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Cost of transport infrastructure and regulatory constraints in Australian cattle supply chains

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Executive summary

Transport infrastructure is essential to moving about 20 million head of cattle through Australian supply chains each year. The livestock industry, particularly in the north, is characterised by long supply chains that link properties, feedlots, abattoirs, live export and markets. Distance between production, processing and markets often exceeds 1,000 km, with costs of transport exceeding $150/head. Industry and all levels of government are seeking to reduce livestock transport using a range of approaches (e.g. road upgrades, increased use of rail, new abattoirs, and changes to policy in tick clearing, driver fatigue and animal welfare).

Here we describe the construction and use of a tool designed to evaluate and prioritise approaches being developed by industry and governments to most cost-effectively improve cattle value chains across Australia. We extended CSIRO's Transport Network Strategic Investment Tool (TraNSIT), previously deployed by government and industry to optimise northern Australia's livestock supply chains, so that it includes all of Australia. It is now possible to optimise individual transport routes using the entire national road/rail network and to calculate the cumulative impacts at both enterprise and regional scale.

We achieved this by using Property Identification Code (PIC) information from each state to represent the locations of 210,000 registered properties, feedlots, saleyards, abattoirs and export yards. This was consolidated into 47,000 representative enterprises, without loss of resolution, by merging some nearby properties and saleyards. Representation of vehicle movements between these enterprises in northern Australia previously relied on direct use of NLIS data. For the new version of TraNSIT, a flexible method for creating cattle vehicle movements was used. This allows an extremely wide range of 'what if' scenarios to be examined, either with or without significant reference to existing supply chain configuration.

A baseline analysis of livestock transport across Australia was created by TraNSIT to resemble the number of vehicles along each road segment given an average year from 2008 to 2013. It was created by mapping the path of about 60,000 origin-to-destination movements representing 20 million cattle transported in Australia per year. It showed that:

- The largest vehicle counts are those along major corridors towards large abattoirs, feedlots and saleyards along the east and southern coast.
- Large vehicle counts are evident on road segments of the Stuart Highway between export depots and Darwin port.
- There are a large number of vehicle trips between Queensland and NSW for cattle transported to abattoirs and feedlots.
- The cost of transporting cattle nationally was about $262 million; this includes the cost of travel, breakdown into smaller vehicle configurations and driver rests.
- The cost of moving empty trailers during return trips added about $228 million.

A further goal of this project was to apply TraNSIT to evaluate a range of priority value chain improvement scenarios. These scenarios were identified at an MLA-hosted workshop in Brisbane (August 2014), and a summary of the transport cost savings for each is below. The scenarios examined here illustrate transport cost savings possible a small subset of all possible scenarios across Queensland. Future work will examine the savings possible for a more comprehensive range of scenarios throughout northern Australia, with further extensions to all Australia.

- Bridge upgrades Theodore to Eidsvold, allow B-Double access – saving $94,671 per year or $1.41 per head
- Toowoomba bypass - saving $140,000 per year or $0.18 per head
- Biloela to Gladstone – Type 1 vehicle access – saving $87,858 per year or $0.92 per head

- Type 2 vehicle access between Rolleston and Miles - via Taroom - saving $1.7 million per year or $1.14 per head
- Type 2 vehicle access between Rolleston and Miles - via Roma – saving $2.7 million per year or $0.93 per head, with additional savings of $17,000 per year by removing tick clearing requirements
- Type 2 Bypass road to abattoir Townsville – saving up to $270,379 per year or $1.92 per head
- Type 1 Road from Roundabout near Rockhampton – saving $738,919 per year or $1.63 per head
- Type 2 vehicle access around Roma from outskirts to the saleyards - saving $1.5 million per year or $0.64 per head
- Type 2 vehicle access between Clermont and Rockhampton – saving $1.7 million per year or $1.38 per head
- Type 2 vehicle access from Roma to Toowoomba – saving $4.9 million per year or $1.24 per head
- Type 2 vehicle access from Alpha to Rockhampton – savings $1.8 million per year or $1.38 per head

A key finding for many of these scenarios was that the transport efficiency improvements across the broader network comprised a large component (up to about 70%) of the total costs savings. It allowed a larger number of vehicle trips to optimally run as a larger configuration (e.g. Type 2) for the entire journey, including the roads segment that received the infrastructure investment or policy change. The current analyses only considers transport cost savings and needs to be extended to accommodate the costs of infrastructure upgrades, risks associated with greater access of heavier vehicles on some roads and broader economic implications. The above scenarios allowing higher combination vehicles on some roads will require infrastructure upgrades of some form, such as bridges, culverts and intersections.

The project also examined methods for improving the utility of TraNSIT. While the use of data with greater resolution than the PIC data provided by the states would increase TraNSIT's capacity to analyse small enterprises, the impact on national scale value chain optimisation would be marginal. Greater benefit may be achieved by improving the geographical representation of property to property movements, affected using the average number of cattle moved between shires.

This project extended the application of TraNSIT from northern Australia to the whole of Australia. It is now possible to optimise individual transport routes using the entire national road/rail network and to calculate the cumulative impacts at both enterprise and regional scale.

The next generation of TraNSIT is currently being developed by CSIRO to include transport of >20 other agriculture commodities including grains, dairy, sheep, pigs, sugar, horticulture and broad acre crops. This will give a broader perspective of heavy vehicle freight flows across the road/rail network for agriculture and increase the value of investment in transport and related agricultural infrastructure.

1 Introduction

In Australia's cattle industry, transport infrastructure is essential to moving about 20 million head of cattle through the supply chains in Australia each year. The industry, particularly in the north, is characterised by long supply chains between properties, feedlots, abattoirs, live export ports and markets. Distance between production, processing and markets often exceeds 1,000 km, with costs of transport exceeding $150/head and the distance to final export customers often exceeding 5,000 km. Despite the longevity, scale and importance of the cattle industry in Australia, the supply chains are usually characterised by high costs, seasonal utilisation, and significant vulnerability to market and weather-related shocks.

To provide a holistic view of the costs and benefits associated with infrastructure investments and policy changes in agriculture supply chains, CSIRO developed a TRAnsport Network Strategic Investment Tool (TraNSIT). The tool, which was initially co-funded in 2012/2013 by the Office of Northern Australia, Northern Territory Government, Western Australia Government and Queensland Government, was built to assess the cattle supply chains in northern Australia. Although initially developed for cattle supply chains, TraNSIT can be adapted to any commodity supply chain.

To provide a holistic view of the costs and benefits infrastructure investments and policy changes in agriculture supply chains, CSIRO developed a Transport Network Strategic Investment Tool (TraNSIT). The tool, which was initially co-funded by the Office of Northern Australia, Northern Territory Government, Western Australia Government and Queensland Government in 2012/2013, was built for the livestock supply chains in northern Australia. It provides stakeholders with advice on both small- and large-scale investments in the agriculture supply chain, and the benefits to all enterprises, including:

- Analysing the impact of road upgrades (such as sealing or improving for higher combination vehicles), where the financial benefits to individual agricultural enterprises and to the industry as a whole are quantified;
- Optimising the use of road versus rail transport and their integration, at different locations;
- Optimally locating new supply chain infrastructure facilities (e.g. abattoirs and spelling yards);
- Testing potential outcomes for changes in policy, e.g. alignment of driver and animal welfare stops, changing vehicle limitations for road classes, removal of tick-clearing regulations for cattle transported directly to abattoirs;
- Selecting infrastructure investment and regulatory change opportunities that maximise transport cost reductions for a given investment budget.

TraNSIT was developed for evaluating and optimising capital investments and operations in livestock logistics (Higgins et al 2015; Higgins et al 2013; McFallan et al 2013). It combined information on livestock supply chains with information on the road network, heavy vehicle access and regulatory constraints covering driver fatigue and livestock biosecurity protocols. TraNSIT performs a mass optimal routing of vehicle movements between the thousands of enterprises in the livestock industry, and scales up to provide industry or locality wide logistics costs. This provides the ability to test logistics opportunities that benefit thousands of livestock enterprises. Its application to northern Australia's (Queensland, NT, northern WA) herd of 12 million cattle, across 52,000 registered properties, accommodated the movement of over 50 million cattle between enterprises (2007 to 2011) and 88,000 unique origin to destination enterprises. A major limitation to the initial focus on northern Australia was that supply chains between northern and southern Australia were not accommodated. This includes situations such as: transport of cattle from NT and Pilbara to abattoirs near Perth; cattle transported from southern states to south east Queensland abattoirs; and movement of cattle between the north and south to manage herds in the event of droughts.

The primary goal of this project was to extend TraNSIT to the livestock industry across all of Australia and evaluate additional priority infrastructure and regulatory scenarios. Specific outputs were:

1) Extending livestock movement parameter set for TraNSIT to all of Australia: That includes produce a national map of livestock transport movements for use in infrastructure planning and prioritisation and modelling regulatory changes and effect of transport reforms.
2) Develop a baseline analysis. Apply TraNSIT to conduct a baseline analysis for cattle logistics across all supply chains. The baseline analysis will inform Government planning and industry policy on infrastructure and transport regulation.
3) Develop case studies. Use combined industry and government knowledge to develop detailed cattle logistics case studies for further investigation with TraNSIT. Case studies were identified via workshops in both northern (completed) and southern Australia. The case studies were evaluated within this project in light of the workshop in northern Australia.
4) Produce a final report: that provides an economic assessment of known transport infrastructure and regulatory bottlenecks across the Australian cattle industry and identify potential investment opportunities that best addresses the transport logistics challenges in the industry.
5) Further refine TraNSIT to include additional data sets to improve accuracy and resilience, and presentation at industry workshop.

1.1 Scope

The project focused on the logistics of moving and holding animals between enterprises of the livestock supply chain, from property gate though to export port or abattoir. This includes movements of cattle into finishing properties, backgrounding, feedlots, saleyards, holding yards, and the port. Modelling the livestock logistics between enterprises of Figure 1 presented several challenges. Quality data was essential and is a complex task due to the presence of thousands of privately owned properties with PICs managed by each state, a vast network of roads under the control of multiple authorities, along with the numerous government agencies who manage data related to the supply chain network (e.g. main roads, bio-security) that is needed to set up a model.

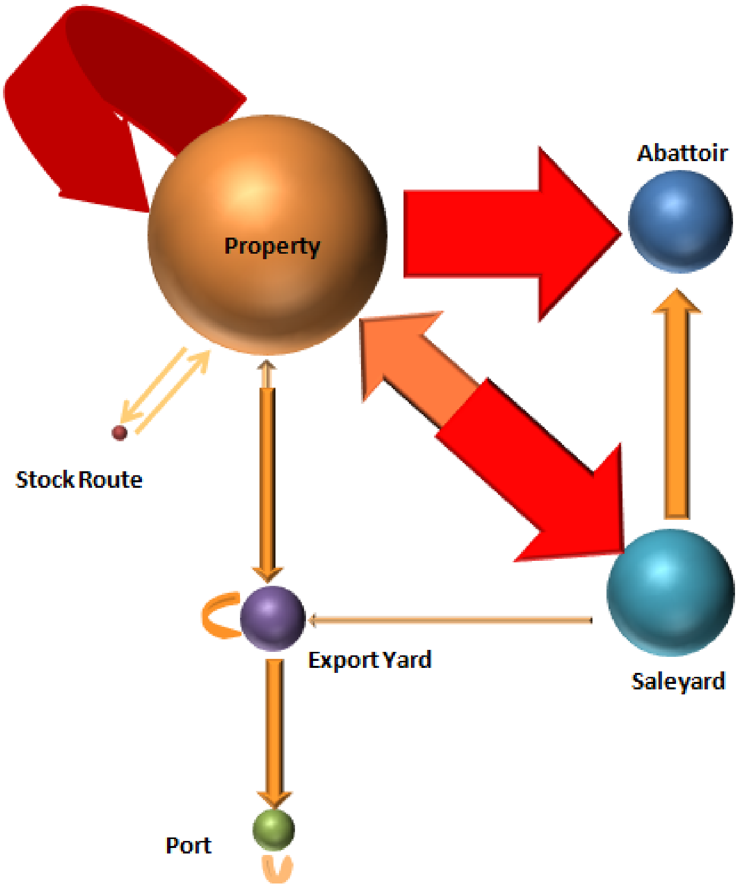

Figure 1 Supply chains of cattle moved between each type of enterprise for the Australian beef industry. The thicker the arrow, the more cattle moved between those supply chain segments.

