient to soak up urine.

5.2.8 Site Rainfall and Temperature

Site rainfall and temperature were monitored by an automatic meteorological station and recorded daily. Rainfall data were collected over a period of 24hrs (0900hrs-0800hrs) and recorded as a daily total. Temperatures were recorded hourly over the same period.

Temperatures were monitored in the transporting vehicles, the overnight holding pen, the home pen and at the market using Tinytalk data loggers (Gemini Data Loggers (UK) Ltd, Chichester).

Three data loggers were used in both the commercial transporter and the livestock trailer. In the commercial transporter, these were located at the longitudinal mid point of the pen, laterally at 0.6m from each external wall and centrally at 1.14m and were attached to the vehicle superstructure 1.0m above the pen floor.

In the livestock trailer, the data loggers were similarly located at the longitudinal mid point, laterally at 0.45m from each external wall, centrally at 0.9m and were suspended from the vehicle superstructure 1.0m above the pen floor.

One data logger was used in the overnight holding pen and another in the home pen to monitor temperature in these locations. These were attached to the pen walls 1.0m above the pen floors.

Similarly, one data logger was located at the livestock market attached to the holding pen allocated to the lambs 1.0m above the pen floor.

All data collected were collated in Microsoft Excel version 7.0 and analysed in either Minitab Release 12.1 (Minitab Inc. 1998) or SPSS Release 9.9.0 (SPSS Inc. 1998) as appropriate. Statistical tests are described within the results reported.

5.3 Results

5.3.1 Site Rainfall and Temperatures

Weather conditions, as measured by site temperature and rainfall, were variable during the experimental period: mean total site rainfall whilst the lambs were held at pasture from Day 1 to Day 4 was 10.62 mm (± 3.55 SEM) and mean site temperature for the same period was 9.76°C (± 1.0 SEM). Mean temperature in the overnight holding pen between 1800hrs on Day 4 to 0500hrs on Day 5 was 7.97°C (± 0.96 SEM). A generalised linear model (glm) one-way analyses of variance indicated that there were no significant differences between treatment means in any case (site rainfall: $F_{2,6} = 0.22$; site temperatures: $F_{2,6} = 0.06$; Overnight Holding Pen temperature: $F_{2,6} = 0.41$. $P > 0.05$ in all cases; Table 5.2).

Table 5.2 Mean Site Rainfall (mm±SEM), Mean Site Temperatures (°C±SEM) from Day 1 to Day 4 and Mean Overnight Holding Temperature (°C±SEM) from 1800hrs on Day 4 to 0500hrs on Day 5. All Treatments

	Direct	Multiple Pickup	Market
Mean Site Rainfall (mm±SEM) Day 1 - Day 4	13.6 (±2.69)	7.2 (±3.62)	11.1 (±11.0)
Mean Site Temperature (°C±SEM) Day 1 - Day 4	9.46 (±1.39)	10.31 (±1.57)	9.51 (±2.72)
Mean Overnight Holding Pen Temperature (°C)	6.71 (±1.53)	8.98 (±1.6)	8.21 (±2.19)

Row means do not differ; $P > 0.05$ in all cases

5.3.2 Overnight Hay and Water Consumption

Mean dry weight of hay consumed by the lambs during overnight housing was 1.68kg (±0.13 SEM) and a glm one-way analysis of variance indicated that there were no significant differences between the treatment means ($F_{2,6} = 0.51$; $P > 0.05$. Table 5.3).

Table 5.3 Mean Dry Weight of Hay Consumed (kgDW±SEM) During Overnight Housing. All Treatments

	Direct	Multiple Pickup	Market
Mean Dry Weight of Hay Consumed (kg±SEM)	1.48 (±0.27)	1.80 (±0.05)	1.77 (±0.33)

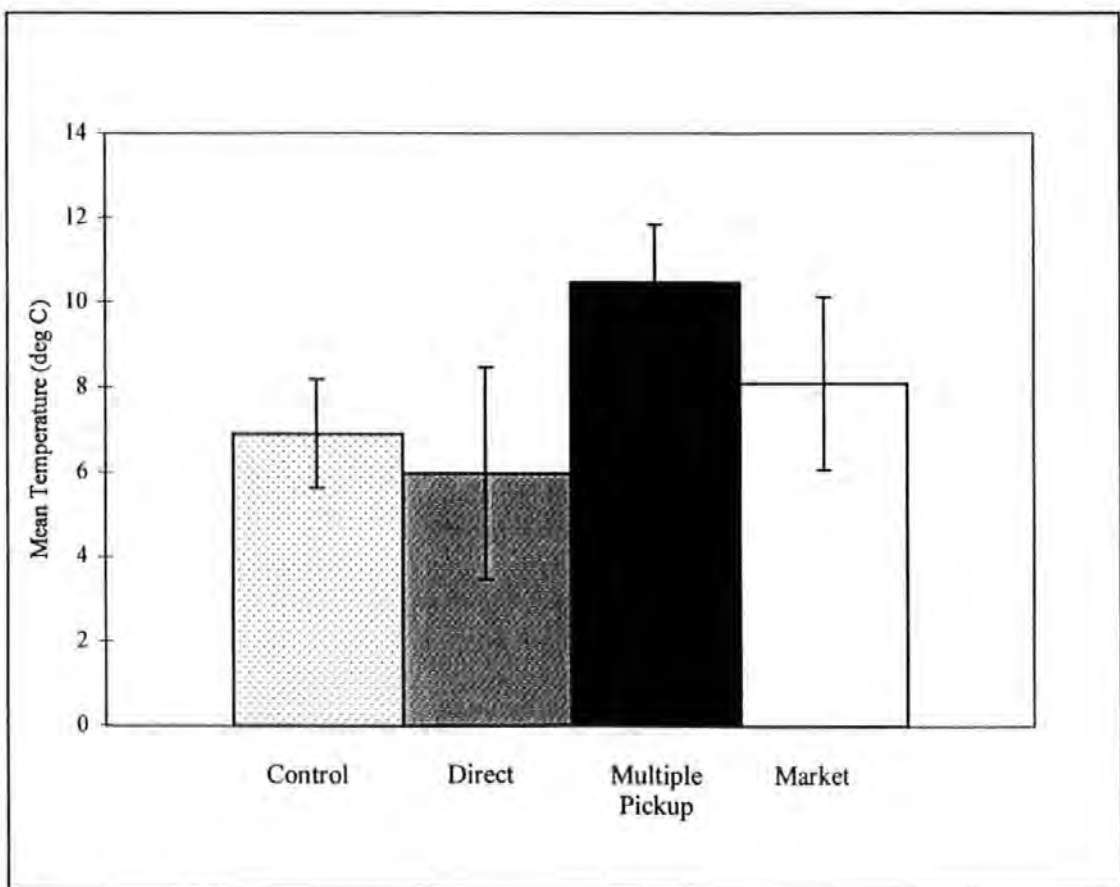
Row means do not differ; $P > 0.05$ in all cases

No water was consumed during overnight housing.

5.3.3 Temperatures During the Transport Period

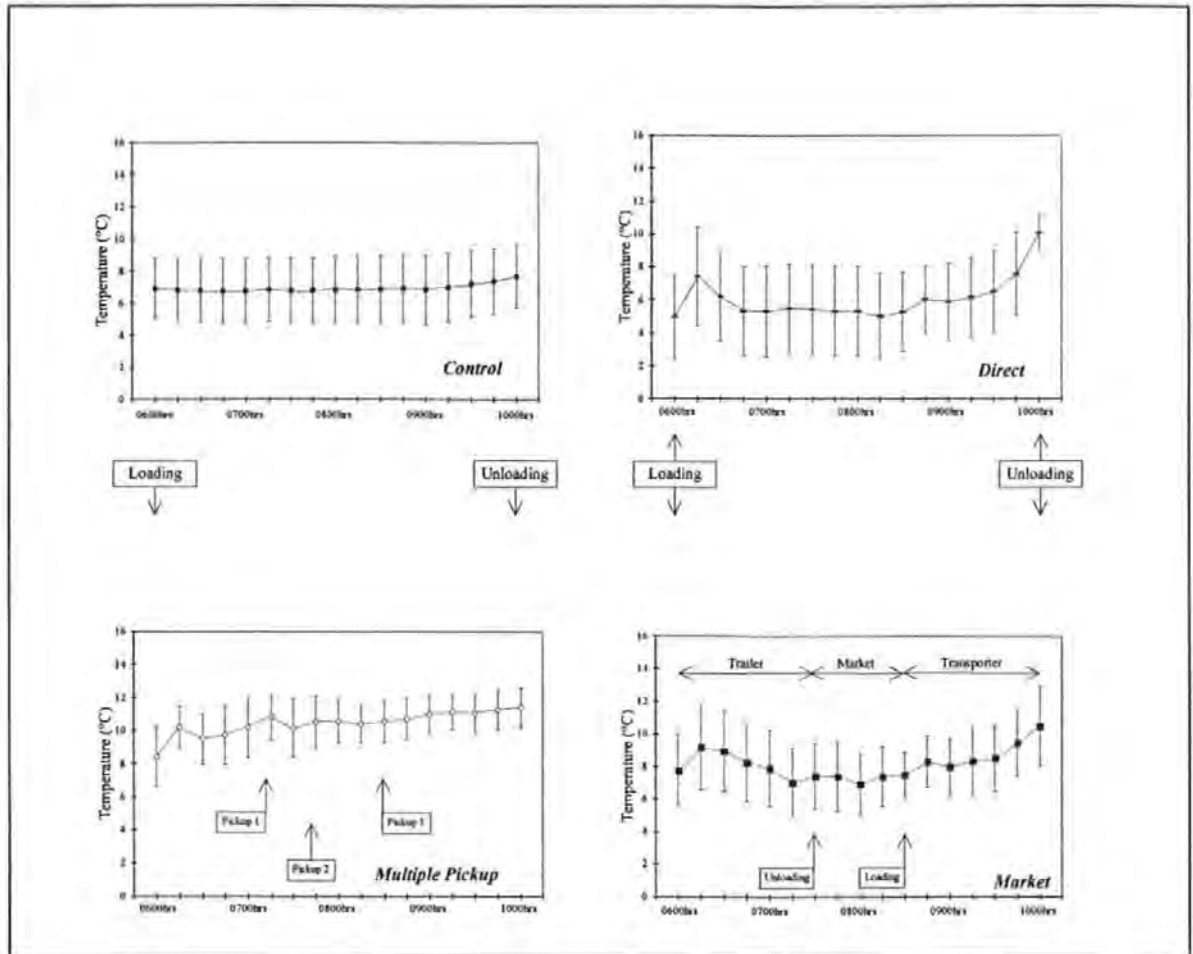
During the transport period, between 0600hrs and 1000hrs on Day 5, whilst the transport treatments were conducted, Control lambs remained on site. Mean temperature experienced by the lambs during the transport period was 8.03 °C ($\pm 0.97^{\circ}\text{C}$ SEM). A glm one-way analysis of variance indicated that there were no significant differences between the treatment or control means ($F_{3,14} = 0.90, P > 0.05$; Figure 5.6).

Figure 5.6 Mean Temperature ($^{\circ}\text{C} \pm \text{SEM}$) for Control, Direct, Multiple Pickup and Market Lambs between 0600hrs and 1000hrs on Day 5



Temperature profiles, at a resolution of 15 minutes ($^{\circ}\text{C} \pm \text{SEM}$), during the transport period for Control, Direct, Multiple Pickup and Market lambs are shown in Figure 5.7. Whilst there were no significant differences in the temperatures experienced during the transportation period, trends in the profiles show that, for Control lambs, mean temperatures remained relatively constant throughout the transport period (range 6.71°C - 7.63°C). For all transport treatments, mean temperatures increased between 0600hrs and 0615hrs, between loading and departure whilst the vehicle was stationary and then declined after the commencement of the journey. For Direct lambs, mean temperatures continued to decline until 0645hrs after which they remained within 1°C of mean loading temperatures until 0830hrs. For the last 1.5hrs of the journeys mean temperatures increased to a maximum of 10.06°C at unloading. For Market lambs, mean temperatures continued to decline after the commencement of the journeys until 0715hrs whilst *en route* to the market. Mean temperatures at the market remained within 1°C of mean temperatures at the start of the transport period. After loading at the market at 0830hrs mean temperatures increased to a maximum of 10.44°C at unloading at the abattoir. For Multiple Pickup lambs, whilst mean temperatures declined between 0615hrs and 0630hrs, they showed a steady increase thereafter.

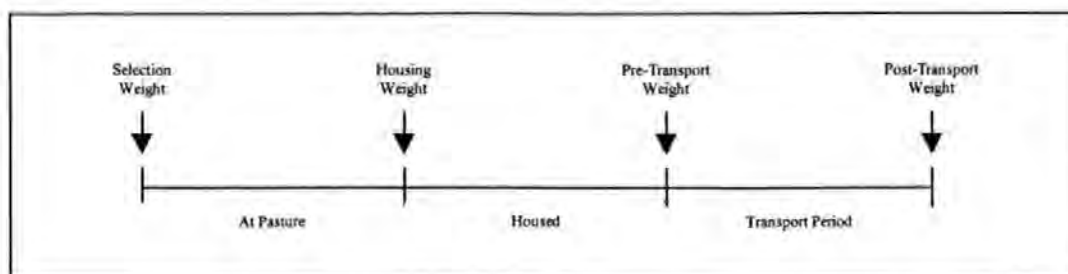
Figure 5.7 Temperature Profiles ($^{\circ}\text{C} \pm \text{SEM}$) at a Resolution of 15 Minutes During the Transport Period for Control, Direct, Multiple Pickup and Market Lambs



5.3.4 Liveweight

Lambs were weighed at selection (Selection Weight), on housing (Housing Weight), prior to the transport period (Pre-Transport Weight) and after the transport period (Post-Transport Weight). A schematic illustrating these processes is given in Figure 5.8.

Figure 5.8 Schematic of Lamb Liveweight Measurement Processes



Because Selection Weight, Housing Weight, Pre-Transport Weight and Post-Transport Weight were repeated measures on the same animals they were, as expected, highly correlated (Pearson product-moment correlation coefficient (Zar 1996); $P < 0.001$ in all cases; Table 5.4).

Table 5.4 Selection Weight, Housing Weight, Pre-Transport Weight and Post-Transport Weight Correlation Matrix.

	Selection Weight	Housing Weight	Pre-Transport Weight
Housing Weight	0.930		
Pre-Transport Weight	0.928	0.972	
Post-Transport Weight	0.928	0.961	0.989

Correlations significant: $P < 0.001$ in all cases

A preliminary analysis of Selection Weight in isolation indicated that the mean was $41.61\text{kg} \pm 0.24$ and that there were no significant differences between treatment means (one way analysis of variance (Zar, 1996); $F_{3,131} = 2.30$; $P > 0.05$; Table 5.5).

Table 5.5 Mean Selection Weight (kg \pm SEM) for Direct, Multiple Pickup, Market and Control Lambs.

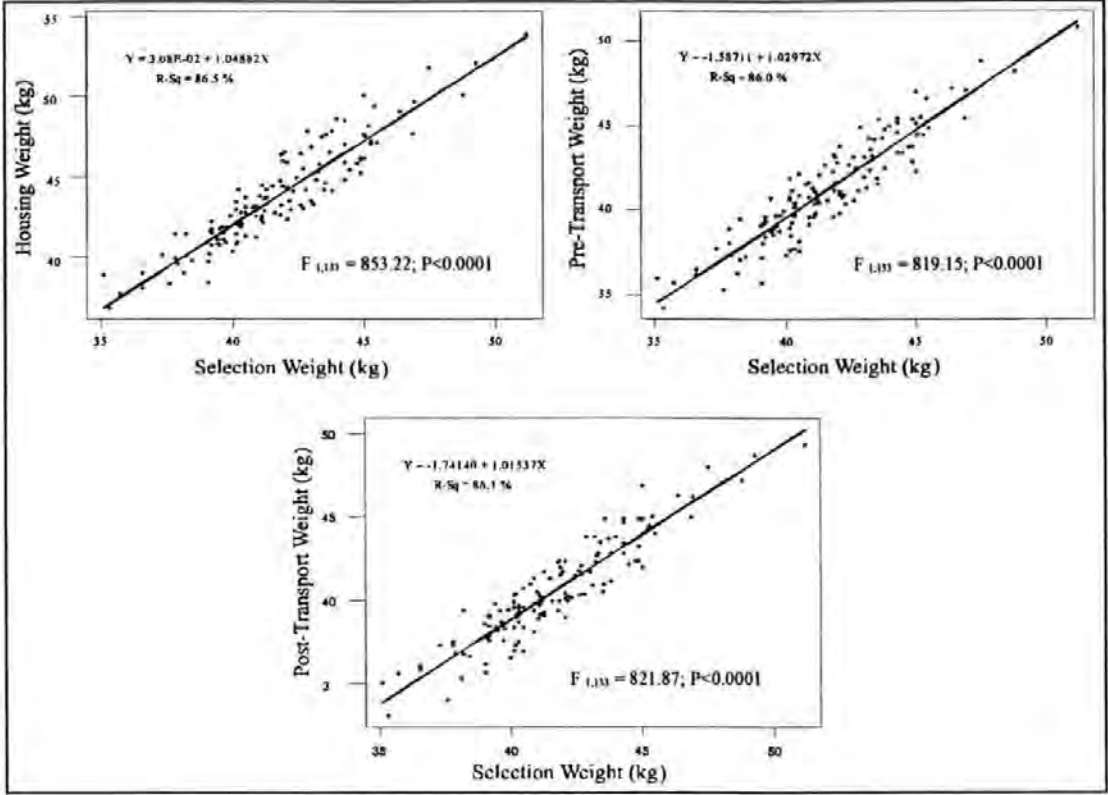
	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)	Control (n=45)
Mean Selection Weight (kg \pmSEM)	42.28 \pm 0.56	40.97 \pm 0.49	42.30 \pm 0.47	41.13 \pm 0.38

Means do not differ; $P > 0.05$ in all cases

However, weights ranged from 35.1kg to 51.2kg and Selection Weights of the lambs may have had an effect on subsequent weights (Mead, Curnow and Hasted 1993). This was investigated using regression analysis techniques described below.

Selection Weight had a significant effect on Housing Weight, accounting for 86.5% of the variance (simple linear regression (Zar 1996); $F_{1,133} = 853.22$; $P < 0.001$). The effects of preceding weights on Pre-Transport Weight and Post-Transport Weight were investigated in hierarchical multiple regression analyses with Selection Weight entered first and subsequent weights entered chronologically (Howitt and Cramer 1999). Selection Weight accounted for 86.0% of the variance in Pre-Transport Weight and 86.1% of the variance in Post-Transport Weight ($F_{1,133} = 819.15$; $P < 0.001$ and $F_{1,133} = 827.87$, respectively). Figure 5.9 illustrates the relationship between Selection Weight and subsequent weights.

Figure 5.9 The Effect of Selection Weight (kg) on Housing Weight (kg), Pre-Transport Weight (kg) and Post-Transport Weight (kg)



Selection Weight was, therefore, used as a covariate in a glm repeated measures analysis of covariance of weight. Weight was the within-subjects factor, defined to have three levels (Housing Weight, Pre-Transport Weight and Post-Transport Weight) and Treatment was the between-subjects factor (Mead, Curnow and Hasted 1993; Hair, Anderson, Tatham and Black 1998).

The effect of the covariate (Selection Weight) was significant ($F_{1,130} = 918.73; P < 0.001$) as was the interaction between treatment and weight over time ($F_{6,260} = 6.053; P < 0.001$). Table 5.6 shows the covariate adjusted means for Housing Weight, Pre-Transport Weight

and Post-Transport Weight for Direct, Multiple Pickup, Market and Control treatments, characterising differences.

