Veterinaria Italiana, **44** (1), 215-222

Engineering and design of vehicles for long distance road transport of livestock: the example of cattle transport in northern Australia

John W. Lapworth

Summary

The author outlines the design of road vehicles for the long distance transport of livestock, mainly cattle, which are used in the tropical and sub-Mediterranean climatic regions of Australia and which have been engineered to meet animal welfare principles. Over 50% of journeys exceed 500 km. Journeys of 2 000 to 3 000 km do occur and involve the resting of animals once or twice during the journey. Specialised vehicles, known as 'road trains', are employed and these consist of multiple trailers with multi-deck containers or stock crates for animals, which are hauled by a prime mover or tractor. The starting point for design is safety for both people and animals and the need to preserve transport infra-structure such as roads and bridges. The move to volume livestock loading, where livestock are loaded according to the volume they occupy rather than their weight, was a major early breakthrough. Details are given of the design of vehicles and loading facilities. Vehicle design includes suspensions and the floors, interior walls, doors, partitions and penning, deck supports and arrangements for through loading of stock crates. Loading and unloading ramps can be a major source of stress and standardised heights have been adopted in Australia.

Keywords

Animal, Australia, Cattle, Engineering, Livestock, Road, Transport, Welfare.

Design e progettazione dei veicoli per il trasporto a lunga distanza su strada di bestiame: l'esempio del trasporto di bovini nell'Australia del nord

Riassunto

L'autore illustra il design dei veicoli per il trasporto su strada di bestiame, soprattutto bovini, utilizzati nelle regioni a clima tropicale e sub- Mediterraneo dell'Australia progettati per soddisfare le teorie per il benessere animale. Più del 50% dei viaggi superano i 500 km. Sono ricorrenti i viaggi da 2000 a 3000 km ed implicano la necessità di far riposare gli animali una o due volte durante il viaggio. Vengono impiegati veicoli specifici conosciuti come road trains*, costituiti da rimorchi multipli con container a più piani oppure da* stock crates*, trainati da una trattrice o da un* prime mover*. L'idea di partenza quando si progettano i mezzi è la sicurezza sia degli animali che delle persone e la manutenzione delle vie di trasporto come strade e fiumi. Il passaggio poi al carico di bestiame in base al volume, ovvero gli animali vengono caricati in base al volume che occupano e non al loro peso, è stata una svolta iniziale importante. Vengono poi forniti i dettagli della progettazione dei veicoli e delle strutture di carico. La progettazione dei veicoli deve tenere conto delle sospensioni e delle pavimentazioni, divisori interni, porte, della partizioni degli spazi e l'uso di transenne divisorie,*

Principal Project Officer, Animal Science, Queensland Department of Primary Industry and Fisheries, GPO Box 46, Brisbane, Queensland 4001, Australia
john.lapworth@dpi.qld.gov.au

delle pedane e gli arrangiamenti tecnici per poter caricare stock crates. *Le rampe di carico e scarico possono essere una delle maggiori fonti di stress ed in Australia sono state adottate delle misure standardizzate.*

Parole chiave
Animale, Australia, Benessere, Bestiame, Bovini, Ingegneria, Strada, Trasporto.

Introduction

This paper relates to the design of road vehicles used by the Australian livestock transport industry. It concentrates on cattle and outlines the development of road vehicle designs for livestock that are based on animal welfare principles and which suit the circumstances of Australia's north. Coverage includes the design of stock crates or containers on vehicles for livestock, handling facilities for livestock, the configuration of vehicles for livestock and the adoption of improved practices for livestock transport. The ideas presented may be relevant elsewhere in the world. For this reason, reference is made to extension material that is available on the Internet.

Background

Animal transport vehicles and handling facilities have undergone continual improvement since animals were domesticated and used for the benefit of mankind. In recent times, however, design improvements have been based on knowledge of animal behaviour and welfare and have resulted in distinct and demonstrable improvements to productivity (1, 5). The result in Australia has been pressure from livestock owners for changes in transport vehicle design to ensure the arrival of their animals at a destination uninjured and as stress-free as possible. At the same time, there has been an accompanying response from transport operators to ensure that they remain economically viable and competitive.

