

Operational Modelling of Livestock Logistics for Simulation based Case Studies

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Abstract: Northern Australia carries about 30 percent of the nation's cattle stock and produces 90 percent of Australia's live cattle exports. The bulk of the cattle are sold from northern breeding regions to southern and south eastern feedlots and fattening properties, where they are further moved onward for live export or to slaughter. Due to the vastness of the region, the northern Australian beef industry's on-shore supply chains have very long transport distances and therefore a substantial transport cost often exceeding A\$150/head (Economic Associates 2010).

This paper presents the operational modelling of the northern beef cattle livestock logistics through real time simulation models. The operational model captures the cattle movements of individual transport vehicles between enterprises, particularly between properties, holding yards, abattoirs, ports and rail/road interfaces. It accommodates various design features of individual ports and holding yards, vehicle and yard capacities, loading/unloading times, queue times, etc.

Two simulation models were developed for case studies. The first case study investigated the beef cattle supply logistics to an abattoir in the Brisbane region, with focus on the cost effectiveness of alternative transport modes, as well as the likely impact on logistic systems if the production capacity is increased. The second case study looked at the livestock cattle export logistics in Townsville Port, focusing on the coordination among different types transport modes (truck, train, and ship) and the utilisation of logistics facilities (holding yards, cattle truck fleet, and loading/unloading facilities). Finally, experimental results on port utilisation in the Townsville Port case study were tabled and discussed to demonstrate the 'what-if' scenario analyses with the simulation models.

Keywords: *livestock logistics, operational modelling, supply chain modelling, transport system simulation*

1. INTRODUCTION

Northern Australia carries about 30 percent of the nation's cattle stock and produces 90 percent of Australia's live cattle exports, with 694,000 head exported in 2011. The bulk of the cattle are sold from northern breeding regions to southern and south eastern feedlots and fattening properties, where they are further moved onward for live export or to slaughter. Due to the vastness of the region, the northern Australian beef industry's on-shore supply chains have very long transport distances and therefore a substantial transport cost often exceeding A\$150/head (Economic Associates 2010).

The paper presents part of our efforts (Higgins et al., 2013) in developing operational models for achieving a better understanding of the logistics system of the northern beef industry, with a focus on the logistics of moving and holding livestock from property gate through to export port or abattoir. More specifically, this paper presents the operational modelling through real time simulation models, which captures the cattle movements of individual transport vehicles between properties, holding yards, abattoirs, ports and rail/road interfaces. It accommodates various design features of individual ports and holding yards, vehicle and yard capacities, loading/unloading times, queue times, etc.

With an operational model, we can develop real-time simulation scenarios to capture and visualise the logistics details, which enables us to conduct case studies on likely impacts of infrastructure or supply chain improvement.

2. METHODOLOGY FOR OPERATIONAL SIMULATION MODELS

2.1. Operational Simulation Models

Simulation models can be developed to capture and visualise the livestock logistics system at different scales and for different purposes. If we intend to present a big picture of the northern Australian livestock logistics, a strategic simulation model would be powerful in accommodating large scale investment decisions on requirements for infrastructure to support transport efficiencies. It would inform policy decisions that impact on the mass flow of cattle across the north of Australia, where geographic information systems (GIS) and statistical methods are excellent techniques. (McFallan et al., 2013).

However, if we need to focus on the operational level of details, such as the time and cost for moving cattle on a specified route by using available vehicles and other facilities at a given time or the likely impact of an investment on a specific road segment or a port facility, then an operational simulation model would be necessary to complement the strategic simulation models. An operational simulation model allows for real-time simulation of movements of individual transport vehicles (trucks and trains) between elements of their supply chains with consideration of uncertainties such as weather and road congestion, as well as queues and delays. An operational model can be used to accommodate design features such as individual ports and holding yards, vehicle and yard capacities, loading/unloading times, queue times, and other site specific management issues, and can provide a capability to analyse smaller scale investments that improve operational efficiency, and help maximise operational efficiencies of existing and new infrastructure investments.

2.2. Elements of an Operational Model for Simulating Livestock Logistics

The livestock logistics system model consists of three groups of elements or entities: the cattle yards, the cattle transport vehicles, and the transport routes. Here the cattle yards represent various places for accommodating cattle, such as cattle properties, holding yards, sale yards, spelling yards, ports, and abattoirs. The cattle transport vehicles and routes represent various transport modes, such as cattle trucks and roads, cattle trains and rail lines, as well as livestock ships and designated sea routes.