Table 5.6 Covariate Adjusted Mean Housing Weight, Pre-Transport Weight and Post-Transport Weight (kg±SEM) for Direct, Multiple Pickup, Market and Control Lambs

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)	Control (n=45)
CA Mean Housing Weight (kg±SEM)	43.96 ±0.21 ^a	43.66 ±0.21	43.62 ±0.21	43.53±0.17 ^a
CA Mean Pre- Transport Weight (kg±SEM)	41.75 ±0.21 ^{a,b,c}	41.03 ±0.21 ^a	41.20 ±0.21 ^b	41.13 ±0.17 ^c
CA Mean Post- Transport Weight (kg±SEM)	41.18 ±0.20 ^{a,b,c}	40.04 ±0.20 ^{a,d}	40.20 ±0.20 ^{b,e}	40.59 ±0.16 ^{c,d,e}

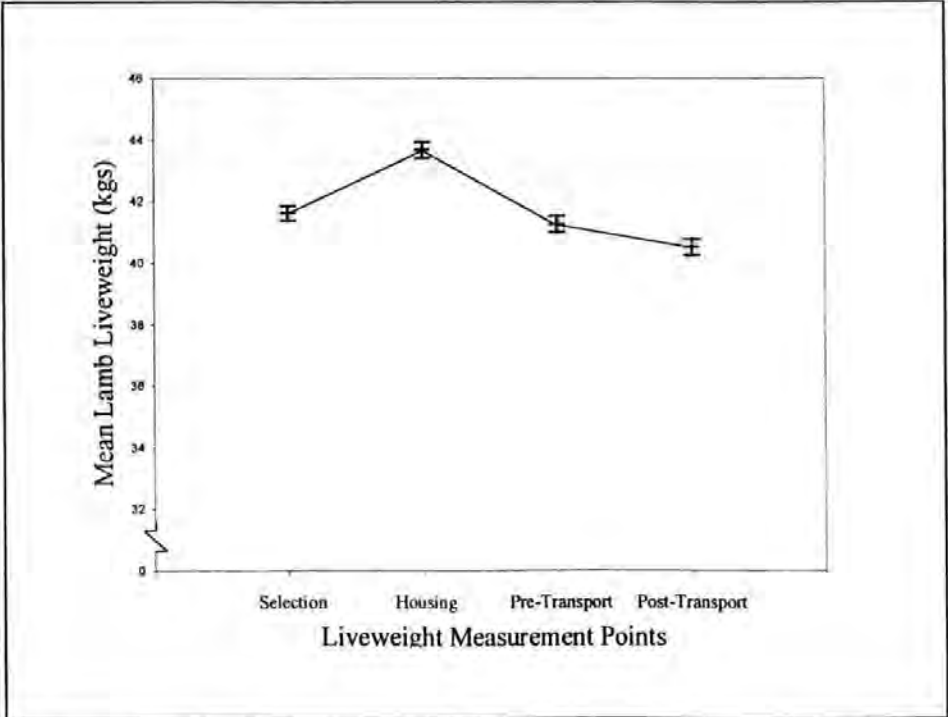
CA = Covariate Adjusted. Row means with similar superscripts differ at P<0.05. Column means differ at P<0.05 in all cases

Pairwise comparisons, using the Tukey WSD test (Zar 1996), indicated that mean Housing Weight of lambs on the Direct treatment was greater than that of Control lambs (43.96kg±0.21 and 43.53kg±0.17, respectively; P<0.05; Table 5.6). There were no other significant treatment differences in Housing Weight (P>0.05 in all cases). Mean Pre-Transport Weight and mean Post-Transport Weight of lambs on the Direct treatment were greater than those of all other treatments (P<0.05 in all cases; Table 5.6). There were no other significant treatment differences in Pre-Transport Weight (P>0.05 in all cases). Mean Post-Transport Weight of Control lambs was greater than that of Multiple Pickup and Market lambs (P<0.05 in both cases; Table 5.6) and there was no significant difference in mean Post-Transport Weight of Multiple Pickup and Market lambs (P>0.05; Table 5.6).

Within all treatments, Housing Weight was greater than Pre-Transport Weight and Post-Transport Weight, and Pre-Transport Weight was greater than Post-Transport Weight ($P < 0.05$ in all cases, Table 5.6).

The preceding analyses indicate that liveweight increased whilst the lambs were at pasture, (between Selection Weight and Housing Weight), decreased during housing (between Housing Weight and Pre-Transport Weight) and decreased further during the transport period (between Pre-Transport Weight and Post-Transport Weight). These phenomena are illustrated in Figure 5.10 for all lambs across all treatments.

Figure 5.10 Mean Lamb Liveweight (kg \pm SEM) at Selection, Housing, Pre-transport and Post-Transport. All Lambs Across All treatments.



Selection Weight was not significantly correlated with Pasture Weight Gain, Housing Weight Loss or Transport Weight Loss (Pearson product-moment correlation coefficient (Zar 1996); $r = 0.117, -0.072$ and -0.089 , respectively; $P > 0.05$ in all cases) and Selection Weight was not, therefore used as a covariate.

Mean Pasture Weight Gain was $2.06\text{kg} \pm 0.01$ and there were no significant differences between treatment means (one way analysis of variance (Zar 1996); $F_{3,131} = 1.04$; $P > 0.05$; Table 5.7).

Housing Weight was significantly correlated with Housing Weight Loss ($r = -0.183$; $P < 0.05$) and was used as a covariate in a glm analysis of covariance of Housing Weight Loss. The effect of the covariate was significant ($F_{1,130} = 6.629$; $P < 0.05$) and there were no significant differences between treatment means ($F_{3,130} = 2.096$; $P > 0.05$; Table 5.7). Mean Housing Weight Loss for all lambs across all treatments was $2.41\text{kg} \pm 0.062$.

Table 5.7 Mean Pasture Weight Gain and Covariate Adjusted Mean Housing Weight Loss and Transport Weight Loss (kg \pm SEM) for Direct, Multiple Pickup, Market and Control Lambs.

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)	Control (n=45)
Mean Pasture Weight Gain (kg \pmSEM)	2.37 \pm 0.22	2.02 \pm 0.20	2.03 \pm 0.19	1.90 \pm 0.18
CA Mean Housing Weight Loss (kg \pmSEM)	2.18 \pm 0.13	2.64 \pm 0.13	2.40 \pm 0.13	2.42 \pm 0.11
CA Mean Transport Weight Loss (kg \pmSEM)	0.56 \pm 0.07 ^{ab}	1.00 \pm 0.07 ^{ac}	0.99 \pm 0.07 ^{bd}	0.55 \pm 0.06 ^{cd}

CA = Covariate Adjusted. Row means with similar superscripts differ at $P < 0.05$

Housing Weight and Pre-Transport Weight were significantly correlated with Transport Weight Loss ($r = -0.171$ and -0.170 , respectively; $P < 0.05$, in both cases). In a stepwise multiple regression Housing Weight was entered first and explained 2.2% of the variance in Transport Weight Loss ($F_{1,133} = 4.003$; $P < 0.05$). Pre-Transport Weight was excluded from the model because it was a non-significant predictor of Transport Weight Loss ($t = -0.168$; $P > 0.05$). Housing Weight was, therefore, used as covariate in a glm analysis of covariance of Transport Weight Loss. The effect of the covariate was significant ($F_{1,130} = 5.098$; $P < 0.05$) and there were significant differences between the treatment means ($F_{3,130} = 15.335$; $P < 0.001$; Table 5.7).

Pairwise comparisons (Tukey's WSD; Zar 1996) indicated that there was no significant difference in mean Transport Weight Loss of Direct and Control lambs ($0.56\text{kg} \pm 0.07$ and $0.55\text{kg} \pm 0.06$, respectively; $P > 0.05$; Table 5.7). There was also no significant difference in mean Transport Weight Loss of Multiple Pickup and Markets lambs ($1.00\text{kg} \pm 0.07$ and $0.99\text{kg} \pm 0.07$, respectively; $P > 0.05$). Mean Transport Weight Loss of both Direct and Control lambs were significantly less than those for Multiple Pickup and Market lambs ($P < 0.05$ in all cases).

Total Weight Loss between Housing Weight and Post-Transport Weight was investigated using a glm analysis of covariance using Housing Weight as the concomitant variable. The effect of the covariate was significant ($F_{1,130} = 12.139$; $P < 0.05$) and, as would be expected from the results of the above analyses, there were significant differences between treatment means ($F_{3,130} = 8.803$; $P < 0.001$).

Pairwise comparisons (Tukey WSD; Zar 1996) indicated that there was no significant difference in mean Total Weight Loss of Direct and Control lambs ($2.73\text{kg} \pm 0.14$ and $2.97\text{kg} \pm 0.12$, respectively; $P > 0.05$; Table 5.8). There was also no significant difference in

mean Total Weight Loss of Multiple Pickup and Markets lambs ($3.64\text{kg} \pm 0.14$ and $3.40\text{kg} \pm 0.14$, respectively; $P > 0.05$). Mean Total Weight Loss of Direct and Control lambs were both significantly less than Multiple Pickup lambs ($P < 0.05$ in both cases) and Market lambs ($P < 0.05$ in both cases). Mean Total Weight Loss for Direct, Multiple-Pickup, Market and Control lambs represented 6.2%, 8.3%, 7.8% and 6.8% of Housing Weight, respectively (data from Tables 5.6 and 5.8).

Table 5.8 Covariate Adjusted Mean Total Weight Loss (kg \pm SEM) for Direct, Multiple Pickup Market and Control Lambs

	Direct (<i>n</i> =30)	Multiple Pickup (<i>n</i> =30)	Market (<i>n</i> =30)	Control (<i>n</i> =45)
CA Mean Total Weight Loss (kg \pm SEM)	2.73 \pm 0.14 ^{ab}	3.64 \pm 0.14 ^{ac}	3.40 \pm 0.14 ^{bd}	2.97 \pm 0.12 ^{cd}

CA = Covariate Adjusted. Means with similar superscripts differ at $P < 0.05$

Weight Loss during the housing and transport periods was further investigated to examine the effect of the two environments. To achieve this, Weight Loss was calculated per hour because of the differing durations of the housing and transport periods. For the purposes of this analysis the Housing period was deemed to extend from the commencement of weighing at Housing to the commencement of Pre-Transport weighing and the Transport Period was deemed to extend from the commencement of Pre-Transport weighing to the commencement of Post-Transport weighing.

Mean Hourly Weight Loss (kg/hr) in the Housing and Transport periods was investigated in a two-factor glm analysis of covariance using Housing Weight as the concomitant variable. The effect of the covariate was significant ($F_{1,261} = 11.15$; $P < 0.001$) and there

were significant differences between the interaction means ($F_{3,261} = 7.50$; $P < 0.001$; Table 5.9).

Pairwise comparisons (Tukey WSD; Zar 1996) indicated that there were no significant differences in mean Hourly Weight Loss between the treatment means during the Housing Period ($P > 0.05$ in all cases; Table 5.9). There were no significant differences in mean Hourly Weight Loss of Direct and Control lambs during the Transport Period (both $0.12 \text{ kg/hr} \pm 0.01$; $P > 0.05$; Table 5.9). Similarly, there were no significant differences in mean Hourly Weight Loss of Multiple Pickup and Market lambs during the Transport Period (both $0.21 \text{ kg/hr} \pm 0.01$; $P > 0.05$; Table 5.9). Mean Hourly Weight Loss of Direct and Control lambs was less than that of Multiple Pickup and Market lambs during the Transport Period ($P < 0.05$ in all cases; Table 5.9).

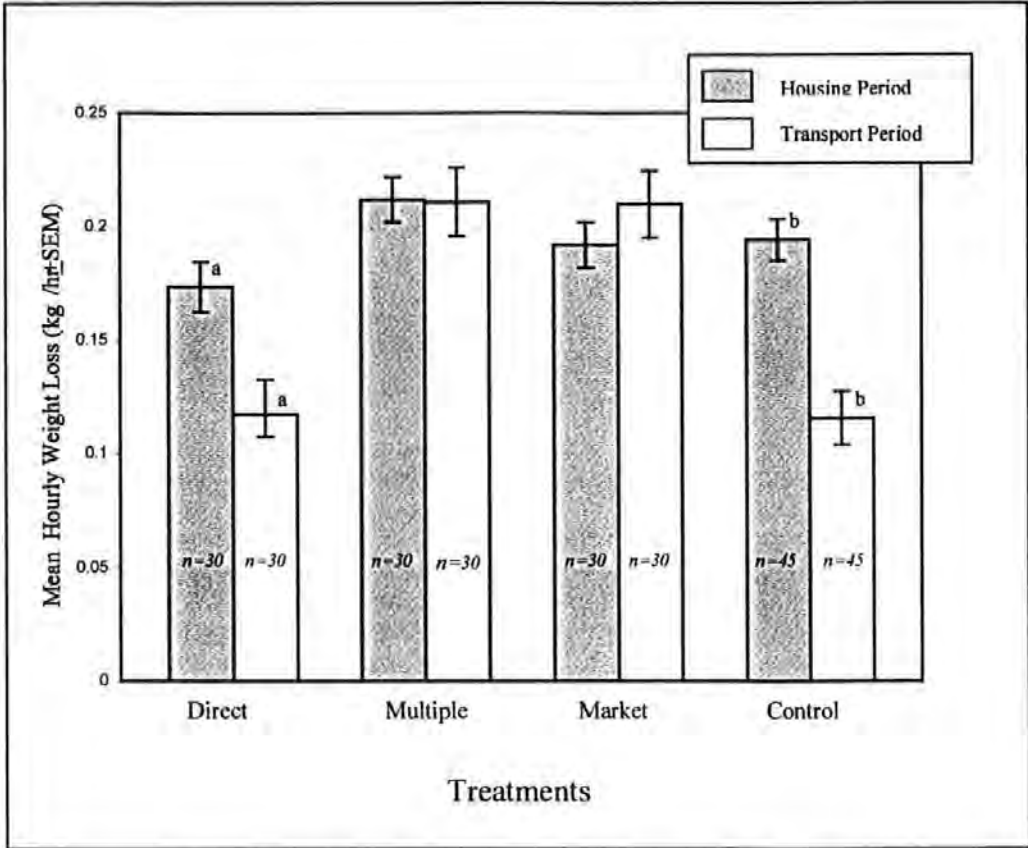
Table 5.9 Mean Hourly Weight Loss (kg/hr \pm SEM) During the Housing and Transport Periods for Direct, Multiple-Pickup and Market Lambs.

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)	Control (n=45)
CA Mean Weight Loss (kg/hr \pmSEM) During Housing	0.17 \pm 0.01	0.21 \pm 0.01	0.19 \pm 0.01	0.19 \pm 0.01
CA Mean Weight Loss (kg/hr \pmSEM) Transport	0.12 \pm 0.01 ^{a,b}	0.21 \pm 0.01 ^{a,c}	0.21 \pm 0.01 ^{b,d}	0.12 \pm 0.01 ^{c,d}

CA = Covariate Adjusted. Row means with similar superscripts differ at $P < 0.05$

Within treatments, there were no significant differences in mean Hourly Weight Loss between the Housing and Transport Periods for Multiple Pickup or Market lambs ($P > 0.05$ in both cases; Figure 5.11). Mean Hourly Weight Loss in the Housing Period was greater than that in the Transport Period for Direct and Control lambs ($P < 0.05$ in both cases; Figure 5.11).

Figure 5.11 Mean Hourly Weight Loss (kg/hr±SEM) Within Treatments



Within treatments, means with similar superscripts differ at P<0.05

5.3.5 Post Mortem Measures

Direct, Multiple Pickup and Market lambs were slaughtered following transportation. Control lambs were not slaughtered because transportation would have been required to do so. Following slaughter, lamb carcasses were dressed according to extant abattoir practice.

Post mortem measures comprised Hot Carcass Weight (kg), Cold Carcass Weight (kg) and Digestive Tract Weight (kg). The lamb carcasses were weighed on completion of all dressing operations (Hot Carcass Weight) and after overnight hanging (Cold Carcass Weight). Digestive Tract Weight, including digesta, was recorded to estimate the fresh weight of the digesta and provide an indication of the extent of gut fill.

All pre-slaughter liveweights and carcass weights were highly correlated, as would be expected (Pearson product-moment correlation coefficient (Zar 1996); $P < 0.001$ in all cases; Table 5.10).

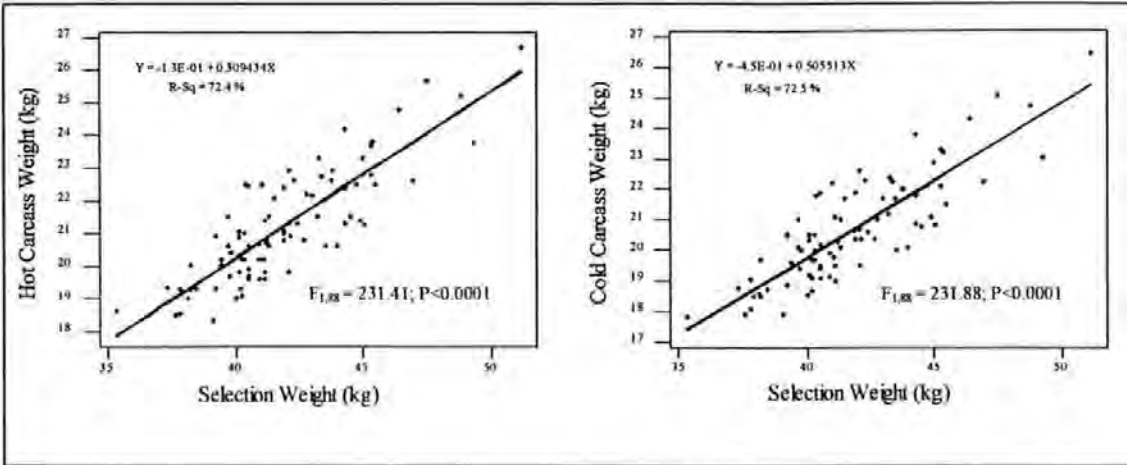
Table 5.10 Selection Weight, Housing Weight, Pre-Transport Weight, Post-Transport Weight, Hot Carcass Weight and Cold Carcass Weight Correlation Matrix.

	Selection Weight	Housing Weight	Pre-Transport Weight	Post-Transport Weight	Hot Carcass Weight
Housing Weight	0.944				
Pre-Transport Weight	0.937	0.975			
Post-Transport Weight	0.936	0.968	0.990		
Hot Carcass Weight	0.851	0.874	0.892	0.870	
Cold Carcass Weight	0.851	0.873	0.893	0.871	0.994

Correlations significant: $P < 0.001$ in all cases

The effects of preceding weights on Hot Carcass Weight and Cold Carcass Weight were investigated in hierarchical multiple regression analyses with Selection Weight entered first and subsequent weights entered chronologically (Howitt and Cramer 1999). Selection Weight accounted for 72.4% of the variance in Hot Carcass Weight and 72.5% of the variance in Cold Carcass Weight ($F_{1,88} = 231.40$ and $F_{1,88} = 231.88$, respectively; $P < 0.001$ in both cases). Figure 5.12 illustrates the relationship between Selection Weight and Hot Carcass Weight and Cold Carcass Weight.

Figure 5.12 The Effect of Selection Weight (kg) on Hot and Cold Carcass Weights (kg)



Selection Weight was, therefore, used as a covariate in a glm repeated measures analysis of covariance of carcass weight. Carcass Weight was the within-subjects factor, defined to have two levels (Hot Carcass Weight and Cold Carcass Weight) and Treatment was the between-subjects factor (Mead, Curnow and Hasted 1993; Hair *et al.* 1998).