2 Overview of TraNSIT

TraNSIT is a modularised tool (Figure 2) where the livestock industry is an input to the core engine. TraNSIT was constructed in the ESRI ArcGIS platform due to its vehicle routing capability whilst accommodating multiple features about the road network and individual segments. For the TraNSIT module, the road network data was critical for the model and primary, secondary and minor (including unsealed) roads were included. These road conditions affect average speed and transport cost per km. An additional feature included is the road access restrictions for B-Doubles, Type 1 and Type 2 vehicles (Figure 3). The main restrictions are in moving cattle to east coast abattoirs and ports, as these are limited to B-double access. Not only is there a higher cost per tonne (Table 1) for transporting in smaller vehicle combinations, there is an additional cost for breaking larger vehicles (e.g. Type 2) into smaller configurations (B-Double). Another restriction is the requirement of tick clearing when transporting cattle from a tick infested location to a tick free location. Drivers will often avoid travelling into the tick free zones (where possible) even if/when it involves a significant detour and a higher transport cost.

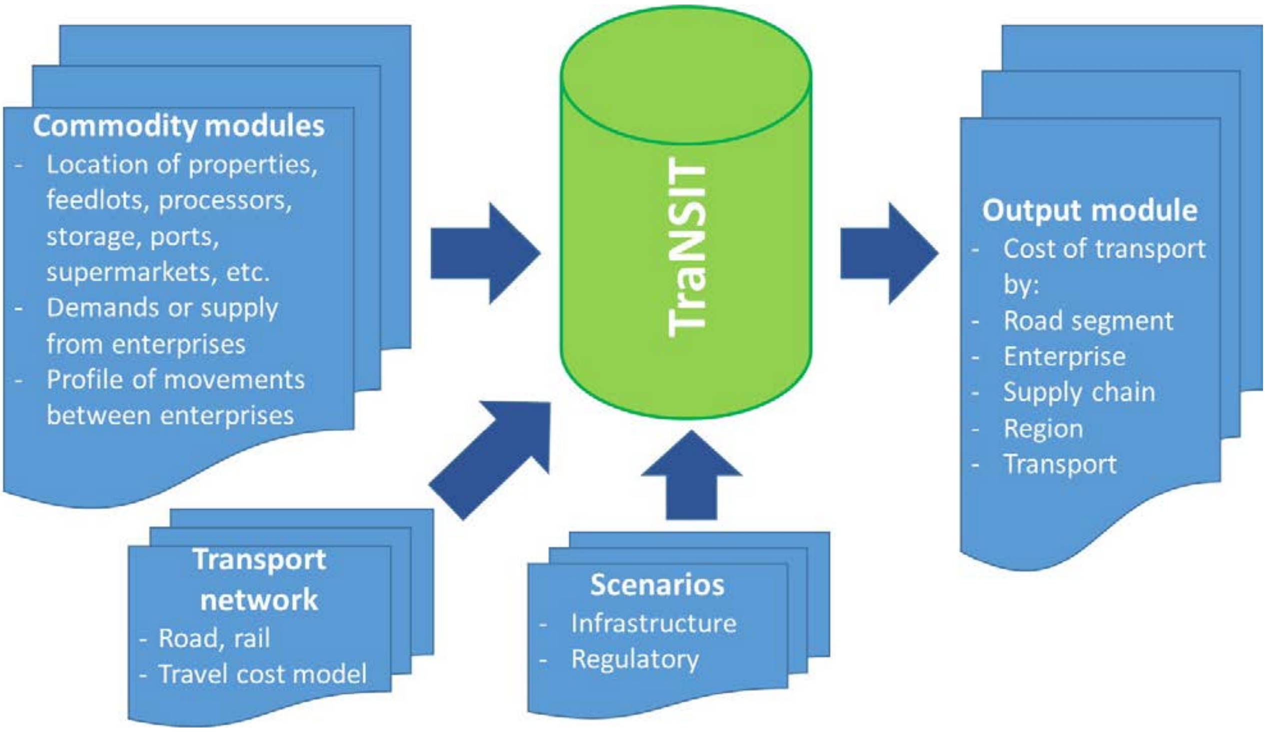

Figure 2 Outline of TraNSIT in its modular form

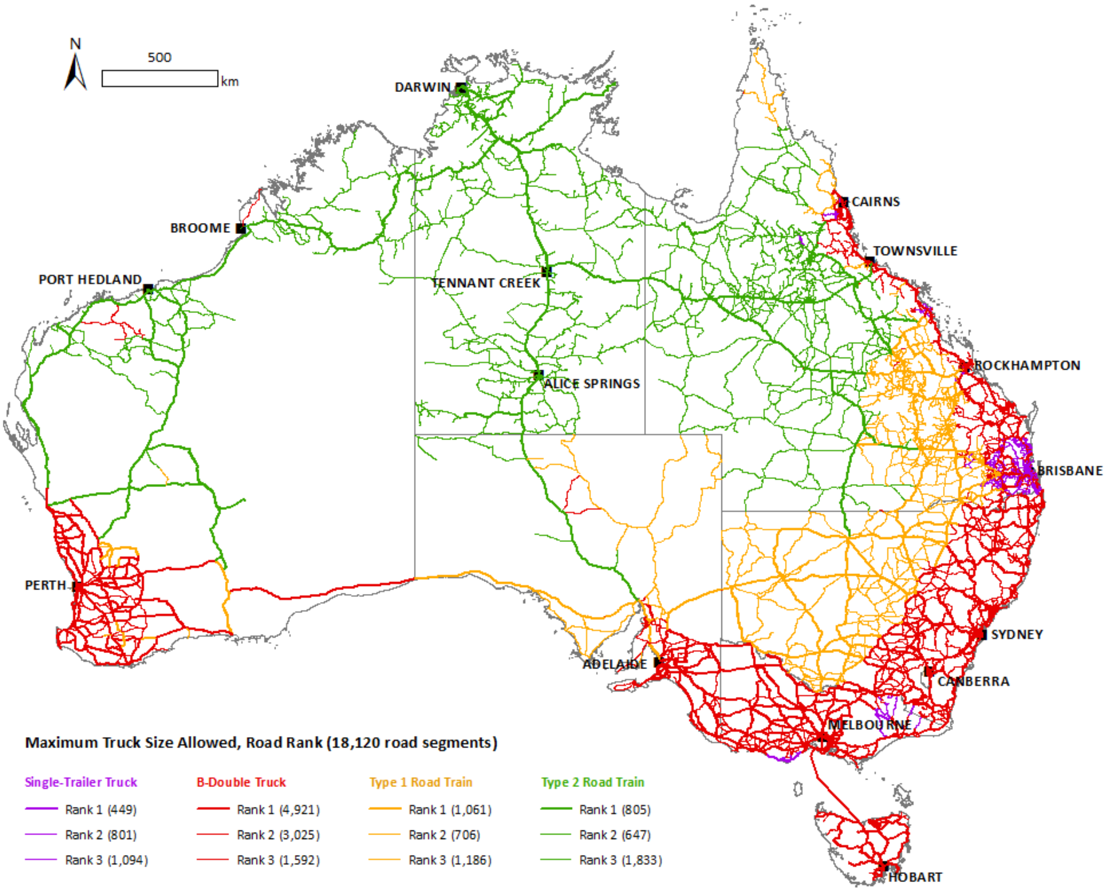

Figure 3 Accessibility and road ranking map of heavy vehicles of Figure 2 in Australia, as per the National Heavy Vehicle Regulator

Table 1 Road transport costs per vehicle

Vehicle Type	Cost (A$/km) for a given travel speed				Idle Cost ($/hr)
	100 km/h	80 km/h	60 km/h	40 km/h	
Single Trailer	1.91	2.16	2.58	3.43	119
B-Double	2.35	2.64	3.13	4.10	141
Type 1	2.71	3.02	3.54	4.57	169
Type 2	3.43	3.78	4.36	5.52	177

TraNSIT is based on simulating the number of vehicle trips per month moved between origin and destination enterprises. The goal of the TraNSIT module is to optimise the transport route along the road/rail for each of these trips from origin to destination, and then calculate the cumulative impacts at the enterprise or regional scale whilst evaluating against constraints on the number of vehicle trips on each route. To determine the optimal route, the analysis takes into account such parameters as costs, descriptions, restrictions or hierarchical value. It is essential for all these parameters to work together logically, to allow proper solving of optimal routes. Network segments must be linked to the one next to it and carry attributes that will enable travel through, unless a restriction is in place. Since a property is not always geographically attached to a road, a trip from an origin to destination (O-D) is modelled to have travelled to the closest road segment from the origin, and finishing at the closest point on a road segment to the destination point. This process is repeated for all routes, always searching for the minimum cost, including penalty costs, selecting it as the optimal route.

A process diagram of TraNSIT is contained in Figure 4. For a given set of inputs, TraNSIT finds the optimal route (based on travel time) and selection of vehicle types, for each O-D pair input. Optimal road sections travelled for each O-D pair are saved. These road sections could be constrained by access restrictions such as vehicle size/load limit which will determine the route final set of route segments. The optimal route selected may not necessarily be the actual route taken by the driver in the existing network but rather the route that would be taken should the driver be seeking a least travel time option. It takes about 5 CPU seconds to find an optimal path for each O-D pair on a Windows Server 12 with a Xeon Quad Core 3.4 GHz processor and 32 gigabytes of RAM. For all 60,000 O-D pairs across Australia, the computation takes about 48 hours over 10 CPUs. Once the optimal set of segments for all O-D pairs are saved, a MS-Access application calculates the cost of transport and number of vehicles for a given resource flow between each O-D. These are then aggregated over all O-D pairs to provide a total cost of transport for the scenario. It currently takes 18 hours, or two working days, to run all of steps of TraNSIT shown in Figure 4.

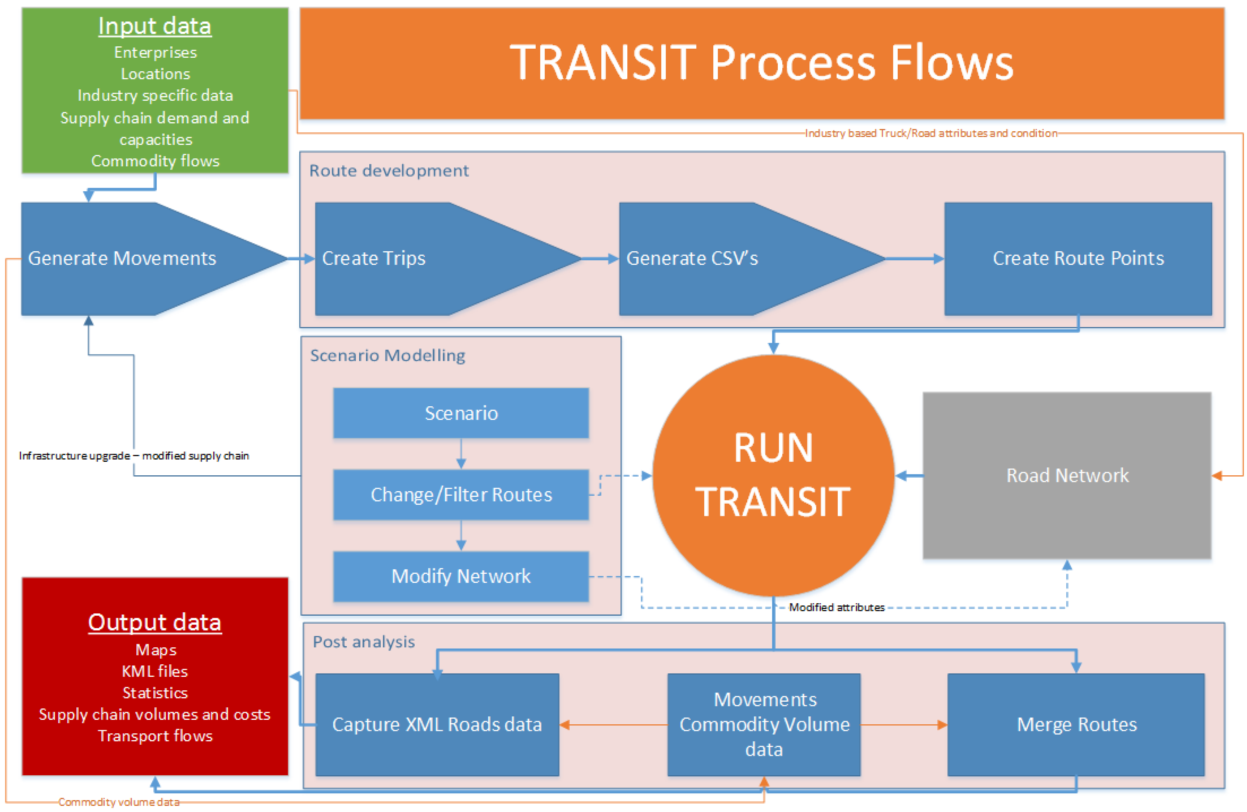

Figure 4 Technical diagram of TraNSIT showing the stages of setting up and running each model component.