Government regulation and legislation to protect the infrastructure of roads and bridges are a consideration in meeting the demand for improved design of livestock transport vehicles in Australia. A crucial consultative process took place during the 1970s and 1980s to formulate workable solutions that could simultaneously protect road infrastructure and the safety of road users and meet community expectations for animal welfare by having better designed livestock transport vehicles. Probably the most revolutionary change was the introduction of 'volume loading (livestock loading)' in Queensland in 1983 (8). Volume or volumetric loading, which refers to the loading animals according to the area they occupy rather than their weight, allowed livestock vehicles to be loaded at densities that were safe for livestock without fear of breaching regulated axle weight limits. The trade-off was a substantial decrease in the tare weights of the trailers and trucks and a maximum external trailer length of 12.2 m.

Conditions in northern Australia

Over 50% of Australia's cattle are in northern Australia and most livestock journeys in this area exceed 500 km. Journeys of 2 000 to 3 000 km do occur and can involve the spelling of stock once or twice during the journey. In Australia, 'spelling' refers to the unloading, watering, feeding and resting of livestock.

Climatic conditions in northern Australia range from tropical in the north to sub-Mediterranean in the south. This climatic consistency allows for the use of the same livestock vehicle design throughout the region. The most prominent environmental variables for livestock transport in the region are heat and dust. These combine with road conditions and distance travelled to significantly influence all other factors involved in the road transport of livestock.

Animal species

Most animal species (domestic and feral), have been successfully transported over long distances by road and in multi-deck stock crates in northern Australia. These species include cattle, sheep, goats, horses (3, 9) donkeys, buffalo, deer and pigs. Success has

resulted from a combination of stock crate design and the efforts of animal attendants or handlers to address the normal physical and behavioural needs of each species, and to consider the effects of weather and climate at the time of year when transport occurs. Pre-transport preparation ensuring animals are fit to travel will significantly improve successful delivery outcomes. Long distance transport can also require that animals are spelled (unloaded, fed, watered and rested) once or more during the journey to minimise transit stress. These events require careful planning prior to departure.

Vehicles

Transport of animals over long distances in the remote areas of northern Australia is normally performed using multi-deck stock crates and road trains of multiple trailers towed by an engine unit or prime mover. The term 'stock crate' refers to the structure on motor vehicles and trailers that contain animals.

Laws govern where and when various prime mover and trailer combinations can be used and these are strictly enforced. Restrictions are based on load limits for bridges, road conditions and traffic densities, and the population in various communities en route.

Some of the prime mover and trailer combinations used in Australia are as follows:

- single trailer – one double-deck stock crate
- road train type1 – two trailers with double-deck stock crates hitched together
- road train type 2 – three trailers with double-deck stock crates hitched together
- B double – this combination comprises a prime mover and trailers that provides space for animals equivalent to three 12.2 m-long decks; the usual combination is a 6.1 m-long double-deck trailer behind the prime mover followed by a 12.2 m double-deck trailer; another less common B double combination comprises a prime mover and with two 9.1 m-long double-deck trailers
- B AB quad – this is a combination of two B doubles hitched together with a double axle dolly supporting the second B double trailer; a dolly is a non-fixed articulated trailer support consisting of two axles and a load sharing suspension which allows two semi-trailers to be coupled.

A type 2 road train is shown in Figure 1. Road trains are not normally allowed to travel within city or town boundaries unless on specified roads. Clearly signed bypass roads direct heavy vehicles and road trains around restricted areas. The same rule applies to nominated roads in some more closely settled intensive cattle production regions in Australia.

Figure 1
A type 2 road train of the sort used in remote areas of Australia for the transport of cattle showing three trailers with double-deck stock crates hitched together

Smaller numbers of animals may also be transported over shorter distances by body trucks (i.e. non-articulated trucks) or single-deck semi-trailers. Body trucks are a variation on the usual sort of truck without a trailer and may be multi-decked for the carriage of small animals, such as calves, sheep, goats and pigs (4).

Design of stock crates

Floors

The floors of all early stock crates were made of high-density hardwood boards about 100 mm wide and 12 mm thick. This material was very serviceable but allowed waste to leak onto the trailer chassis and sub-frame which in time led to extensive corrosion in these areas. Replacement of this flooring was relatively easy but infrequent. To prevent animals

slipping, grating was placed on top of the boards.