2.3. Cattle Yards and Cattle Movements

The cattle yards are places where cattle livestock are held. These places usually have their unique PICs (Property Identification Code) registered within the National Livestock Identification System (NLIS), which captures all cattle movements among these places.

Due to the large number of cattle properties distributed in the vast area of northern Australia, it is neither practical nor necessary to model every cattle property in the operational model. To simplify the model, we developed the concept of a virtual cattle yard that was used to aggregate the actual cattle properties in nearby

areas. In reality, these virtual cattle yards often correspond to the aggregation yards or pickup points where the large capacity cattle trucks or trains can load them in bulk for the more costly long journeys.

By analysing the NLIS cattle movement datasets, we identified a number of such virtual cattle yards. They are usually the major town centres or major road junctions. In Queensland, about 30 virtual cattle yards were identified, and they were further used to aggregate the NLIS data, and derive annual cattle movement data among these virtual cattle yards. This derived NLIS dataset was then used in our case studies, such as the Dinmore Abattoir case study to be discussed later.

While the virtual cattle yards have their capacities, they were not used as constraints in our simulations. These cattle yards provided cattle loading and unloading facilities. We assume that all trucks would queue for accessing the load/unload facilities at any time. Certain cattle yards may impose restrictions on accessing times (eg. abattoirs) and may also impose penalties for exceeding the allocated loading/unloading time slots (such as the demurrage charges in ports).

2.4. Cattle Trucks and Roads

Cattle trucks are the major vehicles for transporting livestock in northern Australia. The capacity of each cattle truck is determined by its number of decks and the weight of cattle. For the expert sized cattle, a deck can accommodate up to 28 cattle. There are mainly four different sized trucks on Northern Australian roads: A semi-trailer (ST) can accommodate 2 decks of cattle, a B-Double (BD) can accommodate 3 decks, while the Type 1 (T1) and Type 2 (T2) road trains can move 4 and 6 decks of cattle respectively.

Northern Australia has a road network consisting of various classes of roads. The classes and conditions of these roads have effects on the average speed and cost. There are also restrictions on certain segments of road to limit access of heavy vehicles such as the Type 1 and Type 2 road trains. These restrictions are common in the east coast area, where a road train from the west would need to have a stopover and break its large truck down to smaller ones. A company transporting a Type 2 combination will usually drop the trailers off at these locations, and these trailers would be transported to the destination in semi-trailer configuration by either itself or another company.

Breaking down to smaller vehicles not only incurs a higher cost per head but also incur an additional cost for the double handling and may cause cattle distress. Often the existing locations for vehicle breakdown (e.g. Clermont) will also require detours for big road trains to reach these points.

2.5. Cattle Trains and Rail Roads

While cattle trucks are flexible and a mainstream transport mode, the cattle trains are seen to be more cost effective and less distressful for bulk cattle transport. Unfortunately, due to the competing demand for rail transport capacity from the mining industry, cattle trains are increasingly becoming unsustainable without government subsidies (Gleeson, Martin and Misfud, 2012).

Cattle trains are currently operating on several rail lines in Queensland. The annual cattle train services are pre-scheduled, and clients can book the services in advance. However, if the booking for a train service is less than 80% of its capacity, the train operator would cancel that service. Consequently the cattle would need to be transported by trucks or a later train service.

3. SIMULATION MODELLING AND CASE STUDIES

With the modelling elements discussed above, we constructed two operational models for case studies based on the scenarios identified by stakeholder groups related to the northern beef industry - state and federal government departments, livestock associations, transport providers, major feedlots and abattoir enterprises. The first case study looked at the livestock logistics for the Dinmore Abattoir, and the second case study investigated the livestock export through the Townsville Port.

The operational simulation models are developed using an advanced modelling and simulation tool called AnyLogic (www.anylogic.com). This tool can generate a stand-alone simulation tools to execute the operation model, therefore enable the “free” distribution of the simulation tool to the stakeholders.

