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Optimal location of spelling yards for the northern Australian beef supply chain

Rodolfo García-Flores [a,*], Andrew Higgins [b,1], Di Prestwidge [b,2], Stephen McFallan [b,3]

[a] CSIRO Computational Informatics, Private Bag 33, Clayton South, Victoria 3168, Australia
[b] CSIRO Ecosystem Sciences, GPO Box 2583, Brisbane, Queensland 4001, Australia

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ABSTRACT

The northern Australia cattle industry is currently facing important challenges, which include increasing demand, a strong reliance on live exports, and a changing climate. This paper presents a strategic optimisation model to help the stakeholders determine the optimal location of cattle rest sites (known as spelling yards) and the optimal flows from breeding farms to ports, abattoirs and saleyards, subject to budget, site capacities and service requirements. The model also considers the operational guidelines that regulate maximum driving hours and water deprivation times. Our contribution is twofold: the model not only recommends spelling yard sites and shows that an additional abattoir can increase the value of the supply chain by over $715 M, but also represents an important step towards rationalising this supply chain's future operations by compiling a body of data that was previously unavailable for research and analysis.

1. Introduction

Cattle and beef production is an industry of paramount economic importance to Australia, with great opportunities for expansion. Australian live cattle exports were worth $660 million (all amounts in Australian dollars, unless otherwise indicated) in 2010–2011 and were sent predominantly to Indonesia (57%), Turkey (13%) and Israel (7%). During the same period, Australia exported 937,301 tonnes of beef and veal in 2010–2011, worth $4.5 billion, mostly to Japan (37%), the United States (17%) and Korea (15%) (Department of Employment, Economic Development and Innovation, 2010). In total, cattle and beef production currently account for 17% of Australia's $32.5 billion agricultural industry.

There is evidence of a shift in the global market for beef consumption, with demand stagnating in traditional northern hemisphere markets and growing rapidly in parts of Asia and the Middle East (Kearney, 2012; Gleeson et al., 2012). This can already be seen in recent changes in Australian beef and veal exports, which have increased from $400 million in the financial year 2009–2010, to $600 million in 2010–2011. Cattle processing is expected to rise 13% to a capacity of 9.5 million head, whereas production is projected to reach 2.4 million tonnes by 2015. Assuming continued export to foreign markets and average seasonal conditions, the Australian cattle herd is expected to increase to 29.7 million head by 2015, 11.9% higher than in 2010.

In addition to increasing demand, the industry faces challenges like the imposition of weight restrictions on livestock exported to Indonesia and the suspension of trade following examples of poor animal welfare in Indonesian abattoirs in June 2012. There have also been reductions in import quotas in that country for both live cattle and boxed beef. Investigation of substitutes to the Indonesian market is a clear priority for the northern beef industry, but in the short term, the domestic market could offer alternatives. In any case, investments should only proceed after careful examination of the potential of the existing supply chain (e.g., Strategic Design and Development, Meateng Pty Ltd, 2010; Department of agriculture, Fisheries and Forestry, 2012).

The logistics of cattle production in the north of Australia is fundamentally different to the more intensive industry of the south. The north is an environment characterised by long distances to market, low herd density, large-scale enterprises on pastoral lease, and significant annual climatic disruptions. Data is not as readily available due to privacy issues, the presence of thousands of privately owned properties, a vast network of roads under the control of multiple authorities, and the numerous government agencies who own relevant data (e.g. bio-security data). The model

* Corresponding author. Tel.: +61 3 9545 8059.
E-mail addresses: Rodolfo.Garcia-Flores@csiro.au (R. García-Flores), Andrew Higgins@csiro.au (A. Higgins), Di.Prestwidge@csiro.au (D. Prestwidge), Stephen.McFallan@csiro.au (S. McFallan).
[1] Tel.: +61 7 3833 5738.
[2] Tel.: +61 7 3833 5724.
[3] Tel.: +61 7 3833 5722.

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Nomenclature

N	the set of all nodes, $N = \{S \cup R \cup P \cup E \cup A\}$
B	the set of breeds
C	the set of road types (primary, secondary, other)
K	the set of commodities, or cattle states (dipped or undipped)
G	the set of cattle age categories, in months
E	the set of export depots
S	the set of breeding properties
P	the set of fattening properties, $P = \{F \cup L\}$
R	the set of transshipment points, $R = \{H \cup D\}$
S^N	the set of breeding properties located north of the tick line
P^N	the set of fattening properties located north of the tick line
S^S	the set of breeding properties located south of the tick line
P^S	the set of fattening properties located south of the tick line
L	the set of feedlots
F	the set of agistment farms
A	the set of terminal nodes, $A = \{X \cup V \cup W\}$
X	the set of ports for live export
V	the set of saleyards
W	the set of abattoirs
H	the set of junctions $H \in R$
D	the set of potential driver rest areas, $D \subset R$
Y	the set of potential spelling yards, $Y \subset D$
T	the set of all periods
L^{SP}	the set of valid links from properties to (possibly junctions) to fattening farms
L^{PA}	the set of valid links from farms to terminal nodes (abattoirs, ports and saleyards). The positions of terminal nodes are fixed
M_i^{SP}	the set of all candidate locations that can cover demand point i within the maximum driving hours
M_i^{PA}	the set of all candidate locations that can cover demand point i within the maximum driving hours
M_i	the set of all candidate locations that can cover demand point i within the maximum water deprivation time