3 Application of TraNSIT to all Australia Livestock

The TraNSIT model needed to be set up to provide a baseline analysis of transport costs for the Australian cattle industry. To create a baseline scenario of cattle and vehicle movements, the beef module of TraNSIT required information on locations of cattle enterprise and a 12 month representative scenario of supply chains to slaughter and live export. Data to create the scenario were collected from multiple sources and the methodology to create the scenario is outlined in this section.

3.1 Property Identification Codes

Information on PICs was gathered from each state individually. PICs for Queensland and Northern Territory were already available via the original Livestock Logistics project (Higgins et al 2013). PIC data for the other states were gathered via suitable State Department and Primary Industry representative identified by MLA. The format of the data varied substantially between each state, with Tasmania, South Australia and New South Wales providing complete data sets with latitude and longitude information. In the cases where there were more than one property represented by a PIC, the largest or most central property was selected to represent the location. Victoria supplied de-identified PIC data only allowing some geographical reference to be gathered via the PICs' Parish. Since there are over 2,000 Parishes in Victoria the geographical accuracy will be sufficient for the TraNSIT model. For Western Australia, PICs contained street or postal addresses. Google was used to provide a latitude and longitude for each address. In the case of addresses for which a location could not be found, the postcode centroid was used to represent the location of that PIC. For up to 30% of PICs in some states, no accurate location data could be found. Western Australia PICs in the Pilbara and Kimberley already had latitude and longitude information from the original Livestock Logistics project. Figure 5 shows the location of all livestock PICs (or representative locations) in Australia that were used for TraNSIT.

Table 2 contains the number of PICs for each state by enterprise type. Not all states had Feedlot PICs. There are over 210,000 PICs in total and many PICs are geographically close together. For the purposes of testing infrastructure and policy scenarios using TraNSIT, a smaller number of PICs are required to represent the locations of cattle across Australia. The original 210,000+ PICs were reduced to 47,000 representative locations (RL) and each RL was given an identifier. For Property and Saleyard PICs, the reduction was achieved by amalgamating PICs that were within 2km of one another. The amalgamation was not applied to feedlots, abattoirs, export depots and ports. The reduction in "property" locations was much higher for Victoria, since the original PICs could only be represented by Parish locations, allowing the identification of approximately 800 PICs. These Parishes with PICs were used as representative locations of cattle in Victoria. Some states (e.g. South Australia) did not have PICs for feedlots. In such cases, existing feedlots were found manually (e.g. Australian Lot Feeders Association).

Table 2 - Number of original PICs and number of enterprises used in TraNSIT by state and enterprise type

State	Original PICs (total)	Number of enterprises used in TraNSIT					
		Property	Feedlot	Saleyard	Abattoir	Export Depot	Port
NSW	73,478	21,487	109	42	22	0	0
VIC	58,686	755	26	21	42	0	1
QLD	48,971	16,210	128	36	20	8	3
SA	11,784	4273	43	5	7	0	0
WA	11,196	1216	97	5	8	17	5
TAS	8,417	1970	2	5	7	0	0
NT	626	293	1	0	0	8	1

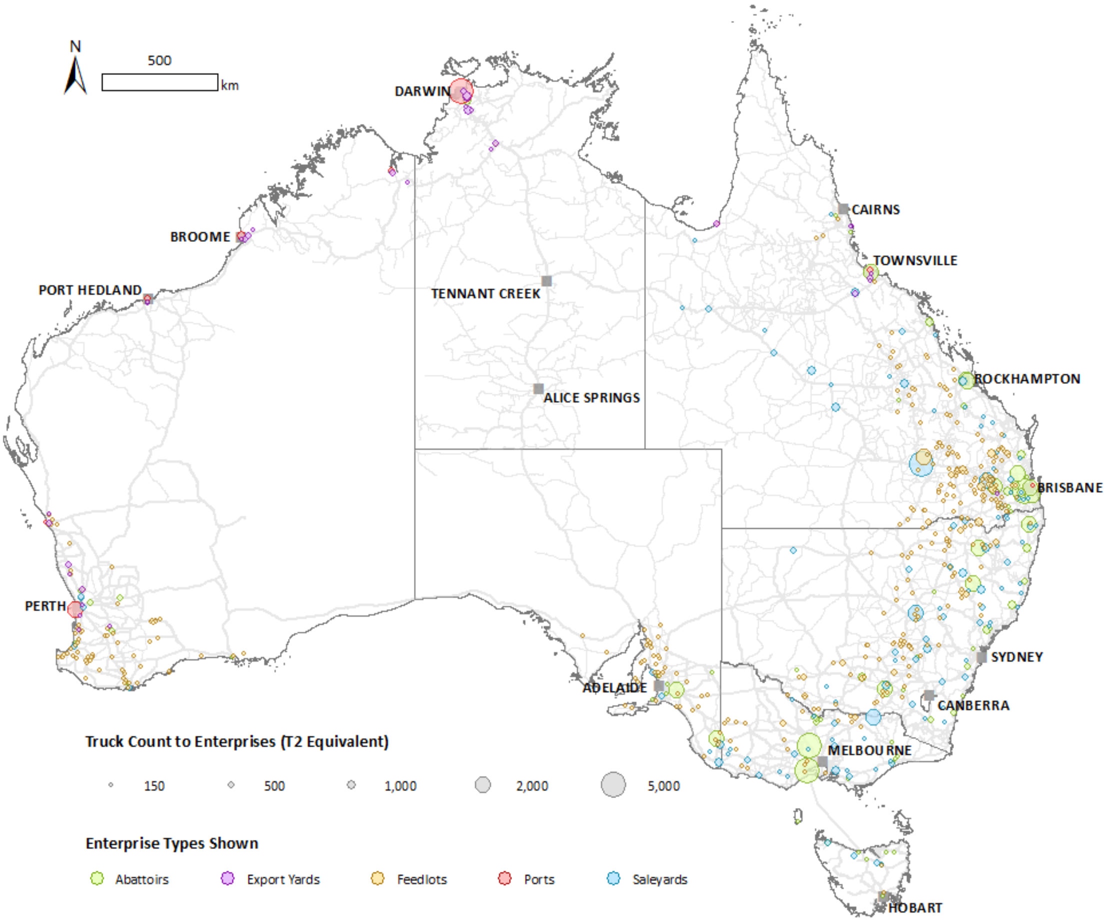

Figure 5 Location of all livestock enterprises in Australia that were used in TraNSIT

3.2 Cattle movements – methodology

A methodology for creating cattle vehicle movements needed the flexibility to reproduce movements for future scenarios in production, markets, infrastructure and policy which may substantially alter existing supply chains. It was also important that the methodology accommodate choice as to which downstream enterprise to supply cattle to (e.g. selection amongst feedlots or abattoirs). In future versions of TraNSIT, such decisions can be constrained or influenced by transport costs, prices, climate, capacities, etc. A further consideration was the need for disaggregated outputs from TraNSIT (i.e. vehicle numbers and costs for each road segment) to be available to industry and government stakeholders, without being restricted by data licensing and confidentiality.

For TraNSIT, the baseline supply chains between enterprises were created for 12 months of supply to slaughter and live export. Aggregated slaughter numbers by state and month are publically available via MLA and ABS. To estimate numbers by abattoir, we used information on the daily slaughter rate of each major abattoir. MLA (2005) contains the estimated slaughter of the top 25 meat processing companies in Australia, as of 2004, which make up 76% of all slaughtered cattle. Using an average of 2008 to 2013 as a total slaughter in each state, the actual capacities of abattoirs in each of the 25 companies were adjusted to provide an average representative throughput in an average year from 2008 to 2013. Monthly throughput of each abattoir was estimated by adjusting the average annual total to the statewide proportion of cattle slaughtered each month. This was different in each state. For example Queensland slaughtered much fewer cattle in the summer months compared to winter. There are a large number of smaller abattoirs in the original PIC data that were not part of the largest 25 companies. These were given uniform capacities to represent the remaining 24% of slaughtered cattle. Live export was much easier to represent since MLA publish LiveCorp statistics on number of head of cattle exported each month from each port. The 2013 export numbers were used. For cattle going into feedlots, the Australian Lot Feeders Association (ALFA) provide quarterly statistics on numbers of cattle going to feedlots by state. The same reports also provide utilisation rates of feedlots by state. A report by MLA (2012) provided maps on the pen capacity of feedlots across Australia, which can be used along with the ALFA reports to estimate the throughput of feedlots at different locations in Australia.

Throughput (2013, 2014) for major saleyards was available from MLA for Queensland, New South Wales and Western Australia. For other states, the list of major saleyards (and some throughput figures) were available from the Australian Livestock Markets Association website (www.saleyards.info). For saleyards with no throughput information, these were estimated by dis-aggregating state level statistics contained in report by Durr et al (2010) and proportioning out the throughput numbers.

This process provided a table of number of cattle required in each month (of an average year) for each port, export depot, abattoir, feedlot and saleyard in Figure 4. The next step was to estimate the probability of cattle moved between enterprise types. For example, for cattle transported to abattoirs, what proportion come from feedlots, saleyards and properties. This was estimated from a summary table in Higgins et al (2013), where 68% of cattle transported to properties came from other properties, whilst 32% came from saleyards. Such percentages can be adjusted for future scenarios. For cattle transported to saleyards, 68% came from properties and 32% came from other saleyards. For cattle transported to abattoirs, 40% came from properties, 32% came from saleyards and 28% from feedlots. These percentages combined with the demand for each enterprise (other than property) by month, allowed the estimation of total cattle travelled by each enterprise type. Whilst this allowed the estimation of total demand from properties (to feedlots, saleyards, other properties, abattoirs), the number of cattle transported from cattle properties in each locations needed to be estimated. In the baseline analysis, the number of cattle from each location was done using a MLA Cattle Numbers Map by Natural Resource Management Region (MLA 2011), combined with the number of properties in each shire to estimate the number of cattle transported out of a shire, and the probability per property. A shire with a large number of cattle and small number of properties will have a higher probability of supplying cattle than a shire with a smaller number of cattle with the same number of representative properties. For future production and live export scenarios, movements from properties can be derived using the corresponding altered herd structure and turn-off scenarios. An example is with the live export scenarios in Higgins et al (2014) where Breedcow was used to produce turn-off scenarios for each ABARES region.