The effect of the covariate was significant ($F_{1,86} = 231.35; P < 0.001$), but there were no significant effects of treatment over time ($F_{2,86} = 0.025; P > 0.05$). Table 5.11 shows the covariate adjusted means for Hot Carcass Weight and Cold Carcass Weight for Direct, Multiple Pickup, Market and treatments.

Table 5.11 Covariate Adjusted Hot Carcass and Cold Carcass Weights (kg±SEM) of Direct, Multiple Pickup and Market Lambs

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)
CA Hot Carcass Weight (kg ±SEM)	20.93 (±0.16)	21.19 (±0.16)	21.46 (±0.16)
CA Cold Carcass Weight (kg ±SEM)	20.45 (±0.16)	20.71 (±0.16)	20.97 (±0.16)

Row and column means do not differ; P>0.05 in all cases

The effect of treatment on Carcass Weight Loss between Hot and Cold Carcass Weights was investigated using a glm analysis of variance. No covariates were used because there were no significant correlations between Carcass Weight Loss and any of the preceding weights (Selection Weight; $r=0.06$; $P>0.05$, Housing Weight; $r = 0.08$; $P>0.05$, Pre-Transport Weight; $r = 0.06$; $P>0.05$, Post-Transport Weight; $r = 0.06$; $P>0.05$ and Hot Carcass Weight; $r = 0.13$; $P>0.05$). Mean Carcass Weight Loss across all treatments was $0.48\text{kg} \pm 0.02$ and there were no significant differences between the treatment means (Table 5.12).

Table 5.12 Mean Carcass Weight Loss (kg ±SEM) of Direct, Multiple Pickup and Market Lambs

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)
Mean Carcass Weight Loss (kg ±SEM)	0.48 (±0.14)	0.48 (±0.19)	0.48 (±0.21)

Row means do not differ; P>0.05 in all cases

Cold carcass weight expressed as a percentage of liveweight is known as the killing out percentage (Kirk 1995). Killing out percentage (KOP) was investigated using covariate

adjusted values for Post-Transport Weight and Cold Carcass Weight (see Tables 5.6 and 5.11, respectively).

The conventional arcsine transformation was not used for KOP data because there was no evidence of non-normal distribution (Anderson-Darling Normality Test; $P > 0.05$). There was no evidence of heterogeneity of variance between the treatments (Levene's Test; $P > 0.05$) and, therefore, a glm analysis of variance was conducted.

There were significant treatment effects for KOP ($F_{2,87} = 8933.98$, $P < 0.001$; Table 5.13).

Table 5.13 Mean KOP (%±SEM) of Direct, Multiple Pickup and Market Lambs

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)
Mean KOP (%±SEM)	49.39 (±0.015)	51.44 (±0.011)	51.86 (±0.016)

Means differ at $P < 0.05$ in all cases

Pairwise comparisons (Tukey WSD; Zar 1996) indicated that mean KOP of Direct lambs was less than that of Multiple Pickup and Market lambs (49.39%±0.015, 51.44%±0.011, 51.86%±0.016, respectively; $P < 0.05$ in both cases) and that mean KOP of Multiple Pickup lambs was less than that of Market lambs ($P < 0.05$).

The effect of treatment on the extent of gut fill at slaughter was investigated in a glm analysis of covariance of Digestive Tract Weight (including digesta) using Selection Weight as the concomitant variable. Selection Weight was significantly correlated with Digestive Tract Weight ($r = 0.701$; $P < 0.001$). The effect of the covariate was significant ($F_{1,86} = 95.54$; $P < 0.001$) and there were significant differences between the treatment means ($F_{2,86} = 10.06$; $P < 0.001$; Table 5.14).

Table 5.14 Covariate Adjusted Mean Digestive Tract Weight (kg±SEM) for Direct, Multiple-Pickup and Market Lambs

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)
CA Adjusted Mean Digestive Tract Weight (kg ±SEM)	9.76 ±0.13 ^{a,b}	9.27±0.13 ^a	8.95±0.13 ^b

CA = Covariate Adjusted. Means with similar superscripts differ at P<0.05

Pairwise comparisons (Tukey WSD; Zar 1996) indicated that covariate adjusted mean Digestive Tract Weight of lambs on the Direct treatment was greater than that of those on the Multiple Pickup and Market treatments (9.76kg ±0.13, 9.27kg ±0.13 and 8.95kg ±0.13, respectively; P<0.05 in both cases; Table 5.14). There was no significant difference in covariate adjusted mean Digestive Tract Weight of Multiple Pickup and Market lambs (P>0.05).

Ultimate pH (pH_u) was measured in the *semimembranosus* to investigate the effects of handling and transportation on *ante mortem* glycogen depletion (See Chapter 4).

There was evidence that the data did not conform to a normal distribution (Anderson-Darling Normality Test; P<0.001) and, therefore, the Kruskal-Wallis Test of the equality of medians was conducted (Zar 1996). There were significant treatment effects on pH_u (df = 2, H =14.01, P<0.01; Table 5.15).

Table 5.15 Median pH_u in the *Semimembranosus* of Direct, Multiple Pickup and Market Lambs

	Direct (n=30)	Multiple Pickup (n=30)	Market (n=30)
Median pH _u	5.50 ^{a,b}	5.55 ^a	5.54 ^b

Medians with similar superscripts differ at P<0.05

Tukey type pairwise comparisons indicated pH_u in the *semimembranosus* of Direct lambs was less than that of Multiple Pickup and Market lambs (median 5.50, 5.55 and 5.54, respectively; $P < 0.05$; Table 5.15) and that there was no significant difference between that of Multiple Pickup and Market lambs ($P > 0.05$; Table 5.15).

5.3.6 Behavioural Measurements

As previously described, an automatic system, operated by a data logging programme (*BehavRec* V1.0; Institute of Grassland and Environmental Research 1996), was used for digital recording of the jaw movements (eating, ruminating and idle and 'undetermined') and lying and standing behaviours of four lambs in each replicate (2 transported and 2 non-transported controls).

As a precursor to examining the temporal characteristics of the behaviours measured, it was important to investigate data independence. The reasons for this are as follows: Martin and Bateson (1993) indicate that behavioural measurements of individual animals that are maintained in groups may not be independent. The authors recommend that, where doubts about the independence of individuals in a group exist, the mean value for the group should be treated as a single measurement. This phenomenon was illustrated in grazing sheep by Rook and Penning (1991) who identified significant synchronisation of eating, ruminating, and idling activities within groups and thus demonstrated that measurements for individual animals were not independent.

The lambs in the current investigation, however, were not maintained at pasture throughout the experimental period. In summary, the lambs were drawn from the farm flock for each of the nine replicates. Lambs in each replicate were then maintained as a discrete group whilst at pasture (Day 1 to Day 4) and during overnight housing (Day 4 to Day 5). Two

sub-groups were then formed to provide 10 transported lambs and 5 non-transported controls for the transport period (Day 5). Thus, two management elements were imposed that may have had an effect on behaviour synchronisation. First, group size was altered on two occasions: on selection and prior to the transport period. Second, the physical environment was also changed on two occasions: at housing and for the transport period. Within these management elements, the source and nature of available food and water was also changed. Whilst at pasture, the animals were grazing with access to water in a trough. During the Housing Period, hay was provided and water was presented in a polypropylene bucket. During the transport period hay and water were withdrawn, but bedding in the form of barley straw was used and may have presented a source of food to the lambs.

The effect of such changes in the external environment on synchronisation of behaviour is not clear from the literature. However, in a study of some effects of housing on the social behaviour of dairy cows, Miller and Wood-Gush (1991) identified that there was less synchrony indoors than at pasture.

Thus, whilst Martin and Bateson (1993) indicate that where doubts about independence of individuals exist, the mean value for the groups should be used as the unit of measurement, it is suggested that there is sufficient doubt in this investigation that synchrony was maintained following changes in the external environment to prompt further investigation.

Table 5.1 identified the comparative focal time periods used in the analysis of behavioural data and is reproduced below showing notation used henceforward for clarity (Table 5.16). To investigate if jaw movement behaviour within these periods was more synchronised than would be expected by chance, the coefficient of agreement for nominally scaled data (the kappa statistic (K); Siegel and Castellan 1988; Rook and Penning 1991) was used.

Table 5.16 Focal Time Periods Used in Analysis of Lamb Behaviour from Day 3 to Day 5

Focal Time Period	Experiment Days	Lamb Location
1800hrs - 0500hrs (P1)	3 - 4	All lambs at pasture
0600hrs - 1000hrs (P2)	4	All lambs at pasture
1800hrs - 0500hrs (HP)	4 - 5	All lambs housed
0600hrs - 1000hrs (TP)	5	Transport Group transported Control Group in Home Pen

Eating, ruminating and idle and 'undetermined' activities identified by the data logging programme for each lamb (*BehavRec* V1.0; Institute of Grassland and Environmental Research 1996) were quantified at a resolution of one minute within each of the focal time periods. Thus, there were 660 one-minute records between 1800hrs and 0500hrs and 240 one-minute records between 0600hrs and 1000hrs. A lamb was deemed to be engaged in a particular activity if it spent more than 30 seconds in any one minute in that activity and data were smoothed where two records of one activity were separated by one record of another. For example, if two one-minute records identifying ruminating behaviour as dominant were separated by a one-minute record of idling behaviour, the lamb was deemed to be ruminating for three consecutive minutes. This was done to overcome any minor non-synchrony between sets of recording equipment.

For each one-minute record, the number of lambs engaged in any of the four activities (ruminating, grazing, idle or 'undetermined') was identified. The kappa coefficient of synchronisation (K) is the ratio of the total proportion of times that the lambs were engaged in the same activity $P(A)$, corrected for chance synchronisation $P(E)$, to the maximum possible proportion of times that the lambs could have been engaged in the same activity, corrected for chance synchrony. Thus, $K = 1$ if there is complete synchronisation and $K =$

0 if there is no synchronisation, other than would be expected by chance. The Z statistic

($Z = \frac{K}{\sqrt{\text{var}(K)}}$) was used to test the significance of K (Siegel and Castellan 1988 and

Rook and Penning 1991).

The results of the analyses for each time period are presented in chronological order commencing with P1 (whilst lambs were at pasture) and ending with TP (the transport period). In each case, observed and expected proportions of synchronisation ($P(A)$ and $P(E)$, respectively), the kappa coefficient of synchronisation (K) and the significance of K for overall synchronisation of behaviour are presented. Synchronisation of behaviour was investigated within time periods in weeks where data sets for two more lambs were complete. Equipment failure, resulting in loss of data, meant that synchronisation of behaviour was not investigated in some cases. These are identified in the following text and tabulated in Appendix 14.

Table 5.17 shows overall synchronisation of behaviour during P1 in weeks 2 – 9. No results are presented for Week 1 because of equipment failure. The kappa coefficients (K) were significantly different from 0 in all weeks ($P < 0.001$ in all cases) indicating that overall synchronisation of behaviour was greater than would be expected by chance during P1.

Table 5.17 Observed and Expected Proportions of Overall Synchronisation of Behaviour ($P(A)$ and $P(E)$, respectively), Kappa Coefficients of Synchronisation (K), Z Values and Significance of K in Weeks 2 – 9 during P1

Week	$P(A)$	$P(E)$	Kappa (K)	Z Value	Significance of K
2	0.6338	0.35665	0.43085	33.939	$P < 0.001$
3	0.5990	0.35699	0.37636	29.735	$P < 0.001$
4	0.6568	0.37057	0.45478	34.030	$P < 0.001$
5	0.3664	0.08452	0.30792	51.863	$P < 0.001$
6	0.6202	0.35340	0.41262	33.228	$P < 0.001$
7	0.7270	0.38082	0.55912	39.355	$P < 0.001$
8	0.5126	0.34524	0.25565	15.377	$P < 0.001$
9	0.6419	0.37602	0.42613	30.921	$P < 0.001$

Table 5.18 shows overall synchronisation of behaviour in weeks 2 – 9 on Day 4 during P2. Again, no results are presented for Week 1 because of equipment failure. The kappa coefficients (K) were significantly different from 0 in all weeks ($P < 0.001$ in all cases) indicating that overall synchronisation of behaviour was greater than would be expected by chance during P2.

Table 5.18 Observed and Expected Proportions of Overall Synchronisation of Behaviour ($P(A)$ and $P(E)$, respectively), Kappa Coefficients of Synchronisation (K), Z Values and Significance of K in Weeks 2 – 9 on Day 4 during P2

Week	$P(A)$	$P(E)$	Kappa (K)	Z Value	Significance of K
2	0.5319	0.34920	0.28080	13.872	$P < 0.001$
3	0.7979	0.71787	0.28371	4.242	$P < 0.001$
4	0.6847	0.33973	0.52250	19.360	$P < 0.001$
5	0.6625	0.36464	0.46880	9.587	$P < 0.001$
6	0.5694	0.33709	0.35051	13.115	$P < 0.001$
7	0.6174	0.36513	0.39729	18.442	$P < 0.001$
8	0.5514	0.41695	0.23058	6.569	$P < 0.001$
9	0.5674	0.36529	0.31837	14.925	$P < 0.001$

Table 5.19 shows overall synchronisation in weeks 1 – 9 on Days 4 – 5 during HP.

Table 5.19 Observed and Expected Proportions of Overall Synchronisation of Behaviour ($P(A)$ and $P(E)$, respectively), Kappa Coefficients of Synchronisation (K), Z Values and Significance of K in Weeks 1 – 9 on Days 4 - 5 during HP

Week	$P(A)$	$P(E)$	Kappa (K)	Z Value	Significance of K
1	0.6177	0.63805	<i>na</i>	<i>na</i>	<i>na</i>
2	0.6558	0.64224	0.03792	1.208	$P > 0.05$
3	0.6078	0.56901	0.09007	3.542	$P < 0.001$
4	0.6343	0.57922	0.13101	5.061	$P < 0.001$
5	0.6540	0.67940	<i>na</i>	<i>na</i>	<i>na</i>
6	0.7141	0.69300	0.06887	1.935	$P < 0.05$
7	0.5030	0.53373	<i>na</i>	<i>na</i>	<i>na</i>
8	0.6194	0.60052	0.04737	1.658	$P < 0.05$
9	0.6505	0.66533	<i>na</i>	<i>na</i>	<i>na</i>

na = not applicable: where $P(A) < P(E)$ no further calculation was conducted.

The kappa coefficients (K) were significantly different from 0 in weeks 3, 4, 6 and 8 indicating that overall synchronisation of behaviour was greater than would be expected by chance. In week 2, the kappa coefficient (K) was not significantly different from 0 ($P > 0.05$) indicating that overall synchronisation of behaviour was less than would be expected by chance and in weeks 1, 5, 7 and 9 the observed proportion of synchronisation ($P(A)$) was less than the expected proportion of synchronisation ($P(E)$) and, therefore, there was no overall synchronisation of behaviour.

Table 5.20 shows overall synchronisation in weeks 1 – 6 and 8 on Days 5 for Control lambs during TP. No results are presented for Weeks 7 and 9 because of equipment failure.

Table 5.20 Observed and Expected Proportions of Overall Synchronisation of Behaviour ($P(A)$ and $P(E)$, respectively), Kappa Coefficients of Synchronisation (K), Z Values and Significance of K in Weeks 1 – 8 on Day 5 for Control Lambs during TP

Week	$P(A)$	$P(E)$	Kappa (K)	Z Value	Significance of K
1	0.6333	0.47195	0.30562	5.008	$P < 0.001$
2	0.6583	0.56006	0.22338	3.067	$P < 0.01$
3	0.3958	0.54586	<i>na</i>	<i>na</i>	<i>na</i>
4	0.9250	0.66110	0.77869	8.637	$P < 0.001$
5	0.7000	0.64199	0.16204	1.875	$P < 0.05$
6	0.6917	0.68503	0.02106	0.221	$P > 0.05$
8	0.7917	0.63847	0.42374	4.940	$P < 0.001$

na = not applicable: where $P(A) < P(E)$ no further calculation was conducted.

The kappa coefficients (K) were significantly different from 0 in weeks 1, 2, 4, 5 and 8 indicating that overall synchronisation of behaviour was greater than would be expected by chance. In week 6, the kappa coefficient (K) was not significantly different from 0 ($P > 0.05$) indicating that overall synchronisation of behaviour was less than would be expected by chance and in week 3 the observed proportion of synchronisation ($P(A)$) was less than the expected proportion of synchronisation ($P(E)$) and, therefore, there was no overall synchronisation of behaviour.

Table 5.21 shows overall synchronisation in weeks 1, 2, 4, 6, 8 and 9 on Days 5 for Transported lambs during TP. No results are presented for Weeks 3, 5 and 7 because of equipment failure.

Table 5.21 Observed and Expected Proportions of Overall Synchronisation of Behaviour ($P(A)$ and $P(E)$, respectively), Kappa Coefficients of Synchronisation (K), Z Values and Significance of K in Weeks 1, 2, 4, 6, 8 and 9 on Day 5 for Transported Lambs during TP

Week	Transport Treatment	$P(A)$	$P(E)$	Kappa (K)	Z Value	Significance of K
1	Direct	0.8167	0.83274	<i>na</i>	<i>na</i>	<i>na</i>
2	Market	0.8667	0.87438	<i>na</i>	<i>na</i>	<i>na</i>
4	Market	0.9000	0.90462	<i>na</i>	<i>na</i>	<i>na</i>
6	Direct	0.9750	0.97121	0.13175	0.351	$P > 0.05$
8	Multiple Pickup	0.9458	0.94730	<i>na</i>	<i>na</i>	<i>na</i>
9	Market	0.9875	0.98758	<i>na</i>	<i>na</i>	<i>na</i>

na = not applicable: where $P(A) < P(E)$ no further calculation was conducted.

In week 6, the kappa coefficient (K) was not significantly different from 0 ($P > 0.05$) indicating that overall synchronisation of behaviour was less than would be expected by chance and in all other weeks the observed proportion of synchronisation ($P(A)$) was less than the expected proportion of synchronisation ($P(E)$) and, therefore, there was no overall synchronisation of behaviour.

In summary of the results presented in Tables 5.17 to 5.21: whilst at pasture ($P1$ and $P2$; Tables 5.17 and 5.18), overall synchronisation of behaviour was greater than would be expected by chance in all weeks. During the Housing Period (HP ; Table 5.19) and during the Transport period for Control lambs (TP ; Table 5.20) overall synchronisation of behaviour was not greater than would be expected by chance in all weeks. During the transport period for Transported lambs (TP ; Table 5.21) there was no significant synchronisation of behaviour in any of the weeks.

Since the aim of this study is to investigate the effect of journey structure on the welfare of lambs, the primary focal period is the Transport Period on Day 5 between 0600hrs and

1000hrs (TP). It has been demonstrated that overall synchronisation of behaviour was not significant in all weeks for Control lambs and that there was no overall synchronisation of behaviour during this period for Transported lambs in any week. Therefore, data for individual lambs, not the group mean, are used as the units of measurement in the following analyses.

The temporal characteristics of eating, ruminating, idling and 'undetermined' behaviours in the four focal time periods are now presented. First, preliminary analyses examining the effect of management procedures and the transportation period on transported and control lambs are given. Second, analyses of the effect of journey structure on the behaviours measured are presented for each of the transport treatments. This procedure has been adopted because of limitations imposed on the experimental design as described in Section 5.3.