Decision variable

y_{bgijkt}	the flow of breed $b \in B$ of age $g \in G$ from $i \in \{S \cup D\}$ to $j \in \{D \cup F\}$ in state $k \in K$ at period $t \in T$ in truckloads
δ_i^O	indicator variable, takes value one if there is flow entering node $i \in N$ during the whole time horizon, zero otherwise
δ_i^I	indicator variable, takes value one if there is flow exiting node $i \in N$ during the whole time horizon, zero otherwise
x_j	indicator variable, takes value one if j is in a resting place $j \in P \cup R$, zero otherwise
q_{bgit}	inventory of breed $b \in B$ of age $g \in G$ in farm $i \in F$ at time $t \in T$ in truckloads
z_i^{SP}	indicator variable, takes value one if demand at node $i \in S$ is covered for the whole time horizon, zero otherwise
z_i^{PA}	indicator variable, takes value one if demand at node $i \in A$ is covered for the whole time horizon, zero otherwise

Parameters

a_{ijt}	availability of road segment from i to j at time period $t \in T$
BUD	budget available for construction of spelling yards
p_{bgikt}	production of cattle of breed $b \in B$ of age g in property $i \in \{S \cup P\}$ at time $t \in T$; different to zero only if $g = 1$ month
θ_{ij}	driving time (in the shortest path) between sites i and j
AK_{it}	capacity of terminal node $i \in A$
TTL	total truckloads in the network
AI_{bgit}	income per truckload of cattle breed $b \in B$ of age $g \in G$ at terminal node $i \in A$ in period $t \in T$
OC_i	the cost of building a rest site at i
DC_i	the cost of dipping a truckload of cattle on export depot $i \in E$
RK_i	the total storage capacity of rest site $i \in \{R \cup P\}$
PK_i	the total storage capacity of breeding property $i \in P$
τ_b^F	agistment period for breed $b \in B$ in agistment farms
τ_b^L	agistment period for breed $b \in B$ in feedlots
Θ^Y	maximum water deprivation time in hours
Θ^D	maximum driving time in hours
TC_{ij}	transportation cost from site i to j in AUD km^{-1} truckload^{-1}
h_i^{SP}	profit from satisfying truckload demand of site $i \in \{S \cup P\}$ in AUD
h_i^{PA}	profit from satisfying truckload demand of site $i \in \{P \cup A\}$ in AUD
AC_{it}	agistment cost in $i \in P$ in AUD truckload^{-1}

introduced in the present paper is part of a broader study of live cattle export supply chains (see Higgins et al., 2013). It addresses the problems of selecting the optimal location of rest sites (i.e., facilities that can act as spelling yards or driver rest areas) and assesses the effects on the supply chain of building a new abattoir in the Kimberley (in addition to an existing one in Darwin), while considering all the above-described particularities.

1.1. The northern Australian beef supply chain

Fig. 1 shows a schematic of the supply chain. Breeding properties typically produce weaner calves to about the age of eight months, when their weight is approximately 330 kg. These cattle can then be sold to live export for finishing in other countries. Cattle born in northern Australia that are not sent to export are often transported long distances to east coast and southern abattoirs, sometimes travelling more than 2500 km. Many breeding properties do not have enough forage to produce cattle to slaughter weight. Such cattle are transported to finishing properties where they are grass fed, or to a more intensive confined feeding system (or feedlot) where they are grain fed. During transportation, and depending on the distances, truck drivers may need to stop in spelling yards, where animals are unloaded, fed and watered, and after a few hours of rest they are loaded back onto the trucks to continue their journey. Sometimes it is only the driver that needs a rest, but driver rest areas are easier to set up and much less expensive than spelling yards. Cattle spend a minimum of 100 days in feedlots until they reach a suitable weight for sale. In saleyards, cattle of multiple classes are sold by auction, which includes sales for abattoirs, breeding and for further finishing. Abattoirs transform the finished cattle into frozen or chilled meat products. Abattoirs vary significantly in terms of throughput, with capacities of up to 3300 head per day. Once processed, meat is either transported in refrigerated containers to terminals or to domestic wholesale.