3.1. Dinmore Abattoir Livestock Logistics Simulation Model

The aim of this operation model was to achieve a better understanding of the current state of operation in the cattle supply logistic system for an abattoir in Dinmore Queensland, which would enable the identification of opportunities for improvements and likely impact of increasing production capacity. For example, we

investigated the impacts if the industry grew by 30%. An increased supply to the abattoir would reduce slaughter costs per head and subsequently increase prices paid, which would make it more financially viable for cattle that would otherwise not be sent to Dinmore.

Some essential background information about the current practices of cattle logistics to the Dinmore Abattoir was collected through interviews and email communications with stakeholders, which enabled us to identify potential focal areas for research. It was identified that the major issue is about the best use of road versus rail across Queensland.

The operation model was developed based on the NLIS cattle movement datasets. We extracted all the cattle movements recorded with the Dinmore Abattoir as the destination PIC (Property Identification Code). The sources of cattle to Dinmore were then aggregated to around 30 major “pickup” locations (the virtual cattle yards), from where the cattle are transported to Dinmore by trucks or trains (illustrated as green circles in the simulation model as shown in Figure 1).

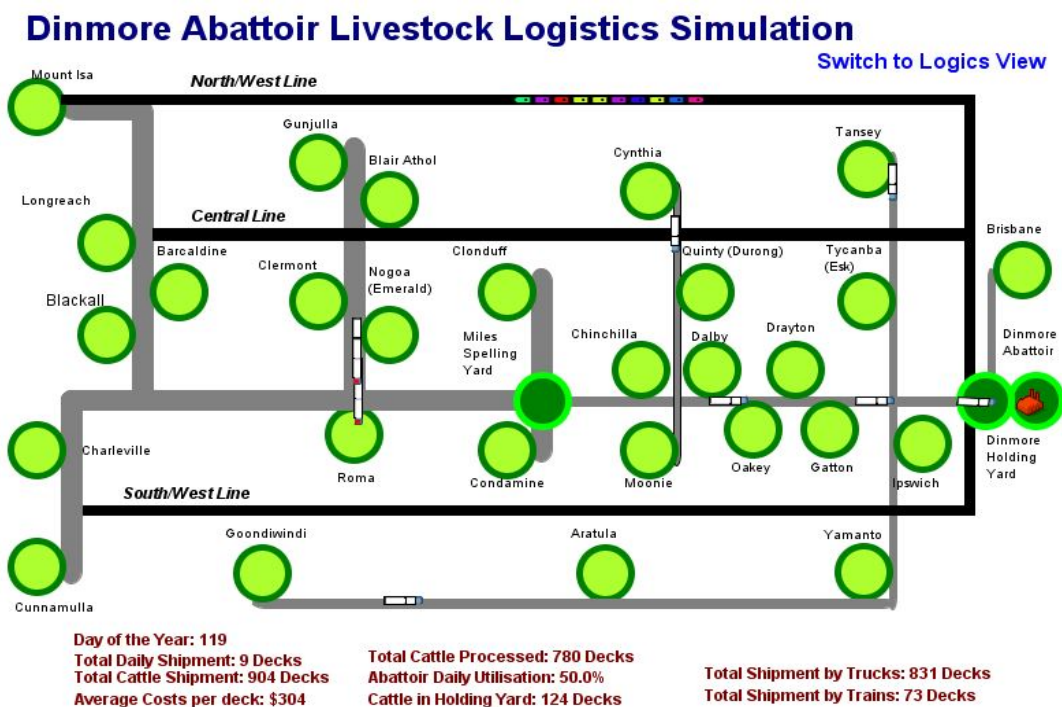


Figure 1. A Snapshot of Dinmore simulation model

In addition to road transport, there are three rail lines used to transport cattle to Dinmore Abattoir. These are the North/West Line, the Central Line, and the South/West Line. The rail lines provide scheduled services to Dinmore.

To demonstrate our understanding of the current practices of the Dinmore Abattoir supply chain, a base case operational model was constructed, as shown in Figure 1. The thick grey lines indicate the segments of road network that permit the heavy Type 1 and Type 2 road trains; while the thin grey lines indicate the road where only the smaller B-Double and semi-trailer trucks are permitted. There is a breakdown spelling yard in the junction of the two segments, where the trailers of the Type 1 and Type 2 road trains were detached, and handed over to another company to run smaller ST trucks in the rest of the trip.

The operation model was driven by the cattle sales orders as derived from NLIS movement datasets. The order for each aggregation locations would be transported by the most cost effective truck combinations and with full load. The unfulfilled orders (not enough for a full load) were added to the next day until they filled the truck load.