Welded steel mesh was initially used as it was readily available, easy to attach and relatively inexpensive but had the disadvantage of breaking up. Furthermore the dimension of the squares (150 mm to 200 mm) did not suit the way larger animals (cattle and horses) preferred to stand during transit. This resulted in hoof problems and faster deterioration of the floor surface. In addition, loose pieces of the wire mesh caused puncture injuries, particularly to the legs of animals, and created slippery spots on the floor, most commonly around the entry/exit point on the vehicle and the gateways to the internal pens.

The use of round or square hollow section steel tubing (approximately16 mm to 25 mm in diameter or width) in 250 mm to 300 mm squares proved to be a workable solution that allowed animals to stand normally and did not cause hoof damage. Corrosion of this material was still a maintenance problem and in the main has been replaced with 12 mm solid steel rod in the same configuration. To assist in cleaning waste from the vehicle, the bottom rods run the length of the trailer with the cross rods on top.

In multi-deck stock crates, top deck floors were mostly made from 25 mm to 30 mm plywood. This method of flooring prevented waste material leaking onto animals beneath. Upper deck floors generally had a slight slope from the centre to the sides of the stock crate to assist drainage. The plywood sheets were protected from damage by covering them with a fine galvanised welded steel mesh (25 × 25 mm squares). If not properly attached, this mesh would suffer the same fate as the larger mesh on the bottom decks.

Floors are now constructed of pressed metal sheeting designed to minimise slippage and allow the animals to stand normally during transit. With this construction, all animal waste can be contained on the vehicle and drained or washed out at nominated locations. This complies with current environmental requirements and has an eye to also comply with future standards.

Exterior walls

Wall cladding of livestock crates in Australia was traditionally made from hardwood boards attached to steel bows or arches spaced about 900 mm apart. Initially, all cladding was on the outside of the bows which left all internal framework exposed and caused unacceptable levels of bruising. Now most livestock vehicles have sheeting on the inside to present a smooth interior that does not cause bruising.

Some small farm trucks (so-called 'body trucks') and single-deck semi-trailers used weldmesh as side cladding. This was entirely unsatisfactory as it gave little protection for the animals, did not provide a visual barrier and appeared to increase levels of stress particularly in 'flighty' animals. In addition, horns were caught and broken in the mesh and hooves and feet were damaged if animals kicked at the mesh, or if the mesh was broken.

There is a caveat here for hot and humid areas where too much solid wall cladding can significantly reduce air flow within the stock crate. The increase in heat load on stock in transit increases the risk of thermal stress. Maintenance of internal airflow is essential to ensure that heat and humidity is dissipated and heat loads are maintained at acceptable levels.

Doors

All doors should be wide enough to discourage animals from jamming as they pass through. Previously, the majority of gates were wide enough for only one or one and a half animals to fit through. Bruising and injuries resulted as animals squeezed in gateways in haste to move from one place to another. In Australia, entry and exit doors on cattle stock crates are now 1 200-1 500 mm wide. Similarly, the doors of internal pens are at least 1 200 mm wide and can be up to 2 000 mm.

Side-loading doors are normally about 1 500 mm wide, made up of two doors, one 900 mm wide and the other 600 mm wide, as shown in Figure 2. This additional width gives better animal control, particularly when interfacing with variations in ramps at farms and public facilities (sale yards and abattoirs).

The result is reduced levels of bruising and stress.

Figure 2
A wide external entry door to a stock crate designed to reduce injury and bruising to cattle

Partitions and penning

Internal partitions in all cattle stock crates run the full width of the vehicle in Australia. In Australia's eastern states, partitions in sheep and pig crates also run the full width of the vehicle. The result is two cattle pens per deck in a 12.2 m-long trailer and four or five pens in sheep and pig trailers. In some parts of Australia, sheep trailers have a central longitudinal division as well, resulting in 8 or 10 pens per deck. There is, however, a trend towards the four or five pen system. The reason is that the more pens there are, the more gates there are. It is well known that every gate has the potential to cause damage to animals.