To produce a set of movements involving origin and destination enterprises, travel distance had to be accommodated. For example, if a property was to supply cattle to a feedlot or a feedlot was to supply cattle to an abattoir, the distance between eligible facilities was a key determinant of which destination facility would be selected. Future versions can include additional variables such as price offered and accessibility. For each enterprise (whether property, feedlot, saleyard, abattoir) a sorted list of nearest downstream enterprises were calculated. That is, for each Feedlot, the nearest 20 abattoirs were found. The same applied for the nearest 20 saleyards for each property, etc. The closer the eligible destination enterprise is to the origin, the higher the probability of it being selected. Destination enterprises that are long distances (e.g. greater than 1000 km) from the origin enterprise, will have a low probability of being selected unless there are few or no local destination enterprises (e.g. abattoirs, feedlots) with spare capacity. The probability formula (as a negative exponential function of distance) can be adjusted so that the average distance resembles that in practice or previous published information (see Durr et al, 2010) in the case of saleyards. Another variable that influences the destination enterprise to select is the capacity of the destination facility. The capacity of the destination enterprise was determined by number of cattle required in each month for that destination, whether it is a port, export deport, abattoir, feedlot or saleyard. For example, cattle from a feedlot or property may have to supply an abattoir with a much further travel distance, if the capacity of nearer abattoirs is already reached. For property to property movements, the selection of the destination property was more difficult, since the destination property could be for the purposes of agistment, backgrounding, finishing or purchase between properties. For movements from breeding to background and finishing properties, we assumed the direction would be towards the location of eligible abattoirs or feedlots and in accordance to the primary breeding, backgrounding and finishing regions in Australia (AusVet Animal Health Services 2006).

For live export, export depots are automatically allocated to the nearest port. The throughput of each export depot is estimated by the capacity of the depot, which was available for NT and north Queensland export depots. For other export depots, the throughput was an average of those supplying the port. Properties supplying cattle to export yards were in accordance to shire catchments that are known to supply each Port (Metang 2010).

3.2.1 OPPORTUNITIES TO IMPROVE THE METHODOLOGY FOR LIVESTOCK

Data availability and access are the main opportunities to enhance the methodology. This will help improve the ability to more accurately represent actual past movements between enterprises on any given year. The model simulates and optimises vehicle movements based on an average year (unless specific demands in abattoirs and live export are inputs) and logic of movements between enterprises using a range of information sources (listed above) that help characterise these movements. Unlike an approach based on recorded NLIS movements, the methodology will not show what happened on a specific year or month. It will also not represent the small amount of movements between enterprises that are not common, such as some property to property movements of very long distances.

The more heavily used routes (e.g. Warrego Highway, Flinders Highway, Stuart Highway) were found to be a close representation of actual practice. For some roads that are less utilised for livestock transport and are a significant distance (e.g. greater than 200km) from major saleyards, feedlot, abattoir or live export enterprises, a larger variability was found. These can be easily calibrated in the model.

These issues relating to the application of TraNSIT to livestock transport would easily be overcome by better information on geographical aspect of property to property movement trends. To remove any sensitivities, this could be the average number of cattle transported between each of more than 700 shires in Australia in a given year.

4 MLA Queensland Workshop

The first stakeholder workshop was held on 15th August 2014 in MLA's Brisbane office. Participants at the workshop represented: Red Meat Advisory Council; AgForce; Queensland Department of Agriculture, Forestry and Fisheries; Queensland Department of Transport and Main Roads; and MLA. An agenda for the workshop is contained in Appendix A. The main purpose of the workshop was to provide an overview and demonstration of TraNSIT, and then collectively identify some priority scenarios for testing. Since the version of TraNSIT presented at the workshop only contained data for northern Australia, scenarios identified at the workshop were limited to Queensland. The following scenarios were identified at the workshop:

- Bridge Upgrade Theodore to Eidsvold
- New bypass impact for Toowoomba bypass
- Biloela to Gladstone (to potential live export) – nearest facility to estimate supply PICs
- Rolleston to Miles - via Taroom
- Rolleston to Miles - via Roma
- Bypass road to abattoir Townsville
- Road from Roundabout near Rockhampton
- Roma from outskirts to the saleyards allow triples
- Clermont to Rockhampton Type 2-Type 1
- Roma to Toowoomba
- Alpha to Rockhampton

Each of the above vehicle access scenarios will require an assessment of the suitability of the road infrastructure for higher combination and heavier vehicle access, and will likely require infrastructure investment of some form such as upgrades to bridges, culverts and intersections.

In each of the scenario analyses completed, the results provided are direct industry benefits only such as improved freight productivity and efficiency, transport cost savings, driver health and safety, as well as vehicle maintenance and fuel savings. For many of the scenarios, co-benefits for communities, other road users as well as environmental benefits are achieved but not quantified here. These benefits can improve safety, sustainability and efficiency and may include:

- increased road safety for all road users
- increased health and safety for drivers
- changes in animal welfare
- less congestion leading to potential increased productivity
- decreased road and bridge maintenance due to reduction in pavement wear,
- decreased tyre use and maintenance for vehicles
- decreased greenhouse gas emissions and decrease in energy consumption

Note that the analysis is based on full vehicles of cattle along with return trip carrying empty cattle trailers. The transport benefits outlined in this analysis would increase significantly depending upon the proportion of total trips being full trips. The scenarios tested in this report are not representative of all possible options in Queensland and northern Australia. In 2015/2016, CSIRO was commissioned by the White Paper for Developing Northern Australia to evaluate a wide range of road upgrade scenarios put forward by governments and industry across the north.

5 Queensland Infrastructure Scenarios

This section highlights the total direct and indirect transport cost savings for each scenario identified at the Queensland workshop. The scenarios are based on average annual livestock movements over the period 2008-2013. Whilst total cost savings are shown in this report, full disaggregated data sets of traffic volumes and costs (of each vehicle type) on each of the 15,000 road segments across Australia are available in a GIS format for each scenario below. The analyses in this section only consider transport cost savings and needs to be extended to accommodate the costs of infrastructure upgrades, risks associated with greater access of heavier vehicles on some roads and broader economic implications. Policy scenarios allowing higher combination vehicles on some roads will require infrastructure upgrades of some form, such as bridges, culverts and intersections.

5.1 Interpretation of results

Each scenario contains: a figure showing the road segments impacted and the type of upgrade implemented; and a table showing the summary of results.

Each table shows transport cost savings broken down into several components:

- travel – savings in transport costs along the road segments being upgraded
- vehicle break down – savings in terms of reduced number of vehicle decoupling and reconnecting
- broader network – additional savings from additional vehicles using the road versus their previous alternative route; and greater use of higher production vehicles in the travel path before the road segment upgraded

The “Trailers Per Annum” column is the weighted number of semi-trailer equivalents using the road corridor. This includes the return trip of empty trailers without cattle. It is weighted by number of trailers on each segment within the corridor. For example, consider a 100 km road corridor that contains two road segments of 30 km and 70 km, with the first segment containing 10 vehicles and the second segment containing 80 vehicles. The weighted number of trailers is calculated as (10*30+80*70)/100 = 59 trailers. The “Trailers Per Annum” column reflects the number of trailers using the route in the baseline analysis, and the “Trailers After Upgrade” are the number of trailers that are predicted to use the route following the proposed improvement. Where the number of “Trailers After Upgrade” is greater than the “Trailers Per Annum” the improvement has resulted in a re-route of vehicles.

5.2 Upgrade Theodore Eidsvold Road to allow B-Doubles

The 142 km road connecting Theodore (565 km north-west of Brisbane) to Eidsvold has several bridges that have load limits. Due to these limitations, cattle transportation is restricted to Semi Trailer. Figure 6 shows the section of road of interest, within the surrounding road network. Access to the road from the west allows the use of Type 1 road trains; only B-Double access is, however, permitted to the east of Eidsvold.

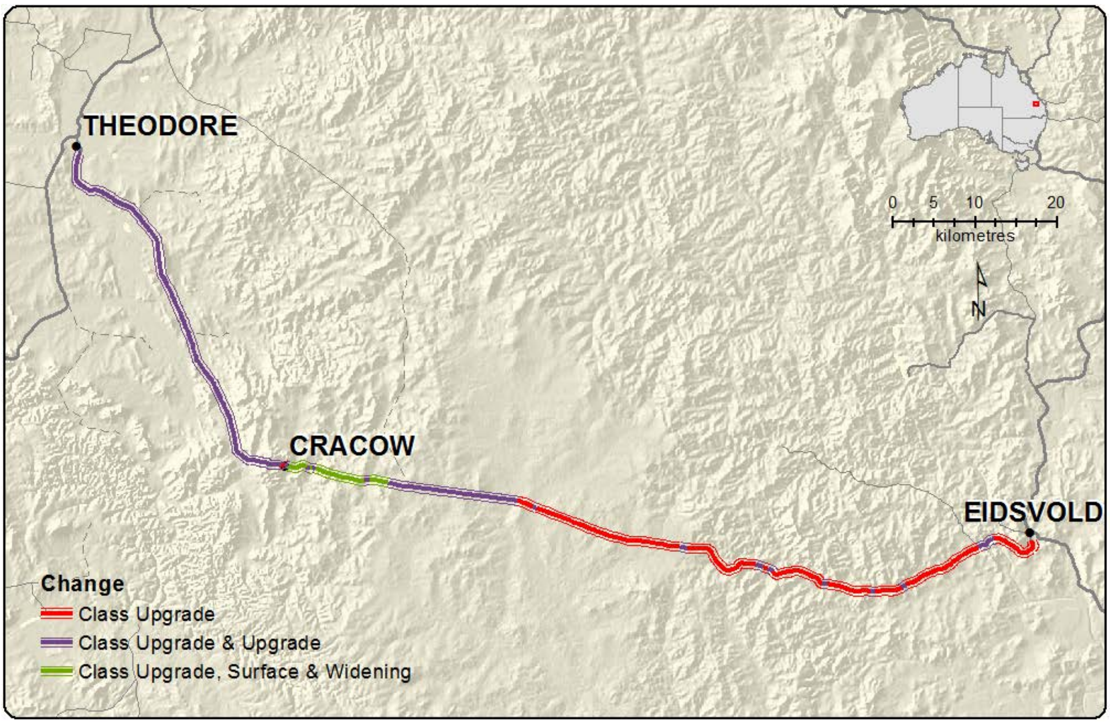

Figure 6 Heavy vehicle accessibility and road ranking for roads between and around Theodore/Eidsvold

The current restrictions force transport movements around this road to avoid breaking down the vehicles into small combinations or taking a detour. However, for trips where the destination requires use of the road there is a need to move stock in a smaller vehicle that is capable of meeting the bridge restriction limits, or use a route that navigates around the restriction resulting in higher cost of transportation.

Table 3 summarises the cost savings per annum. Savings for the modified part of the road network are $79,852 for driving (i.e. when the vehicle is moving) and losses of $7,768 occur for break down of vehicles in to smaller configurations. Additional savings of $7,051 across the connecting road network are due to the increased number of vehicle trips choosing more efficient routings and/or vehicle configurations due to this road network upgrade. After the road upgrade, there would be a significant increase in vehicle trips, from 260 to 1726 (semi-trailer equivalents), as there would be much fewer detours.

Table 3 Summary of costs and savings for Rolleston to Miles via Roma

	Savings per year	Total Trailers	Trailers after upgrade	Savings Per Head
Travel	$79,852			
Vehicle breakdown	$7,768			
Broader network	$7,051			
Total	$94,671	260	1726	$1.41

5.3 New Toowoomba Bypass impact

TraNSIT estimated that 22,674 cattle vehicles (semi-trailer equivalents) pass through the Toowoomba Range on the Warrego Highway in an average year. If the bypass were available (Figure 7), only an additional 54 vehicles (moving 6,480 cattle) would use the bypass route. The negligible increase in vehicle numbers using the bypass is due to the bypass not changing the optimal transport routes across the freight network in that region. The total cost of the movements (between their origins and destinations) without the bypass is $10,859,484, which would reduce to $10,713,563 using the planned bypass. This is a saving of $0.18 per head of cattle.