The effect of management procedures and the transportation period on the jaw movement behaviour of transported and control lambs was investigated using *t-tests* (Zar 1996) as described below. Zar (1996) reports that the underlying assumptions for unpaired *t-tests* are that data conform to normal distributions and that variances are equal. There was evidence within the behavioural data of departures from these assumptions in some cases. However, Zar (1996) states further that unpaired *t-tests* are robust despite such departures and they have, therefore, been utilised. The underlying assumption for paired *t-tests* is that the differences between the values are from a normal distribution (Zar 1996). As above, there was evidence of departure from this assumption in some cases. However, results of paired *t-tests* are presented for clarity. The analogous non-parametric tests (Mann-Whitney U test and Wilcoxon's paired-sample test (Zar 1996)) were also conducted where

appropriate and no disparities in the significance of the results between parametric and non-parametric tests were evident. Results are presented at the 95% confidence level.

Paired *t*-tests of the time spent ruminating, eating, idle and in 'undetermined' behaviours for all lambs during P1 and HP indicated that there were significant differences between the focal period means (ruminating: $t_{28} = 4.7$; eating: $t_{28} = 14.46$; idle: $t_{28} = 11.37$; 'undetermined': $t_{28} = 3.3$, $P < 0.05$ in all cases; Table 5.22).

Table 5.22 Mean Time Spent Ruminating, Eating, Idle and in 'Undetermined' Behaviours (hrs±SEM) for All Lambs during P1 and HP

	All Lambs During P1 (<i>n</i> =29)	All Lambs During HP (<i>n</i> =29)
Mean Time Ruminating (hrs±SEM)	2.93 (+0.13)	2.01 (+0.17)
Mean Time Eating (hrs±SEM)	3.38 (+0.11)	1.00 (+0.14)
Mean Time Idle (hrs±SEM)	4.68 (+0.15)	7.96(+0.27)
Mean Time 'Undetermined' (hrs±SEM)	0.005 (±0.001)	0.012 (±0.001)

Row means differ at $P < 0.05$ in all cases

Mean time spent ruminating and eating during P1 were greater than during HP (2.93hrs±0.13 and 2.01hrs±0.17; 3.38hrs ±0.11 and 1.00hrs±0.14, respectively; $P < 0.05$ in both cases; Table 5.22) and mean time spent idle and in 'undetermined' behaviours were greater during HP than during P1 (7.96hrs±0.27 and 4.68hrs±0.15; 0.005hrs±0.001 and 0.012hrs±0.001, respectively; $P < 0.05$ in both cases).

Across focal periods, unpaired *t*-tests indicated that there were no significant differences in mean time spent in the behaviours measured between transported and control lambs

(ruminating: $t_{62} = 0.60$; eating: $t_{62} = 0.67$; idle: $t_{62} = 0.57$; 'undetermined': $t_{60} = 0.54$; $P > 0.05$ in all cases; Table 5.23).

Table 5.23 Mean Time Spent Ruminating, Eating, Idle and in 'Undetermined' Behaviours (hrs±SEM) for Transported and Control Lambs Across Focal Time Periods P1 and HP

	Transported Lambs (n=33)	Control Lambs (n=32)
Mean Time Ruminating (hrs±SEM)	2.38 (±0.17)	2.52 (±0.17)
Mean Time Eating (hrs±SEM)	2.10 (±0.25)	2.25 (±0.22)
Mean Time Idle (hrs±SEM)	6.50 (±0.37)	6.21 (±0.34)
Mean Time 'Undetermined' (hrs±SEM)	0.01 (±0.001)	0.01 (±0.001)

Row means do not differ; $P > 0.05$ in all cases

Unpaired *t*-tests of the time spent in the behaviours by Transported and Control lambs during P1 indicated that there were no significant differences between the means (ruminating: $t_{28} = 0.35$; eating: $t_{29} = 0.08$; idle: $t_{29} = 0.25$; 'undetermined': $t_{19} = 1.73$; $P > 0.05$ in all cases; Table 5.24).

Table 5.24 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Transported and Control Lambs During P1

	Transported Lambs (n=17)	Control Lambs (n=15)
Mean Time Ruminating (hrs±SEM)	2.90 (±0.05)	2.99 (±0.06)
Mean Time Eating (hrs±SEM)	3.34 (±0.04)	3.32 (±0.05)
Mean Time Idle (hrs±SEM)	4.75 (±0.07)	4.68 (±0.08)
Mean Time ‘Undetermined’ (hrs±SEM)	0.008(±0.0004)	0.004(±0.0005)

Row means do not differ; $P>0.05$ in all cases

Unpaired *t*-tests of the time spent in the behaviours by Transported and Control lambs during HP indicated that there were no significant differences between the means (ruminating: $t_{30}= 0.88$; eating: $t_{30}= 1.84$; idle: $t_{30}= 1.55$; ‘undetermined’: $t_{29}= 0.43$; $P>0.05$ in all cases; Table 5.25).

Table 5.25 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Transported and Control Lambs During HP

	Transported Lambs (n=16)	Control Lambs (n=17)
Mean Time Ruminating (hrs±SEM)	1.84 (±0.23)	2.11 (±0.22)
Mean Time Eating (hrs±SEM)	0.79 (±0.18)	1.29 (±0.21)
Mean Time Idle (hrs±SEM)	8.36 (±0.35)	7.57 (±0.37)
Mean Time ‘Undetermined’ (hrs±SEM)	0.01 (±0.002)	0.01 (±0.002)

Row means do not differ; $P>0.05$ in all cases

Paired *t*-tests of the time spent in the measured behaviours by transported lambs during P1 and HP indicated that there were significant differences in the mean time spent ruminating,

eating and idle between the focal periods ($t_{14} = 3.45$; $t_{14} = 12.38$; $t_{14} = 9.23$, respectively; $P < 0.05$ in all cases; Table 5.26), but not in 'undetermined' behaviours ($t_{14} = 1.55$; $P > 0.05$).

Table 5.26 Mean Time Spent Ruminating, Eating, Idle and in 'Undetermined' Behaviours (hrs±SEM) for Transported Lambs During P1 and HP

	Transported Lambs During P1 (<i>n</i> =15)	Transported Lambs During HP (<i>n</i> =15)
Mean Time Ruminating (hrs±SEM)	2.88 (±0.18) ^a	1.89 (±0.23) ^a
Mean Time Eating (hrs±SEM)	3.41 (±0.16) ^a	0.74 (±0.19) ^a
Mean Time Idle (hrs±SEM)	4.69 (±0.21) ^a	8.35 (±0.37) ^a
Mean Time 'Undetermined' (hrs±SEM)	0.007 (±0.003)	0.012 (±0.003)

Row means with similar superscripts differ at $P < 0.05$

Transported lambs spent significantly more time ruminating and eating during P1 than during HP (2.88hrs±0.18 and 1.89hrs±0.23; 3.41hrs±0.16 and 0.74hrs±0.19, respectively; $P < 0.05$ in both cases; Table 5.26), and significantly less time idle (4.69hrs±0.21 and 8.35hrs±0.37; $P < 0.05$). There was no significant difference in the mean time spent in 'undetermined' behaviours (0.007hrs±0.003 and 0.012hrs±0.003; $P > 0.05$).

Paired *t*-tests of the time spent in the measured behaviours by Control lambs during P1 and HP indicated that there were significant differences in the mean time spent ruminating, eating, idle and in 'undetermined' behaviours between the focal periods ($t_{13} = 3.08$; $t_{13} = 9.08$; $t_{13} = 7.04$; $t_{13} = 3.64$, respectively; $P < 0.05$ in all cases; Table 5.27).

Table 5.27 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Control Lambs During P1 and HP

	Control Lambs During P1 (n=14)	Control Lambs During HP (n=14)
Mean Time Ruminating (hrs±SEM)	2.99 (±0.21)	2.14 (±0.26)
Mean Time Eating (hrs±SEM)	3.34 (±0.15)	1.28 (±0.18)
Mean Time Idle (hrs±SEM)	4.66 (±0.21)	7.55 (±0.39)
Mean Time ‘Undetermined’ (hrs±SEM)	0.004 (±0.001)	0.012 (±0.002)

Row means differ at $P < 0.05$ in all cases

Control lambs spent significantly more time ruminating and eating during P1 than during HP (2.99hrs±0.21 and 2.14hrs±0.26; 3.34hrs±0.15 and 1.28hrs±0.18, respectively; $P < 0.05$ in both cases; 5.3.6.12) and significantly less time idle and in ‘undetermined’ behaviours (4.66hrs±0.21 and 7.55hrs±0.39; 0.004hrs±0.001 and 0.012hrs±0.002, respectively; $P < 0.05$ in both cases).

Mean time spent in the behaviours measured that are presented in Table 5.26 and 5.27 differ from those presented in Tables 5.24 and 5.25. Tables 5.26 and 5.27 present the results of paired *t*-tests of data available in both focal time periods and the Tables 5.24 and 5.25 present the results of unpaired *t*-tests using unequal sample sizes. Appendix 14 identifies useable and non-useable data for the above tests.

Paired *t*-tests of the time spent ruminating, eating, idle and in ‘undetermined’ behaviours during P2 and TP indicated that there were significant differences between the focal period means (ruminating: $t_{23} = 3.96$; eating: $t_{23} = 12.56$; idle: $t_{23} = 18.93$; ‘undetermined’: $t_{23} = 4.57$; $P < 0.05$ in all cases; Table 5.28).

Table 5.28 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for All Lambs During P2 and TP

	All Lambs During P2 (n=24)	All Lambs During TP (n=24)
Mean Time Ruminating (hrs±SEM)	1.15 (±0.09)	0.56 (±0.11)
Mean Time Eating (hrs±SEM)	2.02 (±0.15)	0.11 (±0.04)
Mean Time Idle (hrs±SEM)	0.81 (±0.09)	3.32 (±0.11)
Mean Time ‘Undetermined’ (hrs±SEM)	0.001 (±0.001)	0.012 (±0.002)

Row means differ at $P < 0.05$ in all cases

Mean time spent ruminating and eating during P2 were greater than during TP (1.15hrs±0.09 and 0.56hrs±0.11; 2.02hrs ±0.15 and 0.11hrs±0.04, respectively; $P < 0.05$ in both cases; Table 5.28), and that time spent idle and in ‘undetermined’ behaviours were greater during TP than during P2 (3.32hrs±0.11 and 0.81hrs±0.09; 0.001hrs±0.001 and 0.012hrs±0.002, respectively; $P < 0.05$ in both cases).

Across focal periods, unpaired *t*-tests indicated that there were significant differences in mean time spent ruminating ($t_{49} = 2.7$, $P < 0.05$) between transported and control lambs, but not in the other behaviours measured (eating: $t_{57} = 0.61$; idle: $t_{51} = 0.56$; ‘undetermined’: $t_{56} = 0.80$, $P > 0.05$ in all cases; Table 5.29).

Table 5.29 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Transported and Control Lambs Across Focal Time Periods P2 and TP

	Transported Lambs (n=30)	Control Lambs (n=30)
Mean Time Ruminating (hrs±SEM)	0.72 (±0.11) ^a	1.10 (±0.08) ^a
Mean Time Eating (hrs±SEM)	1.16 (±0.21)	0.99 (±0.21)
Mean Time Idle (hrs±SEM)	2.11 (±0.29)	1.91 (±0.20)
Mean Time ‘Undetermined’ (hrs±SEM)	0.007 (±0.002)	0.006 (±0.002)

Row means with similar superscripts differ $P < 0.05$

Mean time spent ruminating across focal periods P2 and TP by transported lambs was less than that by control lambs (0.72hrs±0.11 and 1.10hrs±0.08, $P < 0.05$; Table 5.29). There were no significant differences in the mean time spent in the other behaviours measured (eating: 1.16hrs±0.21 and 0.99hrs±0.21; idle: 2.11hrs±0.29 and 1.91hrs±0.20; ‘undetermined’: 0.007hrs±0.002 and 0.006hrs±0.002, respectively; $P > 0.05$ in all cases).

Unpaired *t*-tests of the time spent in the behaviours measured by Transported and Control lambs during P2 indicated that there were no significant differences between the means (ruminating: $t_{26} = 0.52$; eating: $t_{25} = 0.20$; idle: $t_{24} = 0.37$; ‘undetermined’: $t_{27} = 0.53$, $P > 0.05$ in all cases; Table 5.30).

Table 5.30 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Transported and Control Lambs During P2

	Transported Lambs (n=16)	Control Lambs (n=14)
Mean Time Ruminating (hrs±SEM)	1.22 (±0.11)	1.13 (±0.13)
Mean Time Eating (hrs±SEM)	2.07 (±0.18)	2.02 (±0.22)
Mean Time Idle (hrs±SEM)	0.71 (±0.10)	0.85 (±0.13)
Mean Time ‘Undetermined’ (hrs±SEM)	0.001 (±0.0007)	0.001 (±0.0006)

Row means do not differ; P>0.05 in all cases

Unpaired *t*-tests of the time spent in the behaviours by Transported and Control lambs during TP indicated that there were significant differences between the means for ruminating and idle behaviours ($t_{25} = 8.88$ and $t_{27} = 6.89$, respectively; $P < 0.05$ in both cases) but not the means for eating and ‘undetermined’ behaviours ($t_{16} = 0.62$ and $t_{25} = 0.48$, respectively; $P > 0.05$ in both cases; Table 5.31).

Table 5.31 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Transported and Control Lambs During TP

	Transported Lambs (n=14)	Control Lambs (n=16)
Mean Time Ruminating (hrs±SEM)	0.15 (±0.06) ^a	1.07 (±0.09) ^a
Mean Time Eating (hrs±SEM)	0.13 (±0.06)	0.08 (±0.02)
Mean Time Idle (hrs±SEM)	3.70 (±0.09) ^a	2.83 (±0.09) ^a
Mean Time ‘Undetermined’ (hrs±SEM)	0.01 (±0.004)	0.01 (±0.003)

Row means with similar superscripts differ $P < 0.05$

Mean time spent ruminating by transported lambs during TP was significantly less than that for control lambs (0.15hrs+0.06 and 1.07hrs+0.09, respectively; $P < 0.05$; Table 5.31). Mean time spent idle by transported lambs in the same period was greater than that for control lambs (3.70hrs+0.09 and 2.83hrs+0.09, respectively; $P < 0.05$). There were no significant treatment differences in mean time spent eating and in ‘undetermined’ behaviours during TP (0.13hrs+0.06 and 0.08hrs+0.02; 0.01hrs+0.004 and 0.01+0.003, respectively; $P > 0.05$ in both cases).

Paired *t*-tests of the time spent in the behaviours measured by transported lambs during P2 and TP indicated that there were significant differences in the mean time spent in all the behaviours measured between focal periods (ruminating: $t_{11} = 8.49$; eating: $t_{11} = 10.14$; idle: $t_{11} = 29.15$ and ‘undetermined’: $t_{11} = 2.92$; $P < 0.05$ in all cases; Table 5.32).

Table 5.32 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs+SEM) for Transported Lambs During P2 and TP

	Transported Lambs During P2 ($n=12$)	Transported Lambs During TP ($n=12$)
Mean Time Ruminating (hrs+SEM)	1.23 (+0.11) ^a	0.10 (+0.04) ^a
Mean Time Eating (hrs+SEM)	1.98 (+0.19) ^a	0.14 (+0.07) ^a
Mean Time Idle (hrs+SEM)	0.79 (+0.10) ^a	3.74 (+0.10) ^a
Mean Time ‘Undetermined’ (hrs+SEM)	0.002 (+0.001) ^a	0.014 (+0.004) ^a

Row means with similar superscripts differ at $P < 0.05$

Transported lambs spent significantly more time ruminating and eating during P2 than during TP (1.23hrs+0.11 and 0.10hrs+0.04; 1.98hrs+0.19 and 0.14hrs+0.07, respectively; $P < 0.05$ in both cases Table 5.32), and significantly less time idle and in ‘undetermined’

behaviours ($0.79\text{hrs}\pm 0.10$ and $3.74\text{hrs}\pm 0.10$; $0.002\text{hrs}\pm 0.001$ and $0.014\text{hrs}\pm 0.004$, respectively $P < 0.05$ in both case).

Paired *t*-tests of the time spent in the measured behaviours by control lambs during P2 and TP indicated that there were significant differences in the mean time spent eating, idle and in ‘undetermined’ behaviours between focal periods ($t_{11} = 7.92$; $t_{11} = 12.80$; $t_{11} = 3.91$, respectively; $P < 0.05$ in all cases) but no significant difference was identified in mean time spent ruminating ($t_{11} = 0.43$; $P > 0.05$; Table 5.33).

Table 5.33 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs \pm SEM) for Control Lambs During P2 and TP

	Control Lambs During P2 (n=12)	Control Lambs During TP (n=12)
Mean Time Ruminating (hrs\pmSEM)	1.09 (± 0.14)	1.02 (± 0.10)
Mean Time Eating (hrs\pmSEM)	2.07 (± 0.25) ^a	0.08 (± 0.02) ^a
Mean Time Idle (hrs\pmSEM)	0.84 (± 0.15) ^a	2.89 (± 0.10) ^a
Mean Time ‘Undetermined’ (hrs\pmSEM)	0.001 (± 0.001) ^a	0.011 (± 0.002) ^a

Row means with similar superscripts differ at $P < 0.05$

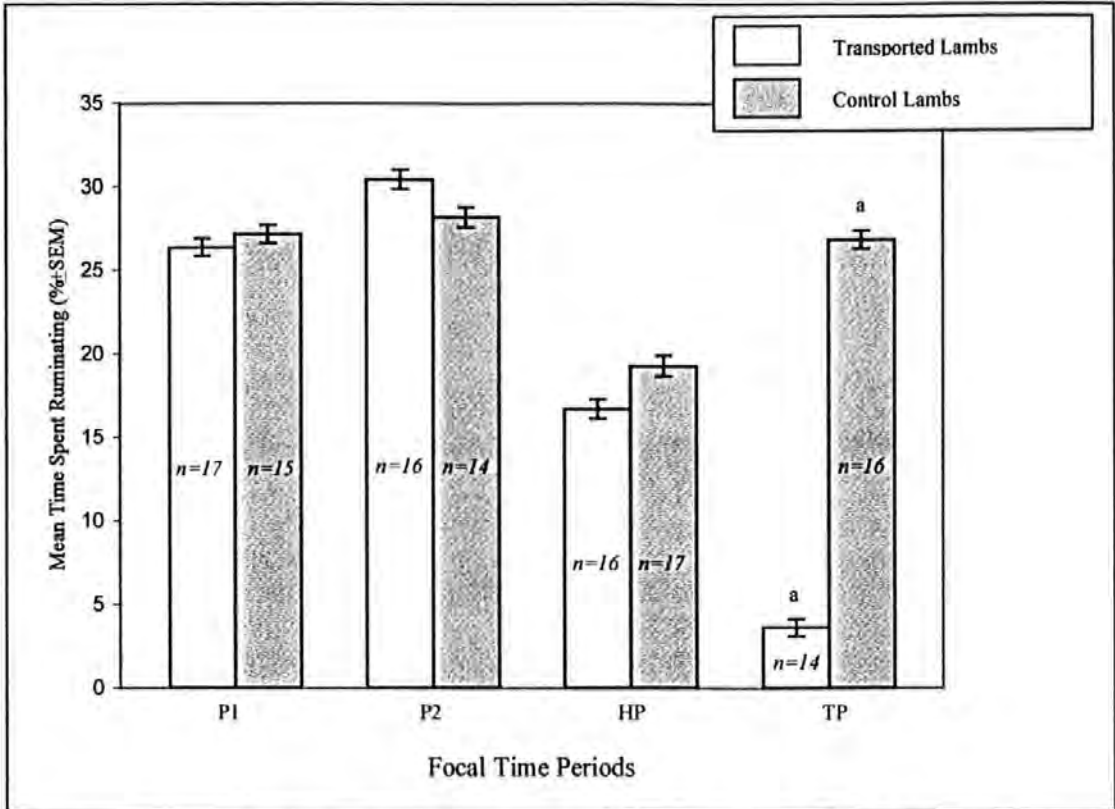
Control lambs spent significantly more time eating during P2 than during TP ($2.07\text{hrs}\pm 0.25$ and $0.08\text{hrs}\pm 0.02$; $P < 0.05$ Table 5.33) and significantly less time idle and in ‘undetermined’ behaviours ($0.84\text{hrs}\pm 0.15$ and $2.89\text{hrs}\pm 0.10$; $0.001\text{hrs}\pm 0.001$ and $0.011\text{hrs}\pm 0.002$, respectively; $P < 0.05$ in both cases). There was no significant difference in mean time spent ruminating between the focal periods ($1.09\text{hrs}\pm 0.014$ and $1.02\text{hrs}\pm 0.10$; $P > 0.05$).