In order to identify potential improvements to the cattle supply chain, we recorded the daily shipment by train and trucks and calculated the average costs per deck for transporting cattle to the abattoir. We also recorded the number of cattle being processed in the abattoir, and calculated the utilisation of its holding yard and processing plant. Uncertainties such as delays were modelled using a simple Triangular Distribution method.

Several scenarios of operations were developed and tested. These include the use of different type of cattle trucks (eg. Use of Type 1 road train and then breakdown to semi-trailer, or use of B-Double all the way), and transport modes (eg trucks only, or trucks and trains). We also used a proportionally augmented movement dataset to simulate the increased order size corresponding to the increased production capability. The utilisation rates of processing facilities were then assessed through these simulated scenarios.

The resulting simulation models were demonstrated to stakeholders. They served as a thought provoking medium to encourage the identification issues in current operations and assessing potential improvements in the new operations. It has also demonstrated its potential in such a simulation model in supporting the participatory decision making process related to major investment and policy decisions.

3.2. Townsville Livestock Export Simulation Model

One of the challenges in the current live export planning is the short time frame between export permits and ship arrival. This challenge is further complicated with the access to the Townsville Port when a large cattle ship needs to be loaded in a short time frame or a heavy demurrage penalty would apply.

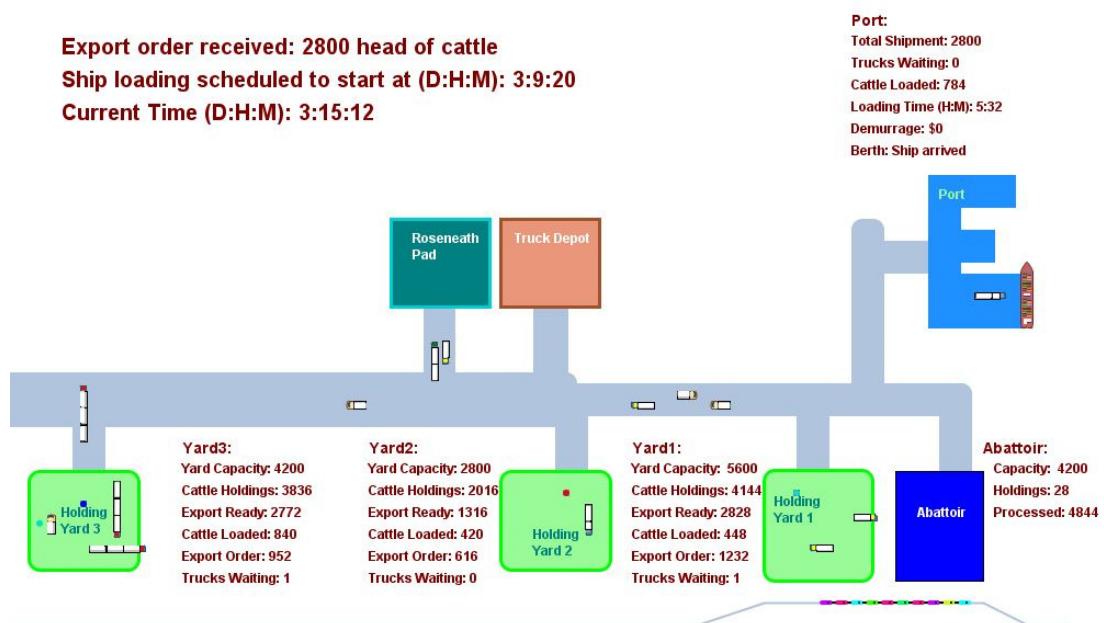


Figure 2, A snapshot of the Townsville Livestock Export Scenario

As shown in Figure 2, the simulation model captured the essence of the cattle livestock export oriented business facilities. This model included three holding yards, a cattle truck fleet with various sized combination of cattle trucks, and a truck breakdown pad. There was also an abattoir with the processing capacity of 800 cattle per day. The cattle trains have unloading facilities in Holding Yard 1 (Y1, about 15km away from the port). The Yard 2 (Y2) and Yard 3 (Y3) are 45km and 145km away from the port respectively.