Pens running the full width of the vehicle are believed to be less stressful on animals as they provide more room for movement, more opportunity to escape from aggressive animals and a better air flow. In addition, full width pens make loading and unloading quicker which helps to reduce stress and allows animals to settle better on trucks during transit and at lairage following transport.

Partitions are an important part of stock crate design and should be incorporated to improve animal welfare. They buffer the effect of mechanical forces on animals when a vehicle has to brake quickly and during travel on hilly, windy or rough roads. Internal partitions and gates to keep cattle in their allotted pens should be fitted with solid sheeting or vertical bars suitably spaced to allow animals to safely extract their legs or other body parts should they get caught. Partitions with horizontal bars are safer for sheep and pigs. Generally speaking, the more pens per trailer, the fewer cattle each trailer can carry. Each additional pen division reduces the carrying capacity by at least one animal.

Deck supports

In the past, multi-deck convertible stock crates were regarded as a major source of bruising in cattle transport because of the presence of multiple deck supports. These vertical steel columns supported the floor and internal penning divisions when the trailer was set up to carry 3 or 4 decks of small animal species.

The presence of these vertical supports within a cattle pen caused bruising when animals were forced against them during the transit, loading and unloading processes. Given a choice, meat processors and producers would not transport cattle in these convertible vehicles which are designed to cater for a variety of species.

The evolution of multi-deck stock crates has seen a reduction in the number of deck supports within trailers from three supports to one support per deck in cattle. In convertible crates, there is now only one, and in 2 × 3 or 2 × 4 convertible cattle to sheep or pig crates there is also one with a temporary support at each gate interface. These single supports have been designed into the structure of the pen divisions to further reduce bruising. The bottom deck of a stock crate with no vertical supports to cause

bruising, plenty of gaps to provide air flow and a three-quarter width internal gate is shown in Figure 3.

Figure 3
View of the bottom deck of a double-deck stock crate showing no vertical deck supports to avoid bruising to cattle, plenty of gaps in the side cladding to give adequate air flow and a three-quarter width internal division gate

The floors of convertible decks have been designed to fold up against the sides of the vehicle when not in use, giving the flat interior surface needed to prevent bruising and damage. All other steel support beams are stored overhead or underneath the trailer.

Through loading

Through loading was developed in Queensland in the late 1970s to reduce the time taken to load and unload cattle on the road trains that are used in remote areas of Australia. Through loading refers to the loading of cattle on the same deck of all trailers of a road train at one time. Stock crates are now designed to allow for through loading (6). Some particular design features are shown in Figures 4 and 5.

At first, through loading was used to load and unload cattle on the top deck using only an internal trailer ramp located either at the front or the rear trailer. The top deck of all trailers in a road train was loaded in one pass and then each bottom deck was loaded separately. This required the road train to move forward several times to load the bottom deck of each trailer at the ramp.

Figure 4
View of a double-deck cattle stock crate with no vertical supports showing a fully opened centre partition that allows through loading of cattle between adjoining trailers on the top and bottom decks

Figure 5
Side view of two adjoining trailers of a road train which are being set up for through loading of cattle

Double-deck loading ramps are now commonly used for cattle in northern Australia and through loading occurs for both decks of all road train trailers. This has decreased the time for loading or unloading cattle on or off

road trains by up to sixty minutes and reduced the impact of stress and bruising.

Suspensions

Suspensions on livestock vehicles have progressed from a set of steel springs per axle to load-sharing springs on axle groupings of two to three axles. Airbag suspensions are also used and may cause less damage to roads and reduce the degree of damage to animals and equipment. However, in the more remote areas of northern Australia where conditions are extremely harsh, steel springs are still in use. Reasons offered are that steel springs are less expensive to install, are easier and cheaper to maintain, and actually give cattle a better ride under rough conditions.

Handling facilities

Ramps

Experience in northern Australia indicates that poor design of loading and unloading ramps can be the single largest contributor to stress in livestock transported over long distances (2). It is now usual in Australia for commercial establishments, such as the larger sale yards, spelling or resting centres and abattoirs, to have well maintained handling facilities. Particular features are double-deck loading ramps capable of handling large through-puts of livestock and curved and sheeted races that make use of the normal following behaviour of cattle. Cattle use these races quite readily.