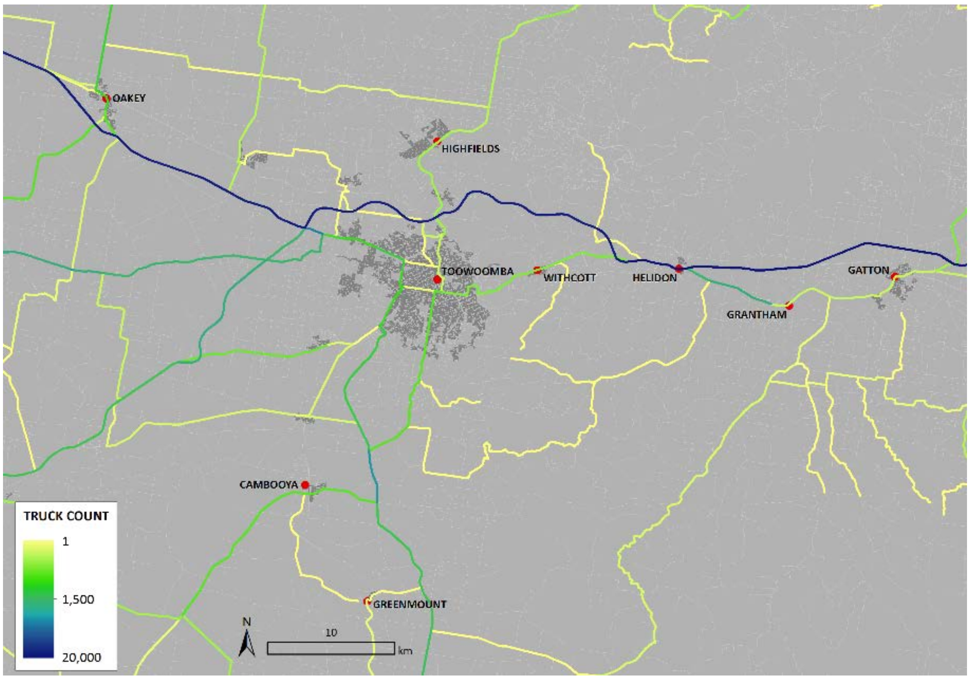

Figure 7 Livestock freight flows through Toowoomba with the proposed bypass

5.4 Biloela to Gladstone

This scenario models the impact of upgrading the Dawson Highway linking Biloela and Gladstone to allow Type 1 road trains, whereas the current restriction is B-Doubles only. This section of the highway is 119km long taking approximately 1.5 hours to travel (Figure 8).

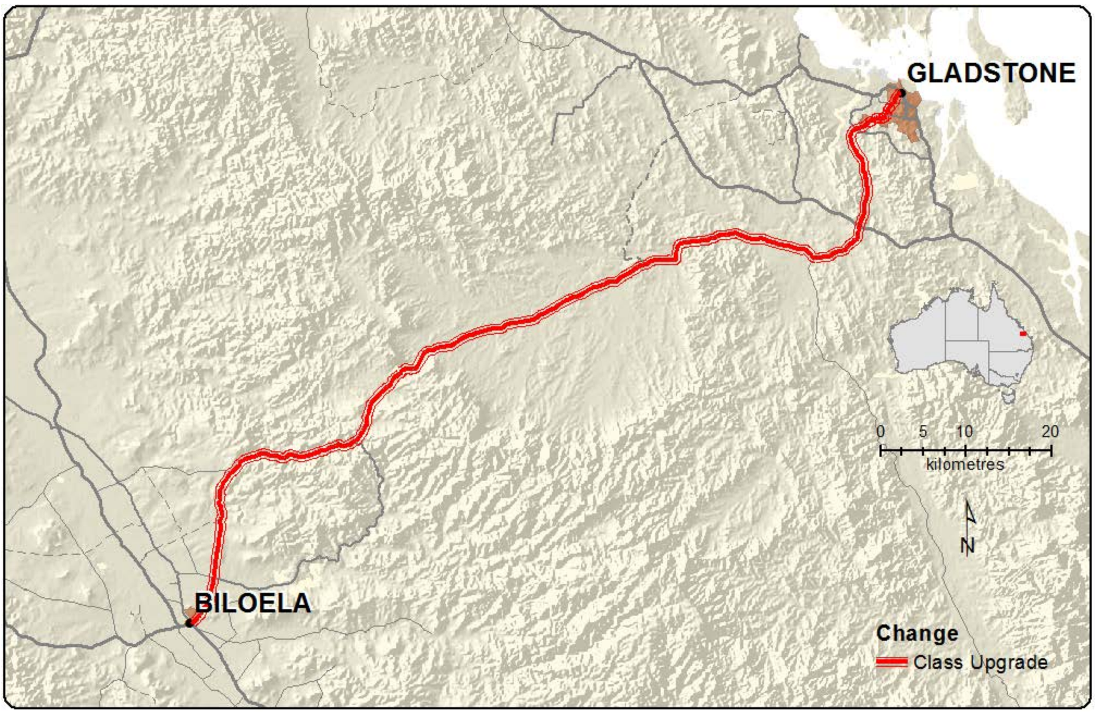

Figure 8 Road upgrade between Biloela and Gladstone to allow Type 1 access

TraNSIT estimated the route from Biloela to Gladstone was utilised by 607 B-Double vehicles moving 35,760 cattle on an average year. The costs for these movements (between origins and destinations) were $596,000 travelling a total of 223,000 km over 2,600 hours and include $50,000 of breakdown costs and $15,000 of fatigue management costs. Should the routes be upgraded to Type 1 access, the total savings would emanate from a reduction in the number of vehicles to 460 Type 1 class vehicles, with an expected saving of $87,858 in transport costs or $0.92/head. There would be a total vehicle kilometres reduction of 17,800 km and 480 hours. The assumptions here are that the entire routes meet the minimum Type 1 access.

5.5 Rolleston to Miles via Taroom or Roma

This scenario was developed to test the potential for savings if vehicles were able to travel through these sections of road and not be impacted by current biosecurity regulations which require cattle vehicles to stop for tick clearing when entering a tick-free zone. It was hypothesised by stakeholders at the MLA workshop that currently vehicle drivers are detouring around the tick line (i.e. staying within the tick infested areas) to avoid the expense and time costs associated with tick clearing. It was expected it would be more efficient to travel south either via Roma or via Taroom (Figure 9). With tick-clearing requirements abolished, of the 12,336 vehicles using the Rolleston to Miles road via Taroom, approximately half cross the tick line at some point, but of these only 1350 originate and finish in the tick-infected region. Of the 17,572 cattle trailers using the Rolleston to Miles road via Roma, approximately 33% cross the tick line at some point but of these only 1,770 originate and finish in the tick-infected region. Removal of the biosecurity regulations for these trips would result in average saving of approximately $17,000 per annum.

An analysis of the benefits of upgrading the road sections between Rolleston and Miles via both Taroom and Roma to allow access to Type 2 combination vehicles was also undertaken. Tables 4 and 5 show the savings that occur on the road segments that were upgraded to allow Type 2 vehicle access, along with additional savings ($0.87 million and $1.4 million respectively) across the connecting road network due to increased number of vehicle trips choosing Type 2 as the least cost configuration.

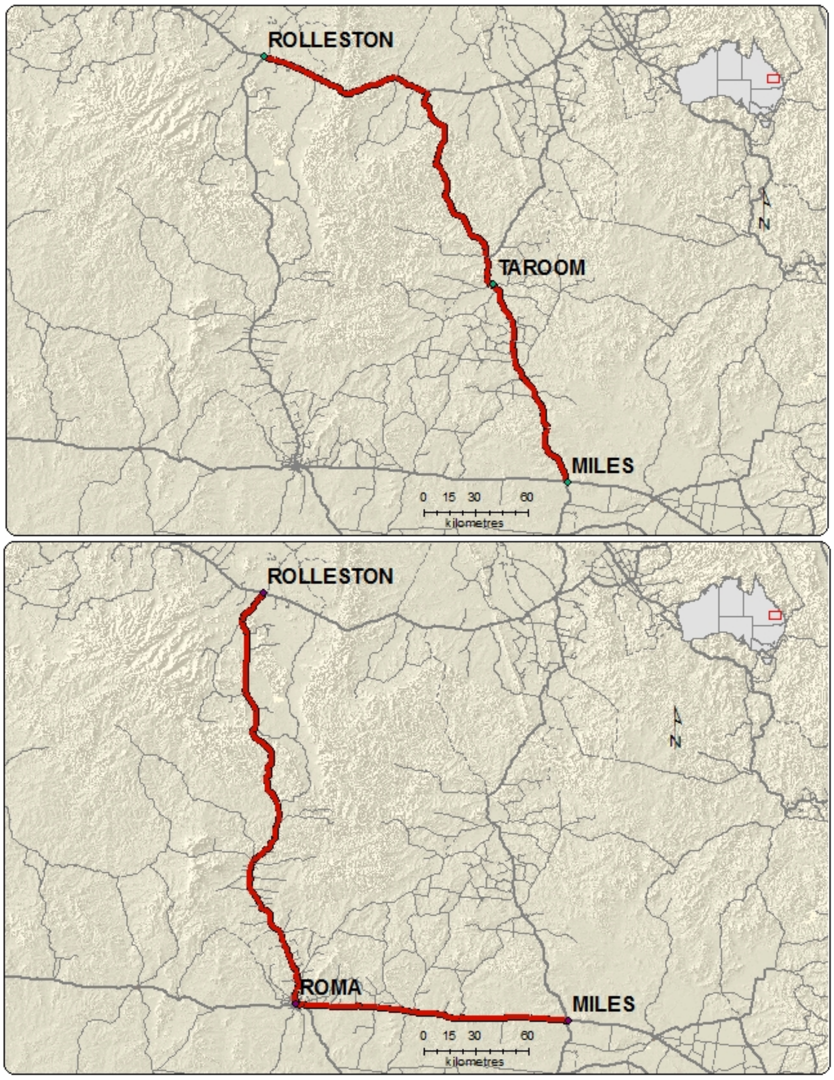

Figure 9 Map showing the travel paths between Rolleston and Miles, via Roma (bottom) and Taroom (top)

Table 4 Summary of costs and savings from Rolleston to Miles via Taroom

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$233,661			
Vehicle breakdown	$600,153			
Broader network	$876,588			
Total	$1,710,402	6168	6168	$1.14

Table 5 Summary of costs and savings for Rolleston to Miles via Roma

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$963,416			
Vehicle breakdown	$325,849			
Broader network	$1,438,577			
Total	$2,272,843	17572	17572	$0.93

5.6 Type 2 access to Townsville abattoir

Access to the Townsville abattoir is via the Bruce Highway which is classified as Type 1 access or via Hunter Street which is B-Double classified. To enable Type 2 class vehicles direct access (Figure 10), approximately 3 km of road would need to be upgraded (currently B-Double access) or 1.15 km section of Bruce Highway upgraded from Type 1 vehicle access. The roads are estimated to be used 133,000 cattle enroute to the abattoir.

Table 6 Summary of costs and savings for the bypass roads to Townsville abattoir

	Savings from Scenario	Total Trailers	Savings Per Head
Travel	$50,252		
Vehicle breakdown	$141,810		
Broader network	$78,319		
Total	$270,379	7048	$1.92

Table 6 show the savings that occur on the short road segment to Townsville abattoir that were upgraded to Type 2, along with additional savings across the connecting road network due to increased number of vehicle trips choosing Type 2 as the least cost configuration. There were significant savings due to reduced break down costs. The broader network savings were due to a large number of vehicle trips (particularly shorter trips along the Flinders highway between Charters Towers and Townsville) would optimally choose a Type 2 vehicle for the entire journey.