The simulation model used a demand driven approach to source cattle according to the export order sizes. When an export order was received, the export holding yards would have a couple of days to procure and process the cattle for export. The transporter would utilise almost all of its fleet to move and load the cattle to the ship as soon as possible when the ship was docked.

The road network to the Townsville Port consists of two segments: the west segments which permit heavy Type 1 and Type 2 road trains, and the eastern segments which only permit smaller B-Double and semi-trailer cattle trucks. A spelling pad is located in the junction (about 40km from the port) of the two segments of road where the Type 1 and Type 2 cattle trucks are broken down into semi-trailers. They would need to make 2 or 3 round trips between the breakdown pad and the port to complete their delivery. The number and combination types of the cattle truck fleet are not fixed and could be reconfigured. It was assumed that all trucks would be made available when an order arrived as long as those available trucks were permitted to operate in that route.

In the Holding Yards, cattle were procured when an order was received. When cattle arrived, they were rested and undergo veterinary checks before trucks transported them to the port for live export. The time and costs for these activities were calculated using a Triangular Distribution to capture expected variations.

On the road, the speed of a truck may be affected by many factors such as the traffic conditions and weather conditions. The variations of its travelling time were also simulated using Triangular Distributions.

3.3. A Case Study with Townsville Livestock Export Simulation Model

With the simulation model, we can explore a number of scenarios to assess where might be causes of delays and how to improve port efficiency by increasing the fleet sizes (measured by the number of decks of cattle trailers) of or changing fleet combinations (eg. as semi-trailer with 2 decks or as Type 1 with 4 decks), as well as the likely impacts of increasing the capacities of the holding yards, or building a new holding yard closer to the port.

We conducted several “what-if” experiments to investigate the likely factors that may affect the port utilisation. Figure 3 shows the simulation outcomes from the experiments on three of the likely factors: the fleet sizes, the fleet combinations, and the distribution of cattle sources in holding yards.

A 100% port utilisation can be defined as an optimal situation where cattle trucks came one after another, and could unload cattle to the ship continuously without interruptions. With a double deck loading ramp, a semi-trailer can unload two decks of cattle in about 6 minutes, or 20 decks in an hour. However, due to delays in trucks arriving, the actual unloading would take much longer than the optimal situation. Therefore, the port utilisation could be derived by the ratio of the optimal unloading time to the actual lapsed unloading time. Usually, it would be acceptable if a typical shipload of 2500 heads (about 90 decks) could be fully loaded within 12 hours, which requires an utilisation rate at about 30% to 40%. Due to the heavy demurrage, it is worthwhile to investigate the likely factors that may affect the port utilisation.