Mean time spent in the measured behaviours presented in Table 5.32 and 5.33 differ from those presented in Tables 5.30 and 5.31. Tables 5.32 and 5.33 present the results of paired *t-tests* of data available in both focal time periods and the Tables 5.30 and 5.31 present the results of unpaired *t-tests* using unequal sample sizes. Appendix 14 identifies useable and non-useable data for the above tests.

In summary of the results presented above in Tables 5.22 to 5.33: for all lambs, mean time spent ruminating and eating during the housing period (HP) and the transport period (TP) were significantly less than those in the respective comparative periods whilst the lambs were at pasture (P1 and P2; Tables 5.22 and 5.28). Mean time spent idle and in 'undetermined' behaviours during HP and TP were significantly greater than that during P1 and P2, respectively (Tables 5.22 and 5.28).

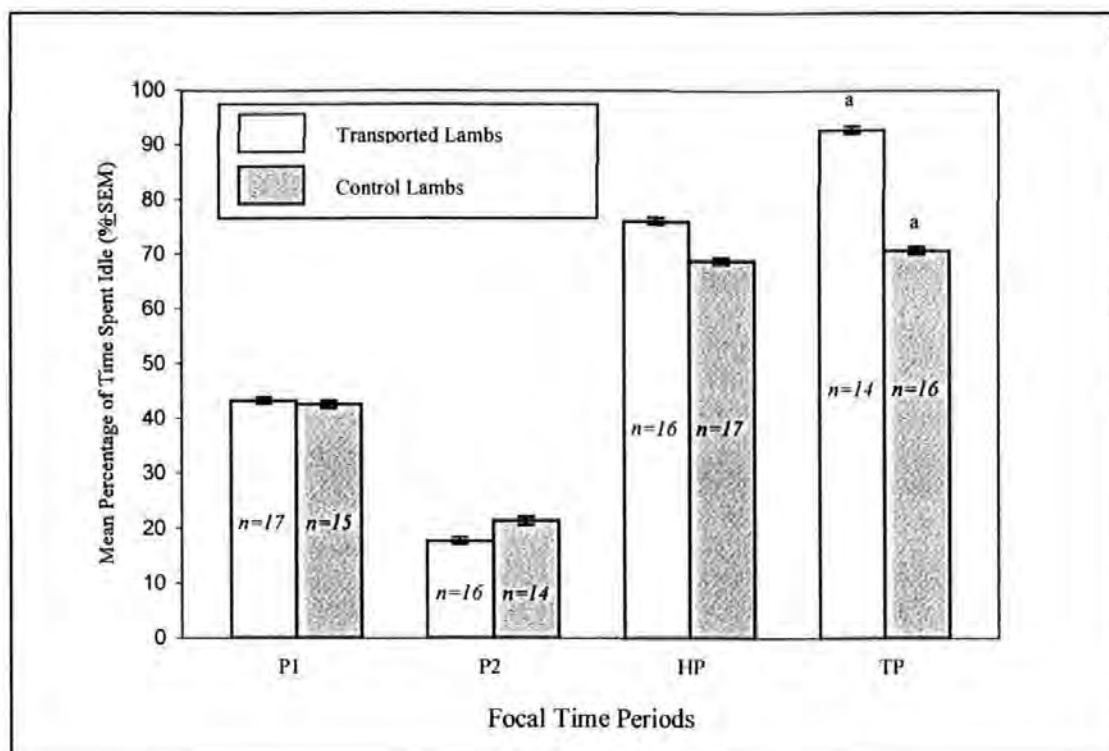
There were no significant differences in mean time spent in the behaviours measured by transported and control lambs during focal time periods P1, HP and P2 (Tables 5.24, 5.25 and 5.30). During TP, transported lambs spent significantly less time ruminating and significantly more time idle than control lambs (Table 5.31). There were no significant treatment differences in mean time spent eating or in 'undetermined' behaviours during this period. Mean time spent ruminating and idle are represented graphically in percentage terms for transported and control lambs during all focal time periods in Figures 5.13 and 5.3.6.2, respectively, and significant differences within focal time periods are identified.

Figure 5.13 Mean Percentage of Time Spent Ruminating (\pm SEM) by Transported and Control Lambs during P1, P2, HP and TP



Within focal periods, means with similar superscripts differ at $P < 0.05$

Figure 5.14 Mean Percentage of Time Spent Idle (\pm SEM) by Transported and Control Lambs during P1, P2, HP and TP



Within focal periods, means with similar superscripts differ at $P < 0.05$

This chapter now proceeds with an examination of the effect of transport treatment on the jaw movement behaviour of Direct, Multiple Pickup and Market lambs during the transport period (TP).

Glm one-way analyses of variance of the time spent ruminating, eating, idle and in 'undetermined' behaviours by Direct, Multiple-Pickup and Market lambs indicated that there were no significant differences between the treatment means (ruminating: $F_{2,11} = 0.43$; $P > 0.05$; eating: $F_{2,11} = 0.50$; $P > 0.05$; idle: $F_{2,11} = 0.10$; $P > 0.05$; 'undetermined': $F_{2,11} = 0.16$; $P > 0.05$; Table 5.34).

Table 5.34 Mean Time Spent Ruminating, Eating, Idle and in ‘Undetermined’ Behaviours (hrs±SEM) for Direct, Multiple Pickup and Market Lambs during TP

	Direct (n=4)	Multiple Pickup (n=4)	Market (n=6)
Mean Time Ruminating (hrs±SEM)	0.21 (+0.18)	0.18 (+0.10)	0.08 (+0.04)
Mean Time Eating (hrs±SEM)	0.03 (+0.18)	0.16 (+0.13)	0.17 (+0.11)
Mean Time Idle (hrs±SEM)	3.75 (+0.16)	3.65 (+0.24)	3.73 (+0.10)
Mean Time ‘Undetermined’ (hrs±SEM)	0.009 (+0.008)	0.012 (+0.008)	0.014 (+0.004)

Row means do not differ; $P > 0.05$ in all cases

Whilst significant differences in the jaw movement behaviour of transported and control lambs during the transport period were identified (Table 5.31 and Figures 5.13 and 5.14), there were no significant differences between the transport treatment means (Table 5.34).

The temporal characteristics of lying behaviour in the four focal time periods are now presented. First, preliminary analyses examining the effect of management procedures and the transportation period on transported and control lambs are given. Second, analyses of the effect of journey structure on the behaviours measured are presented for each of the transport treatments. As for jaw movement behaviour, this procedure has been adopted because of limitations imposed on the experimental design as described in Section 5.3.

The effect of management procedures and the transportation period on the lying behaviour of transported and control lambs was investigated using *t-tests* (Zar 1996) as described below and results are presented at the 95% confidence level. There was evidence that lying data departed from the underlying assumptions for *t-tests*. However, these tests were adopted for the reasons previously explained.

A paired *t-test* of the time spent lying for all lambs during P1 and HP indicated that there was a significant difference between the focal period means ($t_{25} = 3.78$; $P < 0.05$; Table 5.35).

Table 5.35 Mean Time Spent Lying (hrs±SEM) for All Lambs during P1 and HP

	All Lambs During P1 (<i>n</i>=26)	All Lambs During HP (<i>n</i>=26)
Mean Time Lying (hrs±SEM)	4.57 (+0.45)	7.25 (+0.37)

Row means differ at $P < 0.05$

Mean time spent lying was significantly greater during HP than P1 (4.57hrs±0.45 and 7.25hrs±0.37; $P < 0.05$; Table 5.35).

Across and within focal periods, unpaired *t-tests* indicated that there were no significant difference in the time spent lying between transported and control lambs (across focal time periods: $t_{58} = 0.04$; during P1: $t_{27} = 0.47$; during HP: $t_{27} = 0.01$; $P > 0.05$ in all cases; Table 5.36).

Table 5.36 Mean Time Lying (hrs±SEM) for Transported and Control Lambs Across and Within Focal Time Periods P1 and HP

	Transported Lambs	Control Lambs
Mean Time Lying (hrs±SEM) Across Focal Periods P1 and HP	6.25 (±0.48) (n=31)	6.23 (±0.42) (n=31)
Mean Time Lying (hrs±SEM) During P1	5.11 (±0.68) (n=16)	4.70 (±0.53) (n=14)
Mean Time Lying (hrs±SEM) During HP	7.48 (±0.53) (n=15)	7.48 (±0.43) (n=17)

Row means do not differ; P>0.05 in all cases

Between focal periods, paired *t-tests* identified that there were significant differences in meant time spent lying by transported and control lambs (transported lambs: $t_{12} = 2.23$ and control lambs: $t_{12} = 3.29$; $P < 0.05$ in both cases; Table 5.37).

Table 5.37 Mean Time Lying (hrs±SEM) for Transported and Control Lambs during P1 and HP

	Mean Time Spent Lying During P1 (hrs±SEM)	Mean Time Spent Lying During HP (hrs±SEM)
Transported Lambs (n=13)	4.53 (±0.73)	7.19 (±0.55)
Control Lambs (n=13)	4.61(±0.56)	7.31 (±0.51)

Row means differ at $P < 0.05$ in both cases

Mean time spent lying was significantly greater during HP than during P1 for both transported and control lambs (7.19hrs±0.55 and 4.53hrs±0.73; 7.31hrs±0.51 and 4.61hrs±0.56, respectively; $P < 0.05$ in both cases).

Mean time spent in the behaviours measured presented in Table 5.37 differ from those presented in Tables 5.36. Table 5.37 presents the results of paired *t-tests* of data available in both focal time periods and the Tables 5.36 presents the results of unpaired *t-tests* using

unequal sample sizes. Appendix 15 identifies useable and non-useable data for the above tests.

A paired *t*-test of the time spent lying for all lambs during P2 and TP indicated that there was no significant difference between the focal period means ($t_{12} = 1.32$; $P > 0.05$; Table 5.38).

Table 5.38 Mean Time Spent Lying (hrs±SEM) for All Lambs during P2 and TP

	All Lambs During P2 (n=26)	All Lambs During TP (n=26)
Mean Time Lying (hrs±SEM)	1.05 (±0.15)	1.40 (±0.22)

Row means do not differ; $P > 0.05$

Across focal time periods, a unpaired *t*-test indicated that there was a significant difference in mean time spent lying between transported and control lambs ($t_{58} = 4.10$; $P < 0.05$; Table 5.39). Within focal time periods, a unpaired *t*-test indicated that there was no significant difference in mean time spent lying during P2 between transported and control lambs ($t_{27} = 0.86$; $P > 0.05$) but there was a significant difference in mean time spent lying between transported lambs and control lambs during TP ($t_{29} = 7.24$; $P < 0.05$).

Table 5.39 Mean Time Lying (hrs±SEM) for Transported and Control Lambs Across and Within Focal Time Periods P2 and TP

	Transported Lambs	Control Lambs
Mean Time Lying (hrs±SEM) Across Focal Periods P2 and TP	0.86(±0.14) ^a (n=31)	1.78 (±0.17) ^a (n=31)
Mean Time Lying (hrs±SEM) During P2	1.15 (±0.20) (n=16)	1.10 (±0.21) (n=14)
Mean Time Lying (hrs±SEM) During TP	0.56 (±0.18) ^a (n=15)	2.34(±0.17) ^a (n=17)

Row means with similar superscripts differ at $P < 0.05$

Across focal time periods, P2 and TP, transported lambs spent significantly less time lying than control lambs (0.86hrs±0.14 and 1.78hrs±0.17; P<0.05; Table 5.39). There was no significant difference in mean time spent lying by transported and control lambs during P2 (1.15hrs±0.20 and 1.10±0.21, respectively; P>0.05), but transported lambs spent significantly less time lying during TP than control lambs (0.56hrs±0.18 and 2.34hrs±0.17, respectively; P<0.05).

Between focal periods, paired *t*-tests identified that there were significant differences in mean time spent lying by transported and control lambs (transported lambs: $t_{12} = 2.13$ and control lambs: $t_{12} = 4.77$; P<0.05 in both cases; Table 5.40).

Table 5.40 Mean Time Lying (hrs±SEM) for Transported and Control Lambs During P2 and TP

	Mean Time Spent Lying During P2 (hrs±SEM)	Mean Time Spent Lying During TP (hrs±SEM)
Transported Lambs (n=13)	1.07 (+0.22)	0.46 (+0.19)
Control Lambs (n=13)	1.02 (+0.21)	2.32 (+0.19)

Row means differ at P<0.05 in both cases

Mean time spent lying by transported lambs was significantly greater during P2 than during TP (1.07hrs±0.22 and 0.46hrs±0.19, respectively; P<0.05; Table 5.40). Conversely, mean time spent lying by control lambs was significantly less during P2 than TP (1.02hrs±0.21 and 2.32hrs±0.19, respectively; P<0.05).

Mean time spent in the behaviours measured presented in Table 5.40 differ from those presented in Tables 5.39. Table 5.40 presents the results of paired *t*-tests of data available in both focal time periods and Table 5.39 presents the results of unpaired *t*-tests using

unequal sample sizes. Appendix 15 identifies useable and non-useable data for the above tests.

This chapter now proceeds with an examination of the effect of transport treatment on the lying behaviour of Direct, Multiple Pickup and Market lambs during the transport period.

A glm one way analysis of variance of the time spent lying by Direct, Multiple Pickup and Market lambs during the transport period indicated that there was no significant difference between the treatment means ($F_{2,12} = 3.19; P > 0.05$; Table 5.41).

Table 5.41 Mean Time Spent Lying (hrs±SEM) for Direct, Multiple Pickup and Market Lambs during TP

	Direct (n=4)	Multiple Pickup (n=6)	Market (n=5)
Mean Time Lying During TP (hrs±SEM)	1.11 (±0.30)	0.59 (±0.25)	0.07 (±0.27)

Row means do not differ; $P > 0.05$ in all cases

Since Market lambs were unloaded and held at market for one hour before resuming their journey a glm one way analysis of variance of the proportion of actual transport time spent lying was also conducted. This, similarly, indicated that there was no significant difference between the treatment means ($F_{2,12} = 3.00; P > 0.05$; Table 5.42). Analyses were conducted using arcsine square root transformed proportional data because of evidence of non-normality of data distribution (Anderson-Darling Normality Test; $P < 0.05$). There was no evidence of heterogeneity of variances (Levene’s Test; $P > 0.05$). Results are presented in percentage terms for consistency and clarity.

Table 5.42 Mean Percentage of Actual Transport Time Spent Lying (%±SEM) for Direct, Multiple Pickup and Market Lambs during TP

	Direct <i>(n=4)</i>	Multiple Pickup <i>(n=6)</i>	Market <i>(n=5)</i>
Mean Percentage of Time Lying During TP (%±SEM)	27.68 (+7.69)	14.83 (+6.28)	2.47 (+6.88)

Row means do not differ; P>0.05 in all cases

This chapter continues with an exploration of the relationship between ruminating and lying behaviour by examining the proportion of total ruminating time spent ruminating whilst lying. This was examined because Cockram *et al.* (1996) identified that during a 12hr journey most ruminating was conducted while standing and, at stocking densities of 0.22m² and 0.31m² per lamb, non-transported lambs ruminated more than transported lambs.

Two way glm analyses of variance of the proportion of ruminating time spent ruminating whilst lying down for transported and control lambs in all focal periods indicated that there were significant differences between focal periods, transported and control animals and in the interaction terms ($F_{3,108} = 5.87$; $P < 0.01$; $F_{1,108} = 9.97$; $P < 0.01$; $F_{3,108} = 2.92$; $P < 0.05$, respectively; Tables 5.43 to 5.46). Analyses were conducted using arcsine square root transformed proportional data because of evidence of non-normality of data distribution (Anderson-Darling Normality Tests; $P < 0.05$ in all cases). There was no evidence of heterogeneity of variances (Levene's Tests; $P > 0.05$ in all cases). Limitations imposed as a result of non-useable data precluded the use of repeated measures analyses of variance. Useable and non-useable data available for analysis of the proportion of total ruminating

time spent ruminating whilst lying are given in Appendix 16. Results are presented in percentage terms at the 95% confidence level for consistency and clarity.

Table 5.43 Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying (%±SEM) During P1, P2, HP and TP for all Lambs

	All Lambs During P1 (n=29)	All Lambs During P2 (n=28)	All Lambs During HP (n=32)	All Lambs During TP (n=27)
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying (%±SEM)	65.24±5.65	63.20±5.73	83.36±5.36 ^a	49.47±5.92 ^a

Row means with similar superscripts differ at P<0.05

Mean percentages of total ruminating time spent ruminating whilst lying during P1, P2 HP and TP, for all lambs, were: 65.24%±5.65, 63.20±5.73, 83.36%±5.36 and 49.47%±5.92, respectively (Table 5.43). Pairwise comparisons, using the Tukey WSD test (Zar 1996), indicated that the mean percentage of total ruminating time spent ruminating whilst lying during HP was significantly greater than that during TP (P<0.05) whilst all other differences were non-significant (P>0.05 in all cases).

Table 5.44 shows mean percentage of total ruminating time spent ruminating whilst lying for transported and control lambs across focal periods.

Table 5.44 Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying (%±SEM) for Transported and Control Lambs Across Focal Periods

	Transported Lambs (n=57)	Control Lambs (n=59)
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying (%±SEM)	56.51±4.05	74.12±3.97

Row means differ at P<0.05

Across focal periods, control lambs spent a significantly greater percentage of total ruminating time ruminating whilst lying than transported lambs (74.12%±3.97 and 56.51%±4.05, respectively; P<0.05; Table 5.44).

Table 5.45 shows mean percentage of total ruminating time spent ruminating whilst lying by transport and control lambs in focal periods P1, P2, HP and TP.

Table 5.45 Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying (%±SEM) by Transport and Control Lambs During P1, P2, HP and TP

	Transported Lambs	Control Lambs
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying During P1 (%±SEM)	64.06±7.56 (n=16)	66.43±8.39 (n=13)
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying During P2 (%±SEM)	56.01±7.81 (n=15)	70.38±8.39 (n=13)
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying During HP (%±SEM)	79.02±7.81 ^a (n=15)	87.71±7.34 (n=17)
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying During TP (%±SEM)	26.96±9.12 ^{a,b} (n=11)	71.98±7.56 ^b (n=16)

Row and column means with similar superscripts differ at P<0.05

Within focal time periods, P1, P2 and HP, mean percentages of total ruminating time spent ruminating whilst lying by transported and control lambs were $64.06\% \pm 7.56$ and $66.43\% \pm 8.39$; $56.01\% \pm 7.81$ and $70.38\% \pm 8.39$ and $79.02\% \pm 7.81$ and $87.71\% \pm 7.34$, respectively. There were no significant differences between the means for transported and control lambs during these periods ($P > 0.05$ in all cases; Table 5.45). During the transport period (TP), mean percentage of total ruminating time spent ruminating whilst lying by control lambs was significantly greater than that for transported lambs ($71.98\% \pm 7.56$ and $26.96\% \pm 9.12$, respectively; $P < 0.05$).