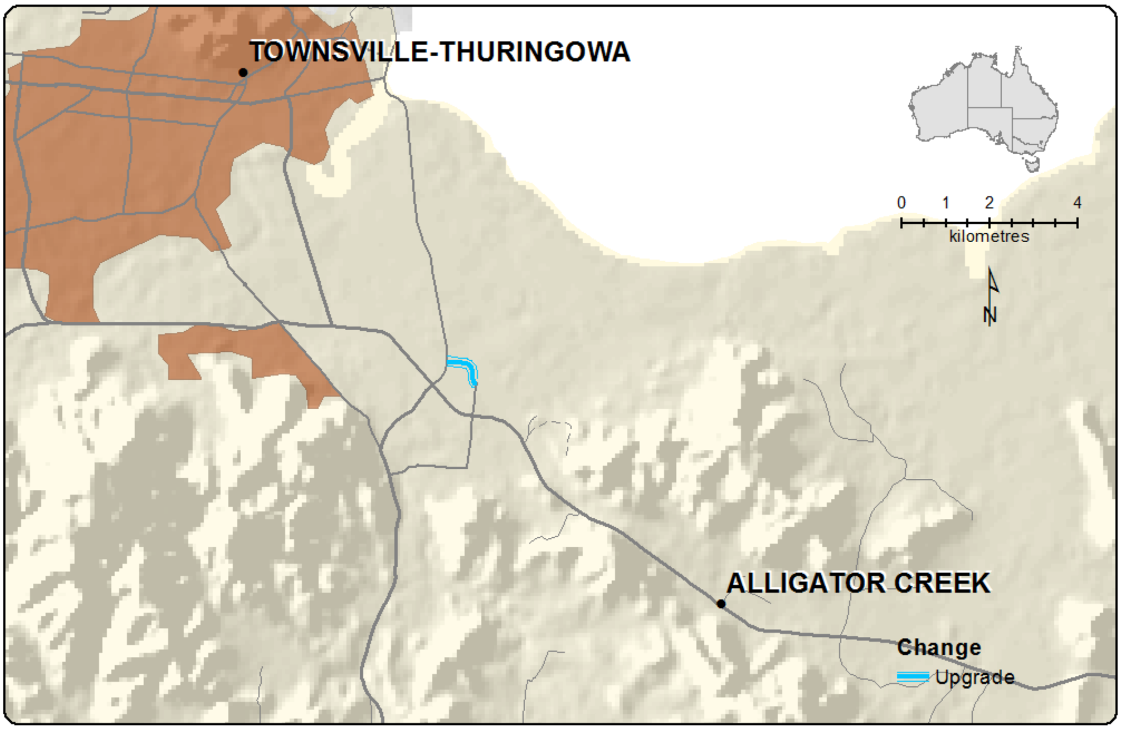

Figure 10 Allow Type 2 vehicles to travel to Townsville abattoir

5.7 Gracemere Roundabout to Rockhampton

This scenario examined the impact on cattle transport of upgrading the road between Gracemere roundabout and Rockhampton abattoirs (currently B-Double access) to allow Type 1 vehicles. TraNSIT estimated about 20,000 trailers traversed the Gracemere to Rockhampton section (Figure 11) of road in an average year. This 12 km section is the primary route for the movement of 368,000 cattle/year. If this 12 km segment was upgraded to Type 1 vehicle access, there would be direct travel cost savings of $198,296 plus additional savings of $374,995 in break down costs (Table 7). There is also a significant broader network ($165,628) which occur due to the reclassification of the short 12 km segment. This is because a large number of vehicle trips would use a Type 1 as opposed to a B-Double for the entire journey, thus leading to transport costs savings on other Type 1 roads leading into Rockhampton. This analysis assumes all other sections remain at the current classification.

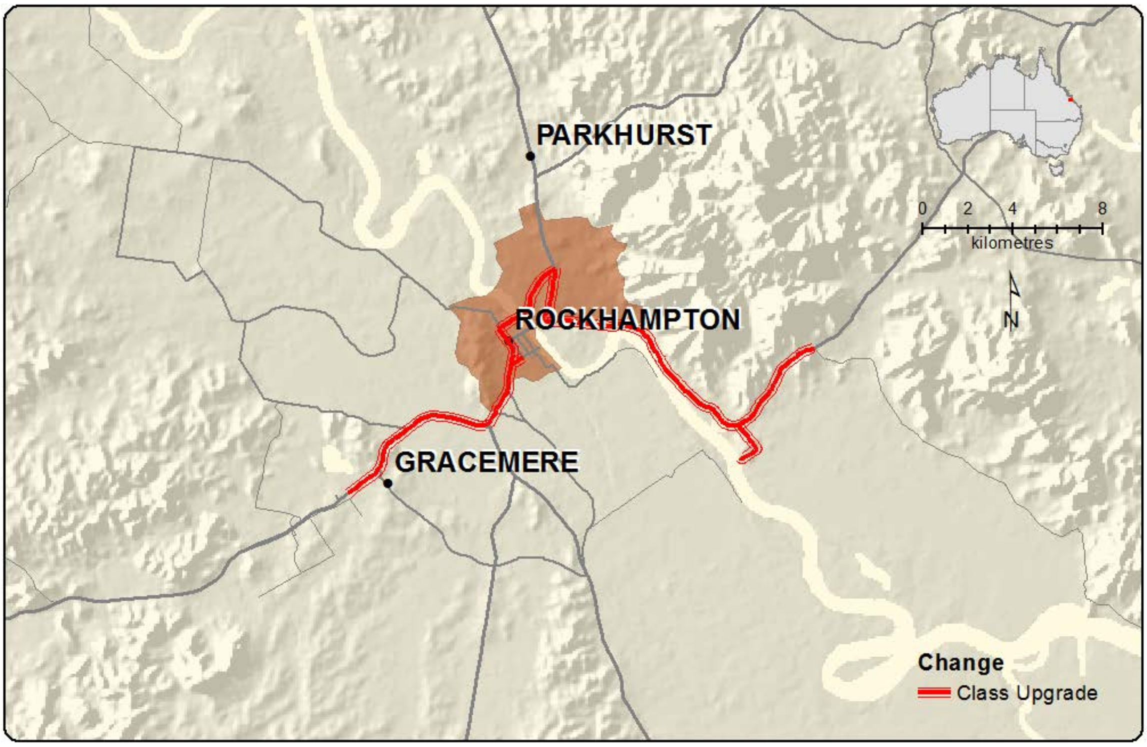

Figure 11 Upgrade to allow Type 1 vehicles from Gracemere and Rockhampton

Table 7 Summary of Gracemere to Rockhampton benefits with access of Type 1 vehicles

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$198,296			
Vehicle breakdown	$374,995			
Broader network	$165,628			
Total	$738,919	20532	22668	$1.63

5.8 Roma from outskirts to the saleyards using Type 2 vehicles

In an average year, approximately 30,000 trailers (semi-trailer equivalents) traverse this the section of road through Roma to the Type 2 access section of the Warrego Highway from the west (Figure 12), represented by 2,900 origin to destination routes (Table 8). These vehicles are typically expected to break down from Type 2 combination vehicles to Type 1 vehicles for the balance of the journey. In all, 10,211 Type 2 vehicles need to be broken down to Type 1 combinations. A road upgrade to allow Type 2 access would see annual savings of $79,167 in transport costs over the 7 km section and further savings of $375,378 in break down costs. There are also additional savings of $1,033,824 from efficiencies gained from greater Type 2 travel in the connecting road network.

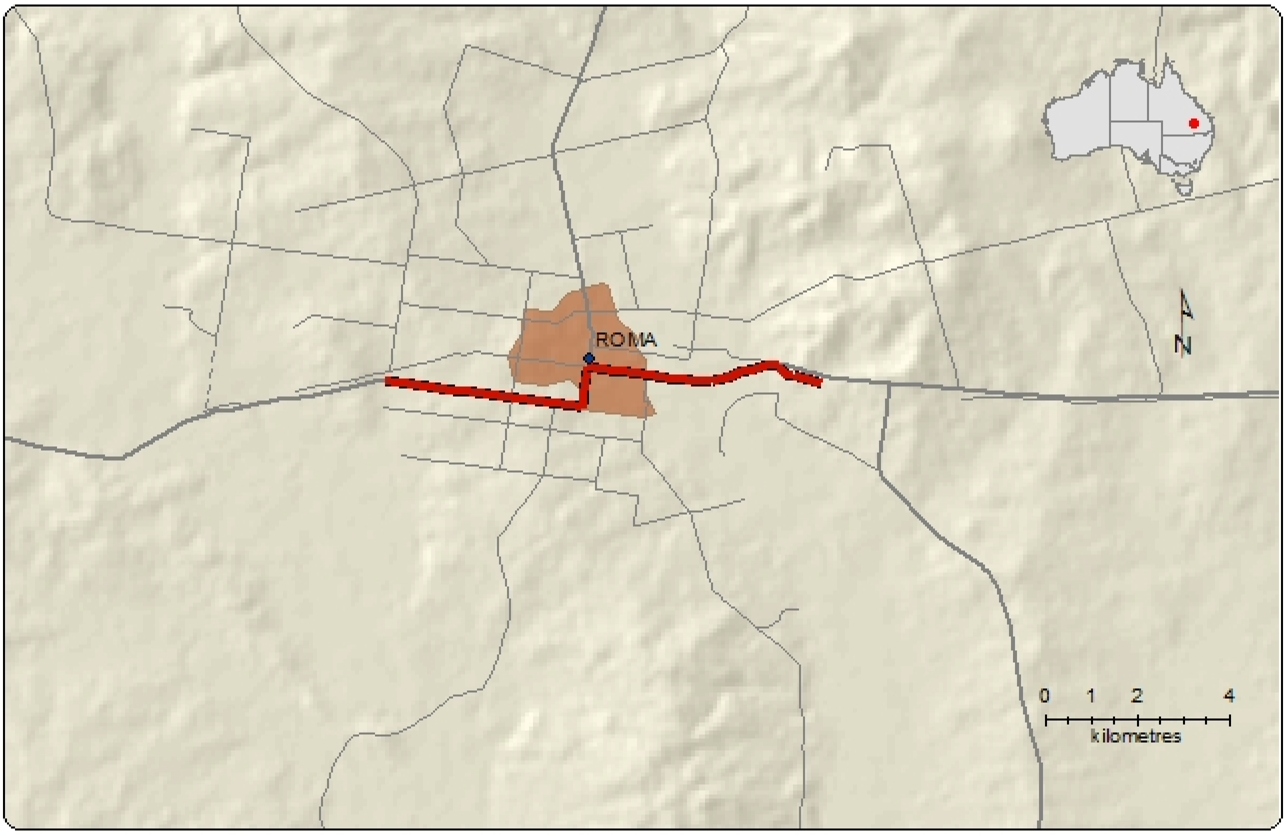

Figure 12 Upgrade of roads around Roma to accommodate Type 2 vehicles

Table 8 Transport savings from increased use of Type 2 vehicles around Roma

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$79,168			
Vehicle breakdown	$375,378			
Broader network	$1,033,824			
Total	$1,488,370	30634	30634	$0.64

5.9 Upgrade corridor between Roma to Toowoomba to allow Type 2 access

The Warrego Highway between Roma and Toowoomba (Figure 13) is approximately 340 km in length and currently limited to Type 1 vehicle access, excluding a small section of the highway at Macalister which is B-Double access. This section is expected to take 5 hours to travel over with a Type 1 vehicle, costing $1,224. This segment of highway is a critical section in the broader cattle transport network, used to transport nearly 4 million cattle per year, or about 35,000 trailers. For optimal movements based on the current vehicle access limitations, each route requires the use of more than one class of vehicle. Upgrading this section of highway to Type 2 class would produce a saving of 9,290 hours of travel, 712,031 km distance travelled. The total cost savings (Table 9) comprise of $2,043,410 in transport costs and $642,711 in break down costs, and the remainder in broader network savings.