This situation was facilitated by the introduction of standardised ramp deck heights for loading and unloading ramps throughout Australia in the early 1980s (7). Standard ramp heights are 1 200 mm for the bottom deck of a two-deck cattle crate and 1 720 mm for the top deck of a two-deck cattle crate. This standardisation has assisted the manufacturers of stock crates and trailers to comply with regulatory requirements.

Adoption of change

The adoption of change in the design of vehicles for the transport of livestock has been historically slow in Australia because of the conservative nature of all parties involved. These parties are government, livestock transporters, equipment manufacturers, livestock farmers and meat processors. Changes to stock crate and vehicle design can be adopted at a faster rate and more easily if fewer organisations are involved and a commercial advantage is perceived. Tradition, government regulations and cost appear to be the major barriers to speedy adoption of innovation. Science, government regulation and economics can all be used to increase the rate of adoption.

A recent study within the Australian livestock transport industry showed that the adoption of innovation was driven most strongly by transporters. The main impetus for transporters was animal welfare (with livestock arriving at the destination in better condition), reductions in the transporter's physical workload and the competitive advantage to ensure more repeat business. At the same time, the demands of farmers, consumers and processors, for transporters to operate according to quality assurance programmes is also producing measurable benefits.

Concluding remarks

The livestock transport industry in Australia has shown a preparedness to adopt innovative change that improves animal welfare in transit. It is recognised that good handling and transport practices result in positive outcomes for animals and that these positive outcomes will stand up to scientific scrutiny.

Livestock transporters, in conjunction with livestock producers and meat processors, have agreed to a range of stocking densities for the various classes of stock, based on a minimum floor space area per animal. This ensures that animals are not packed too tightly or too loosely and that they can provide each other with mutual support when the vehicle is moving.

Long distance transport of livestock is a necessity in northern Australia because extensive production areas are a long way from processing plants. Processing plants are

based mainly on or near coastal cities where there are sufficiently large populations to provide a workforce. The consequence is that livestock transporters, producers and processors are all vitally interested in adopting practices that result in good animal welfare outcomes. This is the only option for ensuring the sustainability of livestock production in remote areas.

Experience in northern Australia indicates that the government, community and the livestock industry can work together to produce positive outcomes for animal welfare.

References

1. Lapworth J.W. 1986. Advances in road transportation. *In* New ways to maximise returns from Queensland beef (J.R. Wythes and T.H. Rudder, eds). *Proc Aust Soc Anim Prod*, **16**, 114-115.
2. Lapworth J.W. 1990. Standards for loading and unloading facilities for cattle. *Appl Anim Behav Sci*, **28**, 203-211.
3. Lapworth J.W. 1997. Long distance road transport of slaughter horses in double deck cattle stock crates. PhD thesis. Department of Farm Animal Medicine and Production, The University of Queensland, St Lucia.
4. Lapworth J.W. 1998. Cattle stock crate design for body trucks. Department of Primary Industries and Fisheries, Brisbane (www2.dpi.qld.gov.au/beef/2437.html accessed on 4 February 2008).
5. Lapworth J.W. 2000. Animal welfare: a vital issue for marketing cattle to South-East Asia. Department of Primary Industries and Fisheries, Brisbane (www2.dpi.qld.gov.au/beef/3508.html accessed on 4 February 2008
6. Lapworth J.W. 2000. Cattle transport loading strategies for road transport. Department of Primary Industries and Fisheries, Brisbane (www2.dpi.qld.gov.au/beef/2435.html accessed on 4 February 2008).
7. Lapworth J.W. 2000. Cattle transport minimum design standards for loading ramps. Department of Primary Industries and Fisheries, Brisbane (www2.dpi.qld.gov.au/beef/2430.html accessed on 4 February 2008).
8. Lapworth J.W. & McIver B.D. 1987. Volume loading of livestock for road transportation. *In* Proc. 4th Asian-Australasian Association of Animal Production (AAAP) Animal Science Congress, 1-6 February, Hamilton. AAAP, Hamilton, 191.
9. Lapworth J.W. & Wythes J.R. 1988. Horses can be trucked safely on double decks. *Qld Agric J*, **114**, 365-368.