Between focal time periods, mean percentage of total ruminating time spent ruminating whilst lying by transported lambs was significantly greater during HP than TP $79.02\% \pm 7.81$ and $26.96\% \pm 9.12$, respectively; $P < 0.05$; 5.3.6.30). There were no other significant differences between the focal period means for transported lambs ($P > 0.05$ in all cases). There were no significant differences between the focal period means for control lambs ($P > 0.05$ in all cases).

A glm one way analysis of variance of the proportion of total ruminating time spent ruminating whilst lying by Direct, Multiple Pickup and Market lambs during the transport period (TP) indicated a significant treatment effect ($F_{2,8} = 6.50$; $P < 0.05$; Table 5.46). As above, analyses were conducted using arcsine square root transformed proportional data because of evidence of non-normality of data distribution (Anderson-Darling Normality Tests; $P < 0.05$). There was no evidence of heterogeneity of variances (Levene's Tests; $P > 0.05$). Results are presented in percentage terms at the 95% confidence level for consistency and clarity.

Table 5.46 Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying (%±SEM) by Direct, Multiple Pickup and Market Lambs During TP

	Direct (n=4)	Multiple Pickup (n=3)	Market (n=4)
Mean Percentage of Total Ruminating Time Spent Ruminating Whilst Lying During TP (%±SEM)	72.54±14.89 ^{ab}	1.51±17.2 ^a	0.47±14.89 ^b

Row means with similar superscripts differ at P<0.05 in all cases

Mean percentage of total ruminating time spent ruminating whilst lying by lambs on the Direct transport treatment was 72.54%±14.89 (Table 5.46). Pairwise comparisons, using the Tukey WSD test (Zar 1996), indicated this was significantly greater than that for Multiple Pickup and Market lambs (1.51%±17.2 and 0.47%±14.89, respectively; P<0.05 in both cases). There was no significant difference between the means for Multiple Pickup and Market lambs (P>0.05).

5.4 Discussion

The results from this experiment provide new insights into the effect of journey structure on the welfare of slaughterweight lambs.

Mean liveweight at selection was 41.61kg ±0.24 and there were no significant differences between the treatment means. Over the five-day handling period for live animals, liveweight increased whilst the lambs were at pasture (between Selection Weight, recorded on Day 1, and Housing Weight, recorded on Day 4), decreased during housing (between Housing Weight and Pre-Transport Weight, recorded on Day 5), and decreased further during the 4hr transport period on Day 5 (41.62kg ±0.24, 43.67kg ±0.27, 41.26kg ±0.26 and 40.51kg ±0.24, respectively). Hay and water were provided during overnight housing

and whilst hay was consumed, the lambs did not drink. Thus, the period of water deprivation, between housing and the end of the transport period, extended to 19hrs. Knowles *et al.* (1995) found that lambs did not become severely dehydrated for transport periods of up to 24hrs and Parrott, Lloyd and Goode (1996), holding sheep for 48hrs at temperatures up to 35°C without food or water, found that sheep remained within water balance. However, the authors showed that the sheep were not able to maintain water balance if food was consumed. Therefore, because hay was consumed during housing, it is possible that the lambs in this experiment were dehydrated to some extent.

There were no significant differences between the treatments in liveweight loss during the housing period, but Multiple Pickup and Market lambs lost more weight than Direct or Control lambs during the transport period. Knowles *et al.* (1995) reported an 8% loss of liveweight in lambs after 24hrs of transport, most of which occurred in the first 15hrs. In this experiment, Direct, Multiple Pickup, Market and Control lambs lost a total of 6.2%, 8.3%, 7.8% and 6.8%, respectively. Liveweight loss during the housing period accounted for 5.0%, 6.0%, 5.5% and 5.5%, respectively. For Direct and Control lambs, the rate of liveweight loss was greater during housing than during the transport period. However, there was no significant difference in the rate of liveweight loss between the two periods for Multiple Pickup and Market lambs. This suggests that the transportation processes may have been more aversive to these groups than to Direct lambs and to holding in the Home Pen for Control lambs.

Whilst the Pre-Transport and Post-Transport weights of Direct lambs was greater than that of lambs on all other treatments, there were no significant differences in Hot or Cold Carcass Weights or Carcass Weight Loss (also known as drip loss) between the treatment means. This suggests that the greater liveweight of Direct lambs comprised gut fill and is

supported by the evidence of Killing out Percentage and Digestive Tract Weight (including digesta).

Mean Killing Out Percentage of Direct lambs was less than that of Multiple pickup lambs, which in turn was less than that of Market lambs. Mean Digestive Tract Weight was greater for Direct lambs than for Multiple Pickup and Market lambs, but there was no significant difference between the Multiple Pickup and Market lambs. Mean Digestive Tract weight for Direct, Multiple Pickup and Market lambs accounted for 22.2%, 21.2% and 20.5%, respectively, of Mean Housing Weight (covariate adjusted as described).

Median pH_u, measured in the *semimembranosus*, was lower for Direct lambs than Multiple Pickup and Market lambs (5.5, 5.55 and 5.54, respectively). This suggests that *ante mortem* glycogen depletion was greater in the lambs on the two more complex journeys than in those on the direct route, thus limiting the extent of *post mortem* glycolysis.

The behaviour of the lambs, as measured in jaw movement activity and lying behaviour of 18 transported and 18 non-transported controls, was modified by the handling and management operations prior to transport and by transport itself. For all lambs, mean time spent ruminating and eating decreased during the housing period when compared to the same time period whilst the lambs were held at pasture on the preceding day. Mean time spent lying and when jaw activity registered as idle or in 'undetermined' movement increased. As stated previously, the nature of 'undetermined' jaw movement behaviours is not clear, but may represent wool pulling, as described by Fraser and Broom (1997) and Lynch, Hinch, and Adams (1992), teeth grinding (*personal observation*) or other unidentified movements. The time spent in these behaviours was minimal, but increased from 18s whilst at pasture to 43.2s during housing (total recording time 11hrs in both cases).

There were no significant differences in the durations of any of the behaviour measures between Transported and Control lambs across and within time periods. Between time periods, the responses of Transported and Control lambs were similar to those for all lambs, with the exception that there was no significant difference in mean time spent in 'undetermined' behaviours by Transported lambs.

Thus, the jaw movement and lying behaviour of lambs was modified by the environment during the housing period, when compared to the same time period whilst the lambs were held at pasture on the preceding day.

For all lambs, mean time spent ruminating and eating decreased during the transport period when compared to the same time period whilst the lambs were held at pasture on the preceding day. Mean time spent when jaw activity registered as idle or in 'undetermined' movement increased. There was no significant difference in the mean time spent lying between the two periods. Food and water were withdrawn during the transport period, although straw bedding was provided. That jaw movement activity associated with eating was recorded during the transport period (6.6 minutes (± 2.1); total recording time 4hrs) suggests that the lambs may have been eating the straw.

Between time periods, Control lambs spent significantly less time eating and more time idle, in 'undetermined' jaw movement activity and lying down during the transport period than during the same time period whilst the lambs were held at pasture on the preceding day. There was no significant difference in mean duration of ruminating behaviour between the two time periods. For Transported lambs, mean time spent ruminating, eating and lying during the transport period were significantly less than during the pasture period, whereas the mean time spent idle and in 'undetermined' jaw movement activity were

significantly greater. There were no significant differences in the behaviours measured between Transported and Control lambs during the pasture period.

During the Transport period, Control lambs spent significantly more time ruminating and lying down and less time when jaw movements were idle. There were no significant differences in mean time spent eating or in 'undetermined' jaw movements. Mean time spent ruminating during the Transport period by Transported lambs was just 9 minutes (± 3.6) and for Control lambs was 1hr 4.2 minutes (± 5.4 minutes). Mean time spent lying down during the transport period by Transported lambs was 0.56hrs (± 0.18) and for Control lambs, 2.34hrs (± 0.17). Thus, Control lambs spent almost 60% of the total transport period lying down, whereas Transported lambs spent 14% of the time lying down.

The reduction in ruminating by Transported lambs may have been as a result of motion sickness (see Austin 1996; Bost, McCarthy, Colby, and Borison 1968 and Eiler, Lyke and Johnson 1981); or because some other aspect of the transportation period was disruptive or aversive to the lambs. For example, vibration, jolting and noise were suggested by Cockram *et al.* (1996) as reasons for increased plasma cortisol concentration and heart rate in transported sheep compared to non transported controls.

It is clear that transportation *per se* affected the jaw movement and lying behaviour of the lambs resulting in a reduction in the time spent ruminating and lying down.

No significant differences in the time spent in any of the measured behaviours was identified between lambs on the Direct, Multiple Pickup and Market treatments during the transport period. However, during the transport period, Control lambs spent 74.12% (± 3.97) of the time spent ruminating doing so whilst lying down, whereas Transported

lambs spent 56.51% (± 4.05). Lambs on the Direct transport treatment spent a significantly higher percentage of ruminating time whilst lying down than Multiple Pickup or Market lambs (72.54% ± 14.89 , 1.51% ± 17.2 and 0.47 ± 14.89 , respectively) and there was no significant difference between the means of these two treatments. This suggests that the behaviour of the lambs on direct and uninterrupted transfer from farm to abattoir was disrupted less than those on the two more complex journey structures.

The results of this experiment indicate that it is important to consider the effect of journey structure on the welfare of slaughterweight lambs transferred from farm to abattoir. Heretofore, investigations of the effect of marketing channel (direct farm to abattoir sales and those via livestock auction markets) have indicated that the welfare of lambs sold via livestock auction markets is worse than that of those sold direct from farm to abattoir. However, within direct farm to abattoir sales, none have distinguished between direct and uninterrupted transfer and journeys involving multiple pickups *en route*. The results from the measurements taken during the three journey types investigated in this experiment show that direct transfer is less aversive to lambs than more complex journeys. But responses during a journey involving three additional pickups *en route* and a journey incorporating holding at a livestock auction market suggest that both journey types have a similarly deleterious effect on animal welfare.

The results of the survey of conducted to trace the journeys experienced by slaughterweight lambs from farm to abattoir showed that complexity increased with distance travelled. In this experiment, to avoid the confounding factor of variable periods of inanition, journey duration was the same for each journey type (4hrs). The Distances travelled by Direct, Multiple Pickup and Market lambs were 262km, 138km and 181km, respectively. Thus, whilst it is clear that direct and uninterrupted transfer from farm to

abattoir is preferable to more complex journeys, that more complex journeys are associated with greater distances means that the effect on the welfare of lambs may be more deleterious than has been demonstrated. However, further work is required to investigate this.

Chapter 6 Concluding Discussion

Major changes are taking place in all sectors of the livestock and meat producing industries from farm to slaughter. These emanate from a multiplicity of interactive factors arising from technological advances, legislative controls and social and economic pressures, all of which have an impact on the distribution of livestock from farm to abattoir and, therefore, on the welfare of animals.

That livestock production remains important in Cornwall and Devon is unequivocal. The industry in the two counties is dominated by dairying, beef and sheep production and, in 1997, over 70% of agricultural land comprised grassland and crops grown for stockfeed. The national average was just 49%. Examination of breeding livestock numbers showed that the two counties accounted for 15% of the national dairy herd, almost 15% of the national beef herd, over 13% of the national sheep flock and over 4% of the pig breeding herd.

The number of holdings throughout the country has been in decline for many years and there has been a concomitant increase in average holding size. Average holding size in Cornwall and Devon (40ha and 44.3ha in 1997; MAFF 1998a) remained below the national average of 63.7ha. The most recently published figures, for 1999, indicate that the position remains largely unchanged for all the above mentioned data (MAFF 2000c).

The size of the agricultural labour force has also been in decline throughout the country, but traditional livestock areas like Cornwall and Devon, with a larger number of smaller farms, have been less affected than areas where arable production dominates and holding size is large. Total agricultural employment in Cornwall and Devon extended to 14,751

and 25,472 in 1997, respectively (MAFF 1998a). This had declined to 24,585 and 14,601 by 1999 (MAFF 2000c). Nonetheless, the total for the two counties accounted for over 10% of the agricultural labour force in England, a percentage similar to 1997.

In 1997, agriculture in the South West region accounted for 1.9% of regional GDP, exceeded only by the East Midlands region at 2.0% (MAFF 1999). By 1999 this had declined to 1.7%, the highest regional figure, the same as the East Midlands and Eastern regions and above the national average of 0.9% (MAFF 2000d).

Farm incomes declined between 1991/2 and 1997/8, with the greatest decline in cattle and sheep (lowland) farms (MAFF 1999). By 1999/2000, provisional figures indicate that this sector maintained its position, but that all other sectors had declined further (MAFF 2000d).

Major changes are taking place within the agricultural sector and it remains relatively more important in Cornwall and Devon than in other areas of the country. Dairying, beef and sheep production are the dominant sectors within the industry in these two counties.

The three main distribution channels from farm to slaughter in this country are direct farm to abattoir sales and those via livestock auction markets and electronic auction systems. There have been shifts in distribution channel utilisation levels in recent years. Electronic auctions were introduced into this country in 1989 and, after an initial rapid increase in use in the first four years, the share of the market for cattle and sheep had declined to 1.5% and 3.4%, respectively, by 1997 (MLC 1996a, 2000 *personal communication*). There is little evidence of pigs being sold via this channel. By 1999, cattle sales via electronic auctions had declined to 0.4% of total slaughterings and sheep sales to 1.9% (MLC 2000 *personal communication*). Between 1997 and 1999 sales of cattle, sheep and pigs via livestock

auction markets had also declined in favour of those direct from farm to abattoir. By 1999, direct farm to abattoir cattle sales accounted for 62.5% of total slaughterings and sheep to 49%. This represented substantial shifts from 1997 when 52.4% of cattle and 35.4% of sheep were sold via this channel.

Structural changes within both the abattoir and livestock auction market sectors have resulted in a reduction of provision in both sectors. The numbers of both markets and abattoirs throughout the country have been in long term decline. By 1997, there were 146 livestock auction markets operating in England and this number was reduced to 127 by 2001 (Livestock Auctioneers' Association 1998, 2001 *personal communication*). Numbers in Cornwall and Devon extended to 6 and 14, respectively, in 2001 (Livestock Auctioneers' Association 2001 *personal communication*), declining from a total of 30 in the two counties in 1980 (Rosenthal 1981). Abattoir numbers in England extended to 410 in 1995, 375 in 1997 and 312 in 2001 (MAFF 1995a, 1997a, 2001). In Cornwall and Devon the number of abattoirs remaining in 2001 extended to 22; 11 in each county (MAFF 2001). Legislative controls, associated with the introduction of the Single European Market in January 1993, had a significant impact on the structure of the abattoir sector, reducing absolute numbers and formally polarising the industry with dual licensing standards based on throughputs.

These structural changes within the livestock market and abattoir sector, in association with fewer livestock farms and shifts in channel utilisation levels, inevitably mean that patterns of livestock distribution from farm to abattoir have changed.

Holistic influences on the distribution of livestock from farm to slaughter, impinging on all sectors, include the introduction of legislation relating to the welfare of animals during

transport, setting maximum species specific journey durations and new vehicle standards; changes in meat demand (which is now consumer led rather than production driven) and changes in the retail sector, with increasing dominance of the multiple retailers.

There is no evidence in the literature of any studies that have characterised the journeys of animals from farm to abattoir in any of the distribution channels. However, an important precursor of examination of the relationship between livestock distribution channels and animal welfare is an understanding of the journeys experienced from farm to slaughter.

Slaughterweight lambs were selected as the focal species for a survey of complete journey structure from farm to abattoir within the three main marketing distribution channels: direct farm to abattoir sales, sales via livestock auction markets and those via electronic auctions. The results, in which electronic auction systems were examined for the first time, clearly demonstrated that journeys experienced by lambs travelling from farm to slaughter vary considerably from the very simple to the highly complex.

All channels differed from each other in terms of median journey duration and distance travelled, with both parameters being lower in direct farm to abattoir sales than within the livestock market or electronic auction systems (median duration: 1.08hrs, 7.83hrs and 7.5hrs; and median distance: 45.1km, 120.7km and 349.2km, respectively). Median transit time for lambs sold through livestock auction markets was significantly greater than for those lambs sold through electronic auctions, but distance travelled was greatest for lambs sold through electronic auctions. However, considerable within-channel variation in both journey duration and distance was also found and although the *median* journey durations and distances travelled by direct sold lambs were shorter than lambs sold through the other two channels, some lambs sold through direct sales actually experienced very long

journeys (more than 10h and over 400km).

In terms of complexity, combinations of the following components were evident: periods of transport; trans-shipping (when animals were transferred from one vehicle to another); multiple pickups from a number of farms; and periods of holding at either assembly points, staging posts or auction markets. The journeys ranged from direct and uninterrupted transfer from farm to abattoir ($n=4,888$) to highly complex itineraries including up to three periods of transportation interspersed with two holding periods at assembly points, staging posts or auction markets ($n=1,034$). Journeys also included those with between 2 and 8 pickups *en route* ($n=2,369$), and those involving holding at assembly points, staging posts or livestock auction markets before transfer to abattoir ($n=10,102$). Twenty-six different journey structures were identified: 18 in direct farm to abattoir sales, 9 in sales via livestock auction markets and 13 within the electronic auction system.

Across all distribution channels, analysis of journey complexity revealed that journeys involving between 1 and 3 pickups *en route* to the abattoir had the lowest journey time and distance compared with itineraries involving two discrete journeys (*i.e.* holding at a livestock auction market or lairage), those involving between 4 and 8 pickups *en route*, and those involving 3 discrete journeys (*i.e.* holding at a livestock auction market or lairage, transfer to a second holding location and then transfer to abattoir). Within all three distribution channels more animals than expected experienced journeys of increasing complexity as distance increased.

This analysis of journey structure, therefore, shows that there is not as clear a distinction between these three marketing channels as has previously been stated (for example, Cockram & Lee 1991; Knowles, Maunder, Warriss & Jones 1994; Jarvis *et al.* 1995).

Indeed, because of the range of journey types in all three distribution channels, it is clear that it is essential to consider the structure of journeys, rather than the channels *per se*, when judging the impact of transportation on welfare of animals.

A number of studies have indicated that the welfare of lambs sold via livestock auction markets is worse than that of those sold direct from farm to abattoir (for example, Cockram and Lee 1991; Kim *et al.* 1994; Knowles, Maunder and Warriss 1994; Knowles, Maunder, Warriss and Jones 1994; and McNally and Warriss 1996 and 1997). Differences have been identified between markets (Jarvis and Cockram, 1995; McNally and Warriss, 1997) and between farms (Jarvis and Cockram, 1994; Murray *et al.* 1996).

The effect of journey complexity on animal welfare has not been thoroughly explored, but Kenny and Tarrant (1987), Evans *et al.* (1987) and Murray *et al.* (1996) have identified that journeys of increasing complexity may have an increasingly deleterious effect on animal welfare. Kenny and Tarrant (1987) investigated the effect of re-penning in a novel environment, confinement on a stationary vehicle, confinement on a moving vehicle and social re-grouping on 15 month old Friesian bulls and found that, as the complexity of treatment increased, the frequency of social interactions decreased. Plasma cortisol concentrations, levels of which may become elevated in response to environmental challenge, increased with increasing complexity of transport treatment.