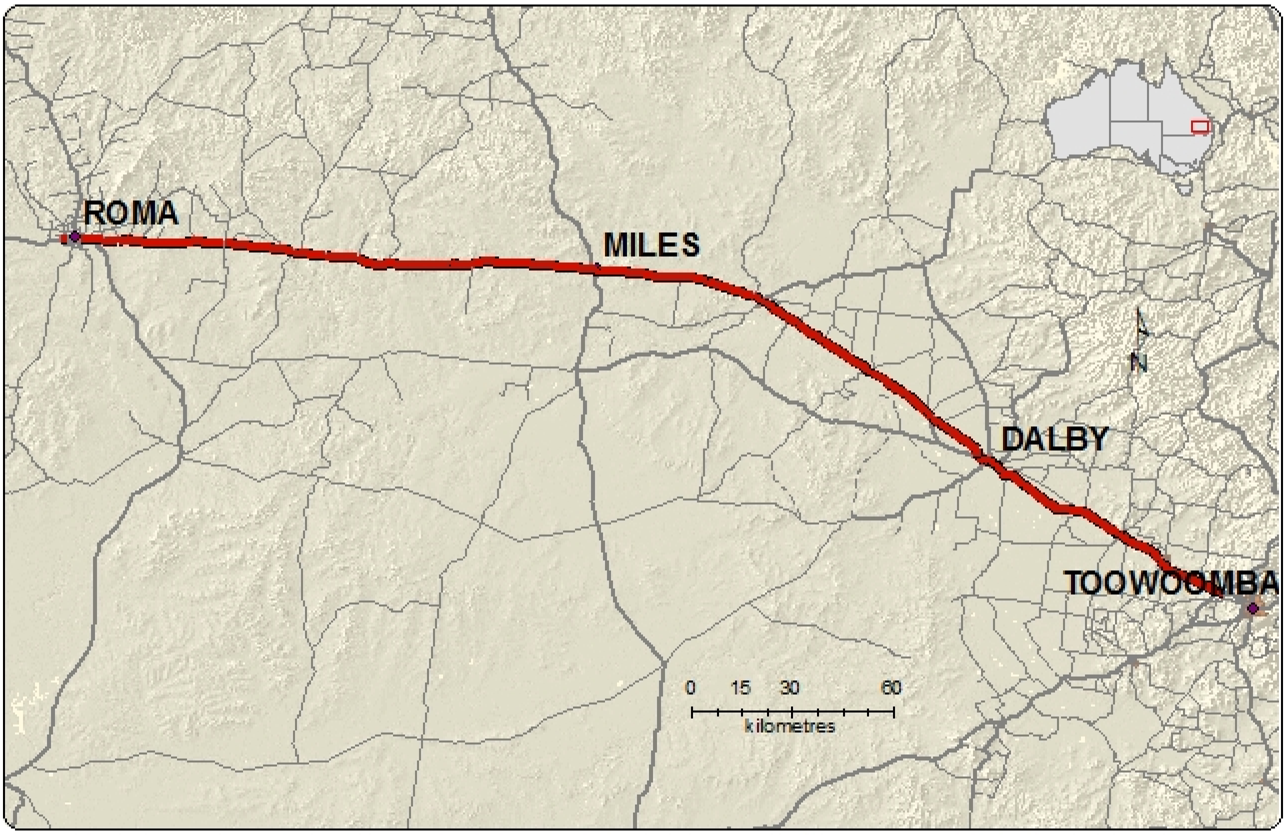

Figure 13 Upgrade of Warrego highway from Roma to Toowoomba to accommodate Type 2 vehicles

Table 9 Summary benefits from Type 2 vehicle access between Roma and Toowoomba

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$2,043,410			
Vehicle breakdown	$642,711			
Broader network	$2,216,815			
Total	$4,902,937	34,824	34,824	$1.24

5.10 Access to Type 2 vehicles from Clermont to Rockhampton

The 350 km section of highway made up of sections of the Gregory and Capricorn Highways (Figure 14) take approximately 4 ½ hrs to traverse. The intersection of the Gregory Highway and the Capricorn Highway has the highest use having almost 70% of the vehicles passing this intersection. TraNSIT estimated this road is used by over 12,000 trailers per year moving 1.2 million cattle. Upgrading the road to allow Type 2 vehicle access would see a reduction of vehicle trips to 7,056 saving 16,060 hours. Total transport cost savings would be approximately $1.7 million (Table 10).

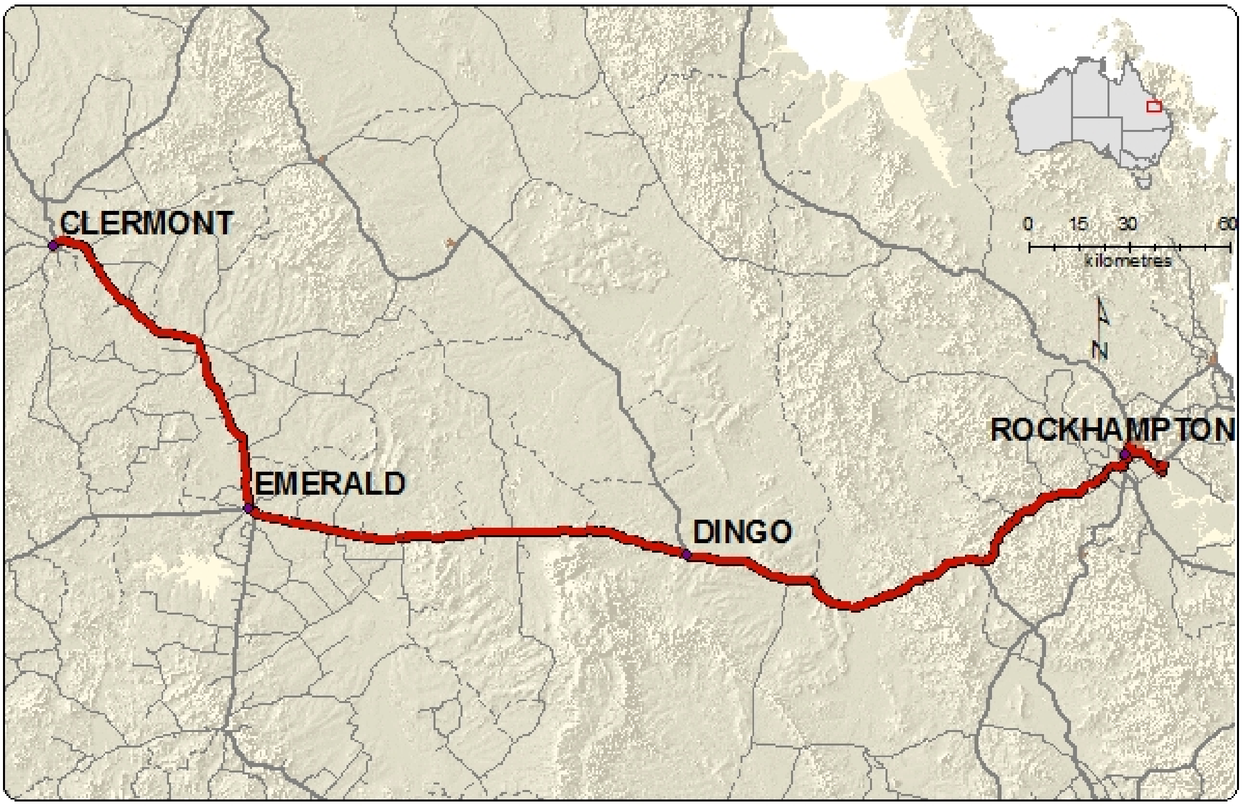

Figure 14 Upgrade to allow Type 2 vehicles from Clermont to Rockhampton

Table 10 Summary benefits from Type 2 vehicle access between Clermont to Rockhampton

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$857,049			
Vehicle breakdown	$253,696			
Broader network	$583,968			
Total	$1,694,713	12312	12446	$1.38

5.11 Alpha to Rockhampton

The 400 km section of the Capricorn Highway from Alpha to Rockhampton (Figure 15) takes approximately 5 hrs. TraNSIT estimated this road is used by nearly 13,000 trailers per year moving 1.3 million cattle. Upgrading the road to allow Type 2 vehicle access would save approximately $1.1m in transport costs between Alpha and Rockhampton as well as $133,952 in breakdown costs (Table 11). There are also $0.58 million in additional broader network efficiency savings due to increased vehicle trips choosing a Type 2 as the optimal configuration.

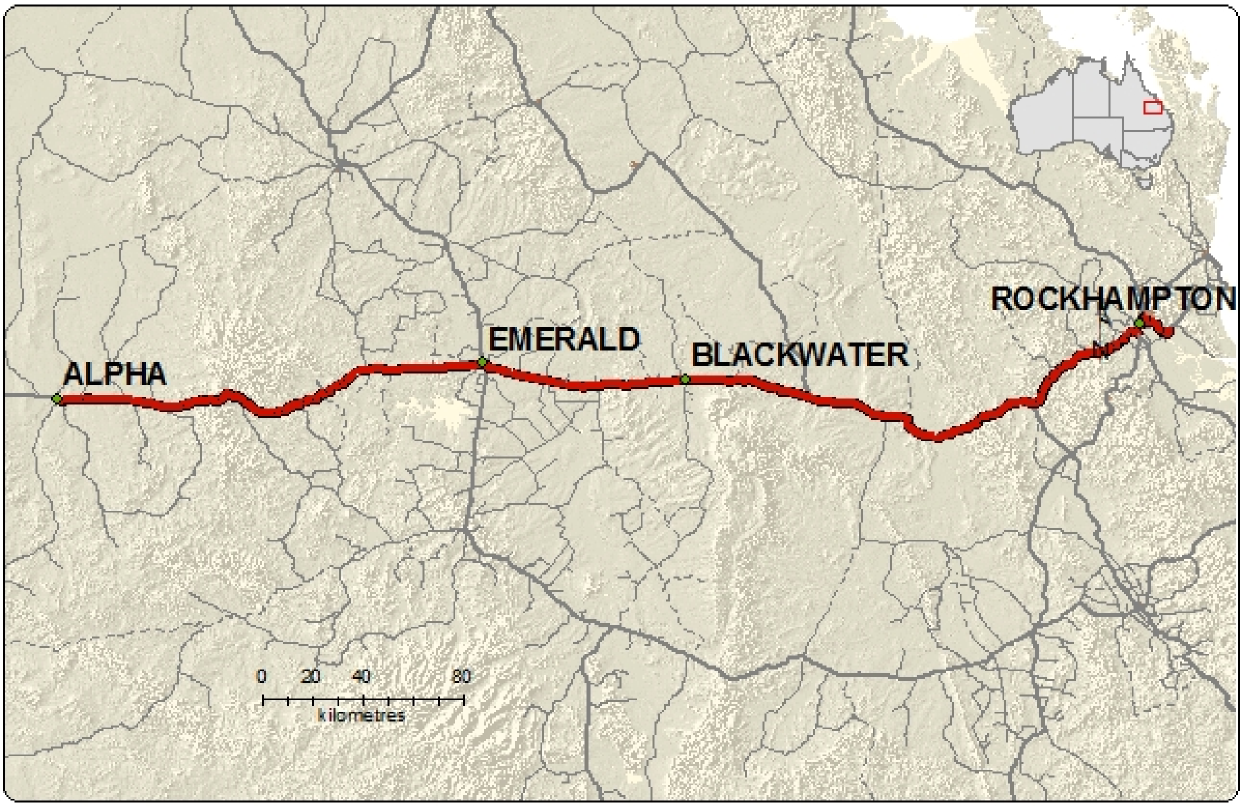

Figure 15 Upgrade to allow Type 2 vehicles from Alpha to Rockhampton

Table 11 Summary benefits from Type 2 vehicle access between Alpha to Rockhampton

	Savings per year	Trailers before upgrade	Trailers after upgrades	Savings Per Head
Travel	$1,097,490			
Vehicle breakdown	$131,952			
Broader network	$583,679			
Total	$1,813,212	12970	13098	$1.38

6 Baseline Analysis of All Australia Livestock

A baseline analysis provides information on the number of vehicles travelling along each road/rail segment, and needs to be undertaken before scenarios can be run and assessed.

In the application of TraNSIT to cattle across the whole of Australia, this baseline analysis was run for an average year between 2008 and 2013. It was derived by mapping the path of about 80,000 origin to destination movements, representing 20 million cattle transported in a given year. A summary map for all cattle vehicle movements is provided in Figure 16. The blue line between Devonport and Melbourne represents cattle shipped between Tasmania and the mainland. There is a similar line between Kangaroo Island and the mainland of South Australia. The vehicle counts in Figure 16 take in to consideration whether the vehicle is a B-Double, Type 1 or Type 2 road train. The largest vehicle counts are those on major corridors towards large abattoirs, feedlots and saleyards along the east and southern coast. Large vehicle numbers on road segments of the Stuart Highway between the export depots and Darwin port are associated with live export. There is a large number of interstate vehicle trips - particularly cattle transported to abattoirs and feedlots between Queensland and NSW. A significant number of cattle are transported from the Northern Territory to Queensland, particularly en-route to feedlots and abattoirs. Figure 15 shows the rail component of the cattle transport, where the demand at loading points was based on a 2008 to 2011 average. Figure 16 shows how Figure 16 can be disaggregated into vehicle numbers on each road segment, including directional information. Figure 16 is specifically relevant to the busy road corridor between Roma and Toowoomba. Note that segments are not of equal length.