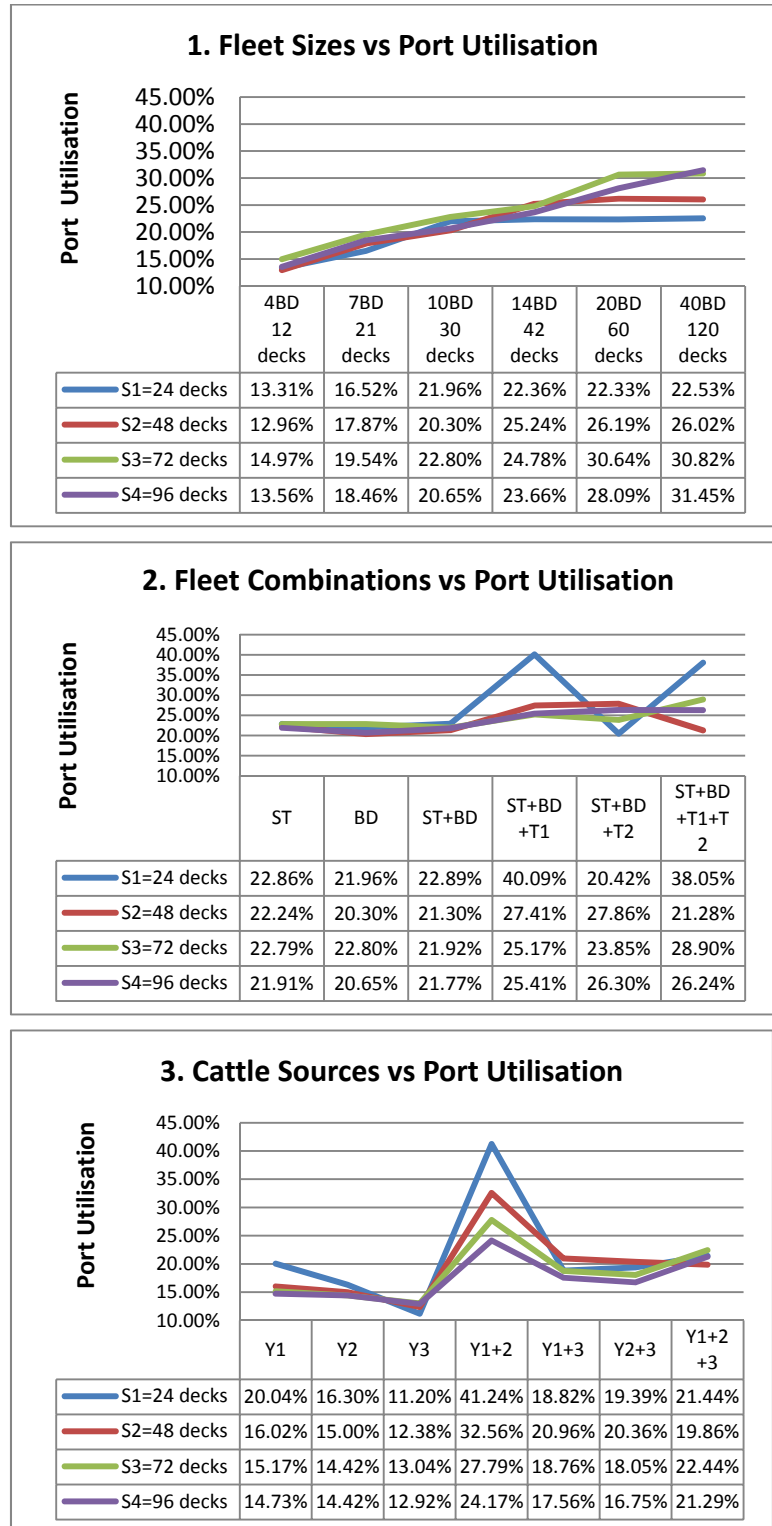


Figure 3. Experiment results from port utilisation case study

Chart 1 of Figure 3 shows the port utilisation rate for different fleet sizes and shipment sizes. It indicates that when the fleet capacity is less than the shipment size, the increase of fleet size would also increase the port utilisation rate. However, it stops increasing when its fleet capacity exceeded the shipment size. This seems to be understandable as the trucks would be used for one trip only; therefore excess of the fleet size has no more impact on the port utilisation. The diagram shows the fleet with a single combination of BD (B-Double) cattle trucks.

Chart 2 of Figure 3 further illustrates the port utilisation rate for different fleet combinations and different shipment sizes. It shows that the fleet combination does not significantly affect the port utilisation; although we could observe that introduction of heavy trucks (Type 1 & Type 2 road trains) might increase the port utilisation if the combination is suitable for the shipment size.

Chart 3 of Figure 3 shows a clear indication that if the cattle were sourced from the two holding yards (Y1+Y2) closer to the port, it could reach the highest port utilisation. This indicates the distance between the holding yards and the port plays a significant role in the port utilisation. However, if the cattle are sources solely from a single yard (Y1 or Y2), it didn't increase the port utilisation even it is close to the port. This hints that the loading efficiency at each holding yards may have also constrained the port utilisation.

4. DISCUSSION

This paper presented the operational modelling of the northern Australian livestock logistics system through simulation based case studies. The animated real time simulation model has demonstrated its advantages in visualising collective understandings of the current and future situations. The “as-is” simulation models in two case studies both reflected the well understood business practices and some rules of thumb. However, the simulation models, especially the “to-be” models have revealed many interesting findings – some seemed to be obvious, but some were not. For example, utilising an additional set of loading ramp would double the loading speed, but in fact it had little effect on increasing the port utilisation rate.

Quantitative assessment and sensitivity analysis of different alternative scenarios were carried out. In addition to the cost and benefits analyses, further incorporation of social and environmental concerns, such as animal welfare, spreading of animal diseases (eg cattle ticks), and pollutions produced by the vehicles and by the animals in different transport mode and route, into the assessment of livestock logistics system is seen to be an important step forward to ensure the sustainability of the livestock logistics industry.

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