Evans *et al.* (1987) studied the effect of marketing route on liveweight loss in slaughterweight lambs. Lambs sent on a single direct journey from farm to slaughter lost 0.53kg liveweight (average time between farm weighing and abattoir weighing - 5 hours) and those sent via a livestock auction market lost 3.07kg liveweight (average time between farm weighing and abattoir weighing 26 hours). The authors concluded that longer, more

complex journey structures resulted in increased weight loss.

In a preliminary study of slaughterweight lambs arriving at an abattoir in Devon from 6 local livestock auction markets and 28 local farms, Murray *et al.* (1996) identified fewer bruised carcasses and lower ultimate carcass pH in lambs that had experienced direct and uninterrupted transfer from farm to abattoir compared with those that had experienced a multi component journey.

No studies have been identified that distinguish between the effects of direct and uninterrupted journeys to abattoir and those involving multiple pickups *en route* on animal welfare and thence, none that distinguish between journeys involving multiple pickups and those involving two discrete journeys.

The effect of journey structure on the welfare of slaughterweight lambs (90 transported and 45 non-transported controls) was investigated in an experiment comprising 3 journey types (direct transfer from farm to abattoir, a journey involving 3 additional pickups *en route* and a journey incorporating holding at a livestock auction market) with non-transported controls held in a pen for the duration of the transport period. The duration of the transport period was 4hrs, established to avoid the confounding effect of different durations of inanition on the variables measured.

Variables measured included physical, behavioural and physiological indicators of the welfare of the lambs and incorporated: liveweight, lying and standing behaviours, jaw movements (ruminating, eating, idle and 'undetermined'), carcass weight, weight of digestive tract (including digesta) and ultimate carcass pH (pH_u). An automatic system for digital recording of jaw movements and lying and standing behaviours was used to characterise these behaviours in 18 transported and 18 non-transported controls (*BehavRec*

Over the five-day handling period for live animals, liveweight increased whilst the lambs were at pasture (between Selection Weight, recorded on Day 1, and Housing Weight, recorded on Day 4), decreased during housing (between Housing Weight and Pre-Transport Weight, recorded on Day 5), and decreased further during the 4hr transport period on Day 5 (41.62kg \pm 0.24, 43.67kg \pm 0.27, 41.26kg \pm 0.26 and 40.51kg \pm 0.24, respectively). Hay and water were provided during overnight housing and whilst hay was consumed, the lambs did not drink. Thus, the period of water deprivation, between housing and the end of the transport period, extended to 19hrs. Knowles *et al.* (1995) found that lambs did not become severely dehydrated for transport periods of up to 24hrs and Parrott, Lloyd and Goode (1996), holding sheep for 48hrs at temperatures up to 35°C without food or water, found that they remained within water balance. However, the latter authors showed that the sheep were not able to maintain water balance if food was consumed. Therefore, because hay was consumed during housing, it is possible that the lambs in the experiment reported here were dehydrated to some extent.

Knowles *et al.* (1995) reported an 8% loss of liveweight in lambs after 24hrs of transport, most of which occurred in the first 15hrs. In this experiment, Direct, Multiple Pickup, Market and Control lambs lost a total of 6.2%, 8.3%, 7.8% and 6.8%, respectively. Liveweight loss during the housing period accounted for 5.0%, 6.0%, 5.5% and 5.5%, respectively. For Direct and Control lambs, the rate of liveweight loss was greater during housing than during the transport period. However, there was no significant difference in the rate of liveweight loss between the two periods for Multiple Pickup and Market lambs. During the transport period, Multiple Pickup and Market lambs lost more weight than Direct or Control lambs (1.00kg \pm 0.07, 0.99kg \pm 0.07, 0.56kg \pm 0.07 and 0.55kg \pm 0.06,

respectively). There were no significant differences in liveweight loss between Multiple pickup and Market lambs or between Direct and Control lambs. This suggests that the transportation processes may have been more aversive to the lambs on the more complex journeys than to Direct lambs and to holding in the Home Pen for Control lambs.

Whilst the Pre-Transport and Post-Transport weights of Direct lambs were greater than that of lambs on both other transport treatments, there were no significant differences in Hot or Cold Carcass Weights or Carcass Weight Loss (also known as drip loss) between the treatment means. This suggests that the greater liveweight of Direct lambs comprised gut fill and is supported by the evidence of Killing out Percentage and Digestive Tract Weight (including digesta).

Mean Killing Out Percentage of Direct lambs was less than that of Multiple pickup lambs, which in turn was less than that of Market lambs. Mean Digestive Tract Weight was greater for Direct lambs than for Multiple Pickup and Market lambs, but there was no significant difference between the Multiple Pickup and Market lambs. Mean Digestive Tract weight for Direct, Multiple Pickup and Market lambs accounted for 22.2%, 21.2% and 20.5%, respectively, of Mean Housing Weight (covariate adjusted).

Following a transport period of 15hrs, Manteca (1996a) reported that pH_u in carcasses of lambs which had experienced a 'smooth' journey were lower than that of those which had experienced a 'rough' journey. In this experiment, median pH_u , measured in the *semimembranosus*, was lower for Direct lambs than Multiple Pickup and Market lambs (5.5, 5.55 and 5.54, respectively). This suggests that *ante mortem* glycogen depletion was greater in the lambs on the two more complex journeys than in those on the direct route, thus limiting the extent of *post mortem* glycolysis. Median pH_u in all treatments was within

the normal range of 5.4 - 5.6 for lamb reported by Lawrie (1992).

The behaviour of the lambs, as measured in jaw movement activity and lying behaviour of 18 transported and 18 non-transported controls, was modified by the handling and management operations prior to transport and by transport itself. For all lambs, mean time spent ruminating and eating decreased during the housing period when compared with the same time period whilst the lambs were held at pasture on the preceding day. Mean time spent lying and when jaw activity registered as idle or in undetermined movement increased. The nature of undetermined jaw movement behaviours is not clear, but may represent wool pulling (Fraser and Broom 1997; Lynch, Hinch, and Adams 1992), teeth grinding (*personal observation*) or other unidentified movements. The time spent in these behaviours was minimal, but increased from 18s whilst at pasture to 43.2s during housing (total recording time 11hrs in both cases).

During the Transport period, Control lambs spent more time ruminating and lying down, and less time when jaw movements registered idle, than Transported lambs. Mean time spent ruminating during the transport period by Transported lambs was just 9 minutes (± 3.6) and for Control lambs was 1hr 4.2 minutes (± 5.4 minutes). Mean time spent lying down during the transport period by Transported lambs was 33.6 minutes (± 10.8) and for Control lambs, 2hrs 20.4minutes (± 10.2 minutes). Thus, Control lambs spent almost 60% of the total transport period lying down, whereas Transported lambs spent 14% of the time lying down.

The reduction in the time spent ruminating by Transported lambs may have been as a result of motion sickness (see Austin 1996; Bost, McCarthy, Colby, and Borison 1968 and Eiler, Lyke and Johnson 1981); or because some other aspect of the transportation period was

disruptive or aversive to the lambs. For example, vibration, jolting and noise were suggested by Cockram *et al.* (1996) as reasons for increases in plasma cortisol concentration and heart rate in transported sheep compared with non-transported controls.

During the transport period, lambs on the Direct transport treatment spent a significantly higher percentage of ruminating time whilst lying down than Multiple Pickup or Market lambs (72.54% \pm 14.89, 1.51% \pm 17.2 and 0.47% \pm 14.89, respectively) and there was no significant difference between the means of these two treatments. This suggests that the behaviour of the lambs on the two more complex journey structures was disrupted more than those on direct and uninterrupted transfer from farm to abattoir.

This study has shown that there is a multiplicity of interactive factors within all sectors of the livestock and meat producing industries affecting the journeys of livestock from farm to slaughter. The survey characterised, for the first time, the structure of journeys experienced by slaughterweight lambs and identified that they are diverse and range in complexity in all three distribution channels. The results from the experiment conducted to investigate the effect of journey structure on the welfare of slaughterweight lambs show that direct transfer is less aversive to lambs than more complex journeys. But responses to a journey involving three additional pickups *en route* and a journey incorporating holding at a livestock auction market suggest that both journey types have a similarly deleterious effect on animal welfare. It is, therefore, essential that journey structure is considered when judging the welfare of animals during transportation and not just the marketing channel *per se*.

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Appendices

Appendix 1 Regional Definitions

England regions are defined by the Government Office Regions (GORs) established in 1995 (Office for National Statistics 1998). Where used, historical data are similarly presented, compiled from relevant extant county statistics.

East Midlands GOR: Derbyshire, Nottinghamshire, Lincolnshire, Leicestershire & Rutland, Northamptonshire.

Eastern GOR: Norfolk, Suffolk, Cambridgeshire, Bedfordshire, Hertfordshire, Essex.

Greater London GOR: Greater London.

North East GOR: Northumberland, Tyne & Wear, Durham, Cleveland & Darlington.

North West GOR: Cumbria, Lancashire, Cheshire, Greater Manchester, Merseyside.

South East GOR: Oxfordshire, Buckinghamshire, Berkshire, Surrey.

South West GOR: Gloucestershire, North Somerset and South Gloucestershire, Wiltshire Somerset, Dorset, Devon, Cornwall and the Isles of Scilly.

West Midlands GOR: Staffordshire, Shropshire, Hereford & Worcestershire, West Midlands, Warwickshire.

Yorkshire & the Humber GOR: North Yorkshire, East Riding & Northern Lincolnshire, West Yorkshire, South Yorkshire.

Appendix 2 The Welfare of Animals (Transport) Order 1997: Schedule 1 and 2

SCHEDULE 1

Article 4(3) to (6)

PART I

GENERAL REQUIREMENTS FOR THE CONSTRUCTION AND MAINTENANCE OF MEANS OF TRANSPORT AND RECEPTACLES FOR ALL MAMMALS AND BIRDS

Avoidance of injury and suffering

1. Means of transport, receptacles, and their fittings shall be constructed, maintained and operated so as to avoid injury and unnecessary suffering and to ensure the safety of the animals during transport, loading and unloading.

Substantial construction

2. Every part or fitting of a means of transport or receptacle which may be exposed to the action of the weather shall be constructed, maintained and operated so as to withstand the action of the weather.

Size

3. The accommodation available for the carriage of animals shall be such that the animals are, unless it is unnecessary having regard to the species of animal and the nature of the journey, provided with adequate space to lie down.

Floors

4. Any floor on which animals stand or walk during loading, unloading or transport shall be -

- (a) sufficiently strong to bear their weight;
- (b) constructed, maintained and operated to prevent slipping; and
- (c) free of any protrusions, spaces or perforations which are likely to cause injury to animals.

Weather and sea conditions

5. Means of transport and receptacles shall be constructed, maintained and operated so as to protect animals against inclement weather, adverse sea conditions, marked fluctuations in air pressure, excessive humidity, heat or cold.

Projections and sharp edges

6. Means of transport and receptacles shall be free from any sharp edges and projections likely to cause injury or unnecessary suffering to any animal being carried.

Cleanliness

7. Means of transport and receptacles shall be constructed, maintained and operated so as to allow appropriate cleaning and disinfection.

Escape-proof

8. Means of transport and receptacles shall be escape-proof.

Noise and vibration

9. Means of transport and receptacles shall be constructed, maintained and operated so as to ensure that animals are not likely to be caused injury or unnecessary suffering from undue exposure to noise or vibration.

Lighting

10. - (1) Means of transport and receptacles shall have sufficient natural or artificial lighting to enable the proper care and inspection of any animal being carried.

(2) Passageways, ramps and other loading equipment shall be provided with adequate natural or artificial lighting to enable the animals to be loaded or unloaded safely.

(3) Artificial lighting required by this paragraph may be provided using a portable light.

Use of partitions

11. - (1) Partitions shall be used if they are necessary -

(a) to provide adequate support for animals; or

(b) to prevent animals being thrown about during transport.

(2) When partitions are used, they shall be positioned so as to prevent injury or unnecessary suffering to animals as a result of -

(a) lack of support; or

(b) being thrown about during transport.

Design of partitions

12. Partitions shall be -

(a) of rigid construction;

(b) strong enough to withstand the weight of any animal which may be thrown against them; and

(c) constructed and positioned so that they do not interfere with ventilation.

PART II

GENERAL PROVISIONS FOR THE TRANSPORT OF ALL MAMMALS AND BIRDS

Jolting

22. Animals shall not be transported in such a way that they are severely jolted or shaken.

Loading and unloading

23. Animals shall be loaded and unloaded in such a way as to ensure that they are not caused injury or unnecessary suffering by reason of -

(a) the excessive use of anything used for driving animals; or

(b) contact with any part of the means of transport or receptacle or with any other obstruction.

Emergency unloading

24. Unless an animal can be loaded and unloaded in accordance with the provisions of paragraph 10(6) or (7) of Part II of Schedule 2 below, a vehicle shall, at all times, carry the means to enable animals to be unloaded without causing them injury or unnecessary suffering at a place where there is no other unloading equipment.

Segregation of animals and goods

25. - (1) Goods which are being transported in the same means of transport as animals shall be positioned so that they do not cause injury or unnecessary suffering to the animals and in particular goods which could prejudice the welfare of animals shall not be carried in pens or receptacles in which animals are transported.

(2) A carcase shall not be carried in the same road vehicle, receptacle, rail wagon or pen as an animal, other than the carcase of an animal which dies in the course of a journey.

Cleaning and disinfection

26. - (1) Animals shall be loaded only into means of transport or receptacles which have been thoroughly cleaned and where appropriate, disinfected.

(2) Dead animals, soiled litter and droppings shall be removed from means of transport or receptacles as soon as possible.

Litter

27. Floors on which animals are transported shall be covered with sufficient litter to absorb urine and droppings unless equally effective alternative arrangements are in place or unless urine and droppings are regularly removed.

Labelling of receptacles

28. Receptacles in which animals are transported shall -

- (a) be marked or labelled so as to indicate that they contain live animals and the species of those animals;
- (b) be marked with a sign indicating the receptacle's upright position; and
- (c) be kept in an upright position.

Securing of receptacles

29. Receptacles shall be secured so as to prevent their displacement during transport.

Humane slaughter on vessels and aircraft

30. Vessels and aircraft on which animals are transported shall carry appropriate means for effecting the humane slaughter of the type of animal being carried if necessary.

Attendants

31. - (1) In order to ensure the necessary care of the animals during transport, consignments of animals shall be accompanied by a sufficient number of attendants, taking into account the number of animals transported and the duration of the journey.

(2) At least one attendant shall accompany the animals except in the following cases -

- (a) where animals are transported in receptacles which are secured, adequately ventilated and, where necessary, contain enough food and liquid, in dispensers which cannot be tipped over, for a journey of twice the anticipated time;
- (b) where the transporter performs the function of attendant; or
- (c) where the consignor has appointed an agent to care for the animals at appropriate stopping or transfer points.

SCHEDULE 2

Article 4(3)

PART I

ADDITIONAL REQUIREMENTS FOR THE CONSTRUCTION AND MAINTENANCE OF MEANS OF TRANSPORT AND RECEPTACLES FOR CATTLE, SHEEP, PIGS, GOATS AND HORSES

Size and height

1. The accommodation available for the carriage of animals shall be such that the animals are provided with adequate space to stand in their natural position.

Ventilation

2. Means of transport and receptacles shall be constructed, maintained, operated and positioned so as to provide appropriate ventilation and sufficient air space above the animals to allow air to circulate properly.

Inspection of interior of receptacles

3. - (1) Receptacles shall be constructed, maintained and positioned so that they allow for the inspection and care of the animals, including, if necessary, the feeding and watering of the animals.

(2) Without prejudice to the generality of paragraph (1) above, receptacles carrying animals in an aircraft -

(a) in the lower deck compartment, shall be constructed, maintained and positioned so that all the animals may be inspected and, if necessary, cared for when the aircraft is on the ground; and

(b) in the main deck compartment, shall be constructed, maintained and positioned so as to provide access to every animal throughout the journey.

Special provisions for road vehicles

4. Vehicles shall be equipped with a roof which ensures effective protection against the weather.

5. Vehicles shall be equipped, on each floor on which animals are carried (other than in receptacles), with barriers, or, in the case of a vehicle exclusively used for the transport of horses, with straps, so constructed and maintained as to prevent any animal from falling out of the vehicle when any door used for loading and unloading is not fully closed.

6. - (1) Every ramp which is carried on or forms part of a vehicle shall be constructed, maintained and operated -

(a) to prevent slipping;

(b) so that it is not too steep for the age and species of the animal being transported;

(c) so that any step at the top or bottom of the ramp is not too high for the age and species of the animal being transported; and

(d) so that any gap between the top of the ramp and the vehicle or at the bottom of the ramp is not too wide for the age and species of the animal being transported.

(2) In this paragraph, a ramp shall be considered too steep, a step shall be considered too high and a gap shall be considered too wide, if animals using the ramp are likely to be caused injury or unnecessary suffering by reason of the slope of the ramp, the height of the step or the width of the gap.

7. Vehicles (other than vehicles in which animals are being carried in receptacles) shall be constructed so that all the animals inside can be inspected from the outside, and for this purpose shall be provided with suitably arranged openings and footholds.

8. In the case of animals which are normally required to be tied, suitable provision shall be made so that animals may be tied to the interior of the vehicle.

Approval of receptacles and pens on vessels

9. - (1) In the case of journeys beginning in Great Britain receptacles or pens used on an exposed deck of a vessel shall have been approved by the Minister before the animals are loaded.

(2) The Minister shall not grant an approval under this paragraph unless he is satisfied that, having regard to the weather and sea conditions likely to be encountered during the voyage, the receptacle or pen provides adequate protection against the sea and weather.

PART II

ADDITIONAL PROVISIONS FOR THE TRANSPORT OF CATTLE, SHEEP, PIGS, GOATS AND HORSES

Loading equipment

10. - (1) Animals shall be loaded and unloaded in accordance with this paragraph.

(2) Save as provided in sub-paragraphs (6) and (7) below they shall be loaded and unloaded using suitable ramps, bridges, gangways or mechanical lifting gear, operated so as to prevent injury or unnecessary suffering to any animal.

(3) The flooring of any loading equipment shall be constructed so as to prevent slipping.

(4) Subject to sub-paragraph (6) below, ramps, bridges, gangways and loading platforms shall be provided on each side with protection which is -

(a) of sufficient strength, length and height to prevent any animal using the loading equipment from falling or escaping; and

(b) positioned so that it will not result in injury or unnecessary suffering to any animal.

(5) Sub-paragraph (4) above shall not apply to ramps used on a vehicle for loading horses if -

(a) the vehicle has been specifically constructed for the carriage of horses; and

(b) loading and unloading is only effected by leading each horse into or out of the vehicle.

(6) An animal may be loaded or unloaded by means of manual lifting or carrying if the animal is of a size that it can easily be lifted by not more than two persons and the operation is carried out without causing injury or unnecessary suffering to the animal.

(7) An animal may be loaded or unloaded without equipment or by manual lifting or carrying provided that, having regard to the age, height and species of the animal, it is unlikely to be caused injury or unnecessary suffering by being loaded or unloaded in this manner.

Internal ramps and means of lifting

11. - (1) Animals shall be moved from one floor or deck of a vehicle, vessel or receptacle to another in accordance with this paragraph.

(2) Save as provided in sub-paragraph (4) below, suitable ramps or mechanical lifting gear shall be used and operated so as to prevent injury or unnecessary suffering to any animal.

(3) Where a ramp or mechanical lifting gear is used it shall be -

(a) provided on each side with protection which is of sufficient strength, length and height to prevent any animal using it from falling or escaping;

(b) positioned so that it will not result in injury or unnecessary suffering to any animal; and

(c) of a gradient which is suitable to the age and species of the animals concerned.

(4) Manual lifting or carrying may be used if the animal is of a size that can easily be lifted by no more than two persons and the movement is carried out without causing injury or unnecessary suffering to the animal.

Tying

12. When animals are tied, the ropes or other attachments used shall be -
- (a) strong enough not to break during normal transport conditions;
 - (b) designed in such a way as to eliminate any danger of strangulation or injury, and
 - (c) long enough to allow the animals, if necessary, to lie down and to eat and drink.
13. Animals shall not be tied by the horns, or by nose rings.

Segregation of animals

14. - (1) Save as provided in sub-paragraphs (2) and (4), the following animals shall not be carried in an undivided vehicle, rail wagon, pen or receptacle with other animals -

- (a) a cow accompanied by a calf or calves it is suckling;
- (b) a sow accompanied by unweaned piglets;
- (c) a mare with a foal at foot;
- (d) a bull over 10 months of age;
- (e) a breeding boar over 6 months of age; or
- (f) a stallion.

(2) Bulls may be carried with other bulls, boars with other boars and stallions with other stallions if they have been raised in compatible groups or are accustomed to one another.

(3) Save as provided in sub-paragraph (4), animals shall be segregated according to species.

(4) Animals of any species may be carried in the same undivided vehicle, rail wagon, pen or receptacle as their companion animals if separation would cause either of the animals distress.

(5) No unsecured animal shall be carried in the same undivided vehicle, rail wagon, pen or receptacle as any animal which is secured other than -

- (a) unweaned young transported with their dam or other animal which they are suckling, or
- (b) a horse registered under the Rules of Racing accompanied by an animal which is its companion.

(6) No animal shall be carried with another animal if, having regard to the differences in age and size between those animals, injury or unnecessary suffering is likely to be caused to one or both of the animals.

(7) Measures shall be taken to avoid injury or unnecessary suffering to any animal as a result of the carriage in the same vehicle, rail wagon, pen or receptacle of animals which are hostile to each other or are fractious.

(8) Measures shall be taken to avoid any animal being caused injury or unnecessary suffering by an animal which becomes fractious during the journey.

(9) Uncastrated male adults shall be segregated from females unless they have been raised in compatible groups or are accustomed to one another.

(10) Horned cattle shall be segregated from unhorned cattle unless they are all secured.

(11) Broken horses shall be segregated from unbroken horses.

(12) Segregation of animals in rail wagons may be effected either by means of suitable partitions or, if space permits, by tying them in separate parts of the rail wagon.

Restrictions on lifting, dragging and use of force on animals

15. - (1) Without prejudice to the provisions of article 6(6), animals shall not be suspended by mechanical means, nor lifted or dragged by the head, horns, legs, tail or fleece.

(2) No person shall use excessive force to control animals.

(3) Subject to sub-paragraph (4) below, no person shall use -

- (a) any instrument which is capable of inflicting an electric shock to control any animal;

(b) any stick, goad or other instrument or thing to hit or prod any cattle of six months or under; or

(c) any stick (other than a flat slap stick or a slap marker), non-electric goad or other instrument or thing to hit or prod any pigs.

(4) The prohibition in sub-paragraph (3)(a) above shall not apply to the use of any instrument of a kind mentioned in that sub-paragraph, on the hindquarters of any cattle over the age of six months or on adult pigs which are refusing to move forward when there is space for them to do so, but the use of any such instrument shall be avoided as far as possible.

(5) Nothing in this provision shall prevent the suspension by mechanical means of a receptacle in which an animal is being carried.

Duties of attendants

16. - (1) The attendant or consignor's agent shall look after the animals, and, if necessary, feed, water and milk them.

(2) Animals in milk shall be milked at appropriate intervals and, in the case of cows in milk, that interval shall be about 12 hours but shall not exceed 15 hours.

SCHEDULE 7

Articles 8, 13 and 14

PART I

WATERING AND FEEDING INTERVALS, JOURNEY TIMES AND RESTING PERIODS FOR CATTLE, SHEEP, PIGS, GOATS AND FOR HORSES (EXCEPT REGISTERED HORSES)

1. Subject to the provisions of this Schedule, journey times shall not exceed 8 hours.

2. The maximum journey time in paragraph 1 may be extended where the transporting vehicle meets the following additional requirements:

(a) there is sufficient bedding on the floor of the vehicle,

(b) the transporting vehicle carries appropriate feed for the animal species transported and for the journey time,

(c) there is direct access to the animals,

(d) there is adequate ventilation which may be adjusted depending on the temperature (inside and outside),

(e) there are movable panels for creating separate compartments,

(f) vehicles are equipped for connection to a water supply during stops, and

(g) in the case of vehicles for transporting pigs, sufficient liquid is carried for drinking during the journey.

3. The watering and feeding intervals, journey times and rest periods which shall apply when a road vehicle meets the requirements in paragraph 2 are as follows -

(a) unweaned calves, lambs, kids and foals which are still on a milk diet and unweaned piglets must, after 9 hours of travel, be given a rest period of at least one hour sufficient in particular for them to be given liquid and if necessary fed. After this rest period, they may be transported for a further 9 hours;

(b) pigs may be transported for a maximum period of 24 hours. During the journey, they must have continuous access to liquid;

(c) horses may be transported for a maximum period of 24 hours. During the journey they must be given liquid and if necessary fed every 8 hours; and

(d) all other cattle, sheep and goats to which this Schedule applies must, after 14 hours of travel, be given a rest period of at least one hour sufficient for them in particular to be given liquid and, if necessary, fed. After this rest period, they may be transported for a further 14 hours.

4. At the end of the journey time laid down, animals must be unloaded, fed and watered and be rested for at least 24 hours.

5. Animals must not be transported by train if the maximum journey time exceeds 8 hours. However, the journey times laid down in paragraph 3 shall apply where the conditions laid down in paragraphs 2 and 3, except for rest periods, are met.

6. - (1) Animals must not be transported by sea if the maximum journey time exceeds that laid down in paragraph 1, unless the conditions laid down in paragraphs 2 and 3, apart from journey times and rest periods, are met.

(2) In the case of transport by sea on a regular and direct link between two geographical points of the Community by means of vehicles loaded on to vessels without unloading of the animals, the latter must be rested for 12 hours after unloading at the port of destination or in its immediate vicinity unless the journey time at sea is such that the voyage can be included in the general scheme of paragraphs 1 to 3.

7. In the interests of the animals, the journey times in paragraphs 3 and 6(2) may be extended by 2 hours, taking account in particular of proximity to the place of destination.

PART II

ADDITIONAL PROVISIONS RELATING TO THE TRANSPORT OF ANIMALS THROUGH A MARKET WHERE DOCUMENTATION IS UNAVAILABLE FOR THE WHOLE PERIOD OF THE JOURNEY

8. The provisions in this Part shall apply where a journey involves passing through a market, and the documentation is unavailable to a person transporting animals from that market to establish the time the animals left the point where the journey to that market began.

9. If a person transports from a market animals which he did not take to that market, the documents required under article 14 shall show the market as the beginning of the journey for the purposes of recording the place, date and time of loading.

10. If a journey to market was not more than 4 hours, no person shall transport animals from that market for more than 4 hours except in accordance with the following provisions of this Part.

11. The animals to be transported shall have been at market for a period of at least one hour sufficient in particular for them to be given liquid and, if necessary, fed.

12. The journey from the market shall be in a vehicle complying with paragraph 2 of Part I of this Schedule.

13. Unweaned calves, lambs, kids and foals which are still on a milk diet and unweaned piglets may be transported for 9 hours from a market if the journey to market was not more than 4 hours (or 9 hours if it was in a vehicle complying with paragraph 2 of Part I of this Schedule).

14. Pigs or horses may be transported for 8 hours from a market if the journey to market was not more than 4 hours (or 8 hours if it was in a vehicle complying with paragraph 2 of Part I of this Schedule).

15. All other cattle, sheep and goats to which this Schedule applies may be transported for 14 hours from a market if the journey to market was not more than 4 hours (or 14 hours if it was in a vehicle complying with paragraph 2 of Part I of this Schedule).

16. It shall be a defence for a transporter transporting animals from a market to show that he took all reasonable steps to establish that the conditions in paragraphs 9 to 15 of this Schedule relating to the transport of animals to the market were satisfied.

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Appendix 3 Journey Information to Accompany All Transported Animals

The name and address of the owner of the animals

The name and address of the transporter of the animals

The place that the animals were loaded and their final destination. If sent to a livestock auction market, this is the final destination.

The date and time that the first animal was loaded

The date and time of departure

The time and place of rest periods (for domestic journeys over 8 hours)

The species of animal and whether unweaned

The number of animals and status (breeding livestock, slaughter livestock etc.)

The date and time of unloading

The registration number of the transporting vehicle

Source: MAFF 1998c.

Appendix 4 Data Collection Proforma - Lambs Arriving at Livestock Auction
Market, Collection Point, Lairage and Abattoir

Location/ID			Channel					Date:					
Arrival Time	Name, Origin Location & Type	D/M	Load Order	Dep Time	Distance	Total Lamb Nos	Lot No	Lamb Nos	Lot No	Lamb Nos	Notes (inc stocking density)	Load In ID	Load Out ID
	Vendor Name		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										
	Name:		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										
	Name:		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										
	Name:		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										
	Name:		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										
	Name:		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										
	Name:		of										
	Origin Location		Unloaded ?										
	Type: F / TP / L / M / AP		Distance next pickup										

Appendix 6 Journey Structures Identified in Direct Farm to Abattoir Sales

1 pickup, abattoir
2 pickups, abattoir
3 pickups, abattoir
4 pickups, abattoir
5 pickups, abattoir
6 pickups, abattoir
7 pickups, abattoir
8 pickups, abattoir
1 pickup, trans-shipment, 2 pickups, abattoir
1 pickup, holding, abattoir
2 pickups, holding, 2 pickups, abattoir
3 pickups, holding, abattoir
3 pickups, holding, 2 pickups, abattoir
4 pickups, holding, 1 pickup, abattoir
2 pickups, holding, 4 pickups, abattoir
5 pickups, holding, 1 pickup, abattoir
4 pickups, holding, 2 pickups, abattoir
1 pickup, holding, 6 pickups, abattoir

holding = holding at livestock auction market, assembly point, staging post or lairage

Appendix 7 Journey Structures Identified in the Livestock Auction Market System

1 pickup, holding, abattoir
3 pickups, holding, abattoir
4 pickups, holding, 1 pickup, abattoir
2 pickups, holding, 1 pickup, trans-shipment, 1 pickup, abattoir
3 pickups, holding, 1 pickup, trans-shipment, 1 pickup, abattoir
2 pickups, holding, 1 pickup, holding, 1 pickup, abattoir
3 pickups, holding, 1 pickup, holding, 1 pickup, abattoir
4 pickups, holding, 1 pickup, holding, 1 pickup, abattoir
5 pickups, holding, 1 pickup, holding, 1 pickup, abattoir

holding = holding at livestock auction market, assembly point, staging post or lairage

Appendix 8 Journey Structures Identified in the Electronic Auction System

1 pickup, abattoir
2 pickups, abattoir
3 pickups, abattoir
4 pickups, abattoir
5 pickups, abattoir
6 pickups, abattoir
7 pickups, abattoir
8 pickups, abattoir
1 pickup, trans-shipment, abattoir
1 pickup, holding, abattoir
2 pickups, holding, 2 pickups, abattoir
1 pickup, holding, 3 pickups, abattoir
2 pickups, holding, 1 pickup, holding, 1 pickup, abattoir

holding = holding at livestock auction market, assembly point, staging post or lairage

Appendix 9 The Relationship between Journey Complexity and Distance from Farm to Slaughter (number of lambs) in the Direct Farm to Abattoir System

	<50km	>50 - 100km	>100 - 250km	>400km
1-3 Pickups	4145	984	160	0
2 Discrete Journeys	15	1110	261	418
4-8 Pickups	0	112	362	80

$\chi^2 = 5796; df = 6; P < 0.001$

Appendix 10 The Relationship between Journey Complexity and Distance from Farm to Slaughter (number of lambs) in the Market System

	<50km	>50 - 100km	>100 - 250km	>250 - 400km	>400km
2 Discrete Journeys	545	2636	1943	974	1596
3 Discrete Journeys	0	0	0	0	984

$\chi^2 = 2623; df = 4; P < 0.001$

Appendix 11 The Relationship between Journey Complexity and Distance from Farm to Slaughter (number of lambs) in the Electronic Auction System

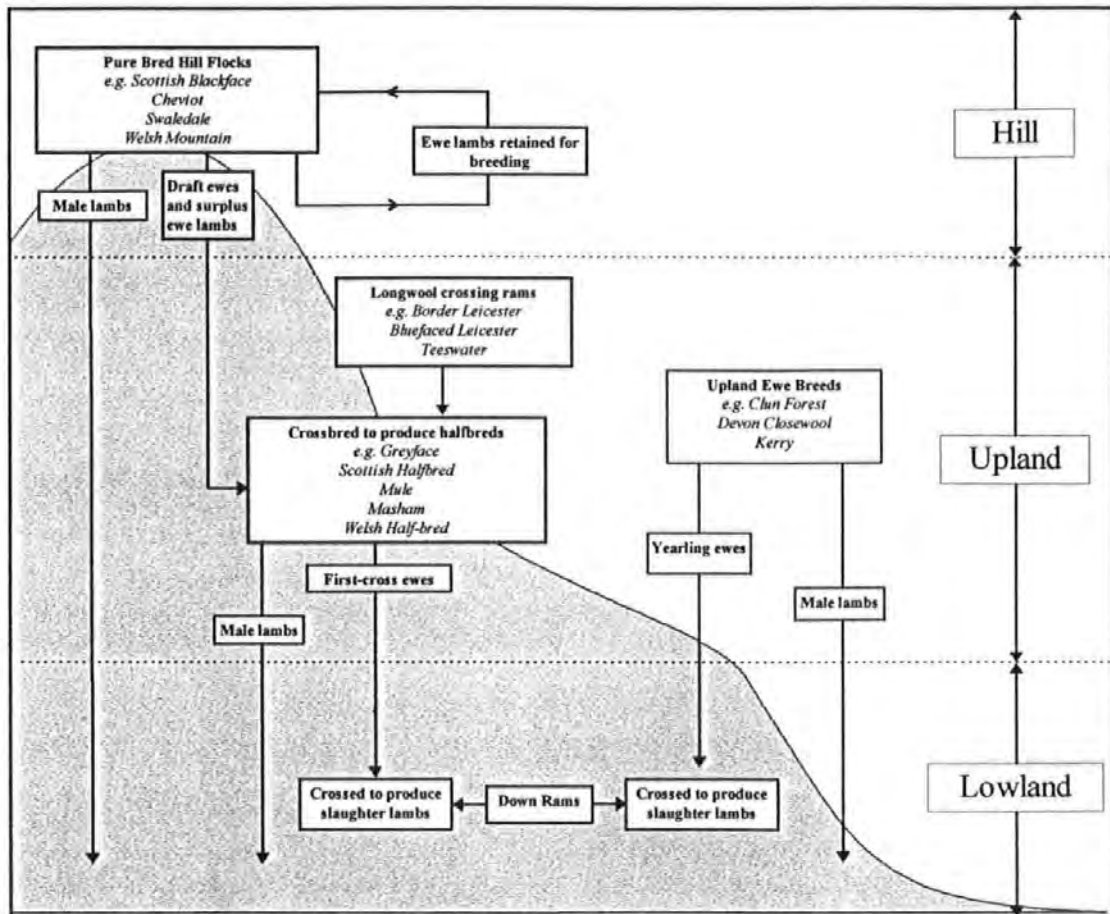
	>100 - 250km	>250 - 400km	>400km
1-3 Pickups	197	333	14
2 Discrete Journeys	0	359	245
4-8 Pickups	0	524	346
3 Discrete Journeys	0	50	0

$\chi^2 = 770.911; df = 6; P < 0.001$

Appendix 12 Vehicles (number) Used to Transport Lambs in Direct Farm to Abattoir Sales, the Livestock Auction Market and Electronic Auction Systems

	Number of Vehicles		
	Direct Farm to Abattoir Sales	Livestock Auction Market System	Electronic Auction System
Commercial Livestock Haulage Vehicles	58	136	13
Pickup Trucks	38	103	2
Towed Trailers	187	318	9
4 Wheel Drive Vehicles (e.g. Landrover)	5	12	0
Vans	22	59	1
Tractor Linkbox	7	6	0
Passenger vehicles	0	2	0

Appendix 13 Diagrammatic Representation of Stratification in the Sheep Industry in the UK



Source: Fell 1989

Appendix 14 Useable and Non-useable Data for Analysis of Jaw Movement

Behaviour

	Treatment	Focal Period																
		P1				P2				HP				TP				
		Lamb No.				Lamb No.				Lamb No.				Lamb No.				
		Trans		Control		Trans		Control		Trans		Control		Trans		Control		
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Week 1	1	✓	X	X	X	✓	X	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 2	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 3	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Week 4	3	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 5	2	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Week 6	1	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 7	1	✓	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	X	X	✓	✓	X
Week 8	2	X	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 9	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	X

✓ = Useable data

X = Non-useable data as a result of equipment failure

Trans = Transported lambs

Control = Control lambs

Treatment 1 = Direct

Treatment 2 = Multiple Pick-up

Treatment 3 = Market

Appendix 15 Useable and Non-useable Data for Analysis of Lying Behaviour

	Treatment	Focal Period															
		P1				P2				HP				TP			
		Lamb No.		Lamb No.		Lamb No.		Lamb No.		Lamb No.		Lamb No.		Lamb No.			
		Trans	Control	Trans	Control	Trans	Control	Trans	Control	Trans	Control	Trans	Control				
Week 1	1	✓	X	X	X	✓	X	X	X	✓	✓	✓	✓	✓	✓	✓	✓
Week 2	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 3	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 4	3	✓	✓	✓	X	✓	✓	✓	X	✓	X	✓	✓	✓	X	✓	✓
Week 5	2	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 6	1	✓	✓	✓	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓
Week 7	1	✓	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	X	X	✓	✓
Week 8	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 9	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	X

✓ = Useable data

X = Non-useable data as a result of equipment failure

Trans = Transported lambs

Control = Control lambs

Treatment 1 = Direct

Treatment 2 = Multiple Pick-up

Treatment 3 = Market

Appendix 16 Useable and Non-useable Data for Analysis of Ruminating Whilst

Lying Behaviour

	Treatment	Focal Period																
		P1				P2				HP				TP				
		Lamb No.				Lamb No.				Lamb No.				Lamb No.				
		Trans		Control		Trans		Control		Trans		Control		Trans		Control		
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Week 1	1	✓	X	X	X	✓	X	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 2	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	NR	✓	✓	✓	✓
Week 3	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Week 4	3	✓	✓	✓	X	X	✓	✓	X	✓	X	✓	✓	✓	X	✓	✓	✓
Week 5	2	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	NR	X	✓	✓	✓
Week 6	1	✓	✓	✓	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 7	1	✓	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	X	X	✓	X	X
Week 8	2	✓	✓	✓	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week 9	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	X

✓ = Useable data

X = Non-useable data as a result of equipment failure

NR = No ruminating during this period

Trans = Transported lambs

Control = Control lambs

Treatment 1 = Direct

Treatment 2 = Multiple Pick-up

Treatment 3 = Market