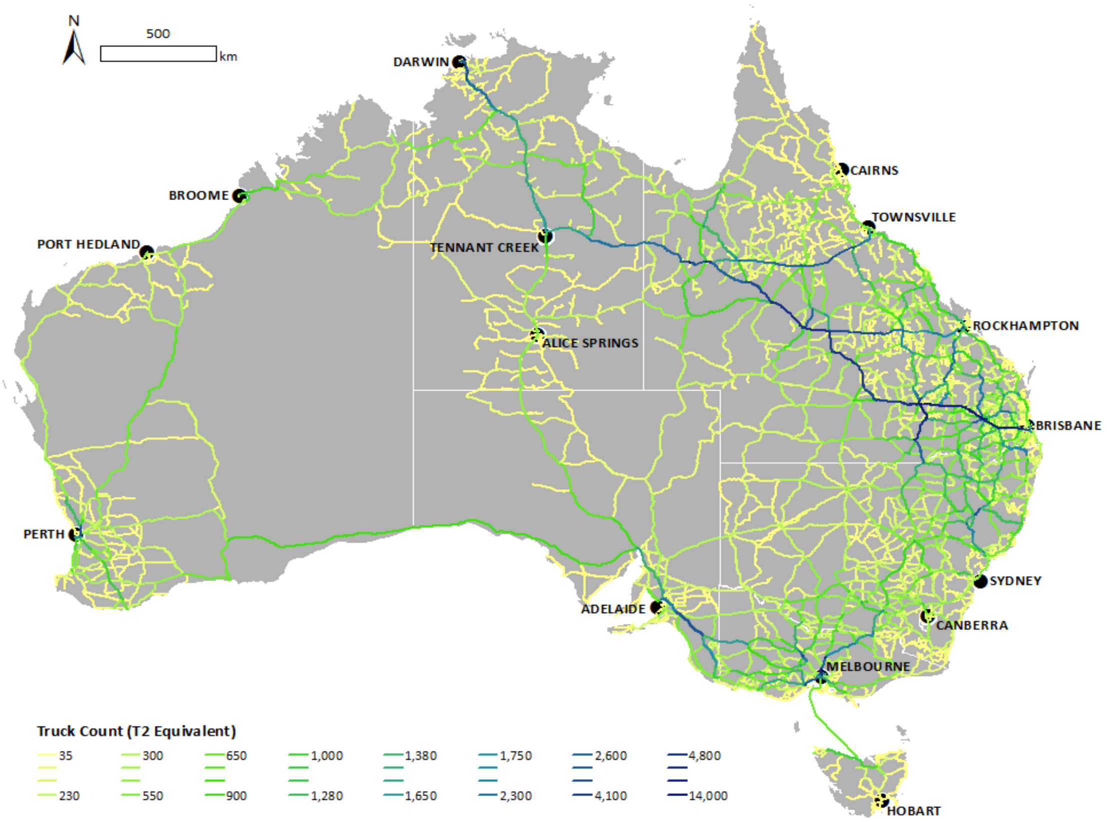

Figure 16 Livestock vehicle numbers across the Australian road network as estimated by TraNSIT, for an average year

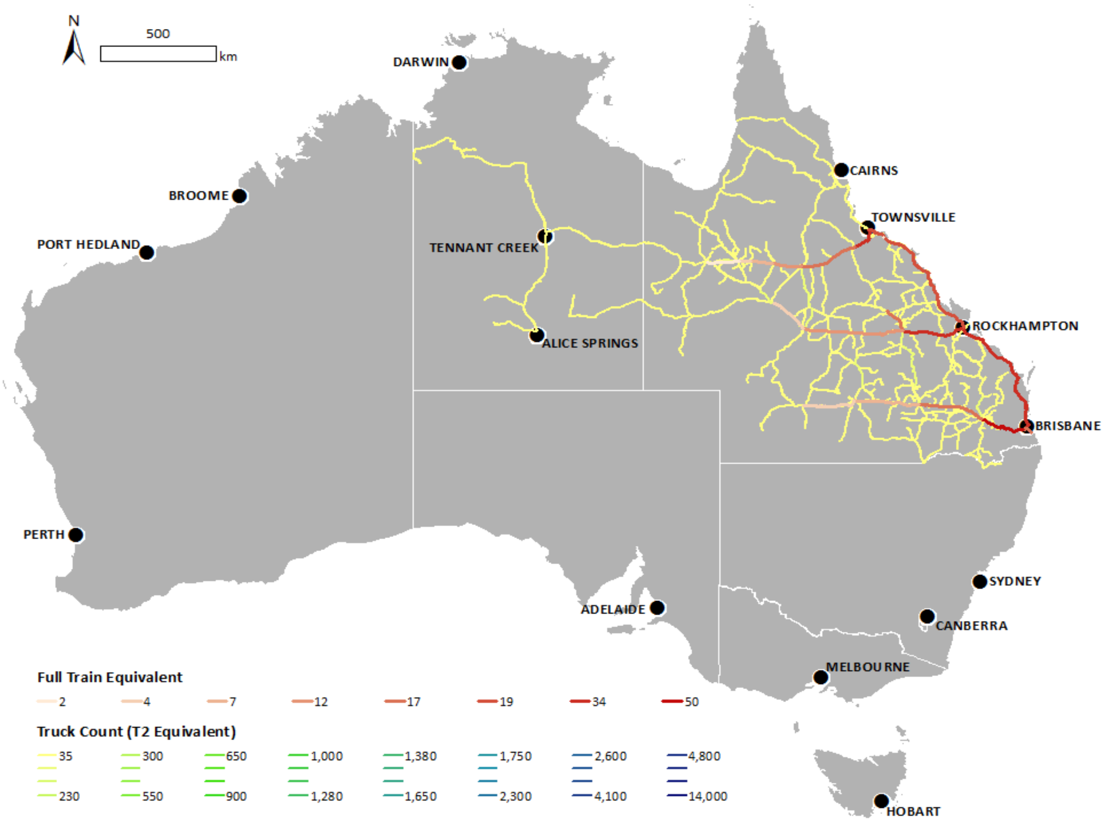

Figure 17 Vehicle counts across the Australian rail network (year average)

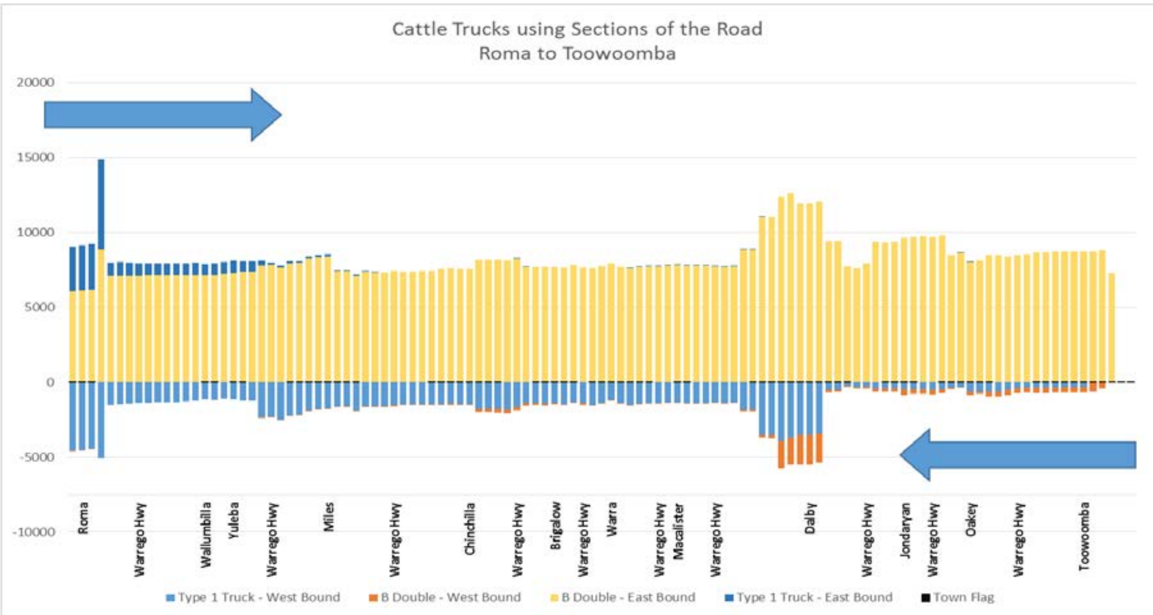

Figure 18: Modelled number of cattle vehicle by road segment between Roma and Toowoomba. Arrows indicate whether vehicles travel from Roma to Toowoomba (top) or from Toowoomba to Roma (bottom). Segments are not of equal length. There are higher vehicle counts in towns (e.g. Dalby) due to intersections with north-south traffic.

Table 12 shows the total cost of transport broken down by enterprise type. Results for each state were for trips where the destination resides in that state. Costs were separated out for driving (i.e. when the vehicle is moving), breakdown of vehicles into smaller configurations, and costs associated with stopping for driver rests. For all Australia livestock transport, the total cost was about $261 million and this would almost be doubled to $490 million to accommodate for return trips of empty trailers. Cattle transported to properties and abattoirs represented the highest total and costs per head. Costs of transport to abattoirs were high due to these enterprises being predominately located in regions limited to B-Double access. Low transport costs to ports were due to the close proximity of export depots to the major ports (e.g. Darwin, Townsville, Wyndham) from which live animals are exported.

Table 12 Summary of transport costs to each enterprise type

Destination Enterprise	Total Cattle	Total Costs	Total Driving Cost	Total Breakdown Cost	Total Costs of Driver Fatigue Stops	Cost Per Head
Property	7659600	$84,050,193	$67,384,651	$3,070,656	$4,154,662	$10.97
cost per head		$10.97	$8.80	$0.40	$0.54	
Abattoir	5495760	$110,764,410	$89,284,062	$3,443,216	$5,927,907	$20.15
cost per head		$20.15	$16.25	$0.63	$1.08	
Saleyard	3400080	$39,668,245	$30,421,316	$1,159,381	$962,747	$11.67
cost per head		$11.67	$8.95	$0.34	$0.28	
Feedlot	2697360	$17,230,714	$11,961,824	$839,674	$515,542	$6.39
cost per head		$6.39	$4.43	$0.31	$0.19	
Export yard	753600	$7,204,863	$5,840,464	$237,849	$395,300	$9.56
cost per head		$9.56	$7.75	$0.32	$0.52	
Port	759780	$3,078,272	$2,227,685	$64,094	$11,623	$4.05
cost per head		$4.05	$2.93	$0.08	$0.02	

6.1 Transport Cost Maps

This section provides maps (Figures 19,20) showing the average transport costs per head (not including backloading cost) from origin enterprises to their destination enterprise across Australia for trips to saleyards and abattoirs. In most cases enterprises in central and northern Australia had the highest costs for that supply chain leg. There are a few considerations when interpreting these graphs. Firstly enterprises are not evenly distributed, and the enterprises with the higher transport costs (larger circles) are much fewer than the enterprises with lower costs. Secondly the costs are not reflective of travel to the nearest destination enterprise but to the one it was allocated to. In many cases (e.g. abattoirs), cattle were transported to facilities much further away from the closest as the nearby facilities often reached capacity during a given month. Thirdly the ability to use Type 2 versus Type 1 and B-Double routes, along with speed limits will impact costs. A good example of this is high costs to saleyards and abattoirs from enterprises west of Cairns. Those enterprises would navigate to the Townsville (or other) abattoir in B-Doubles at slower average speeds compared to trips from enterprises further south-west (e.g. >150km) of Cairns.

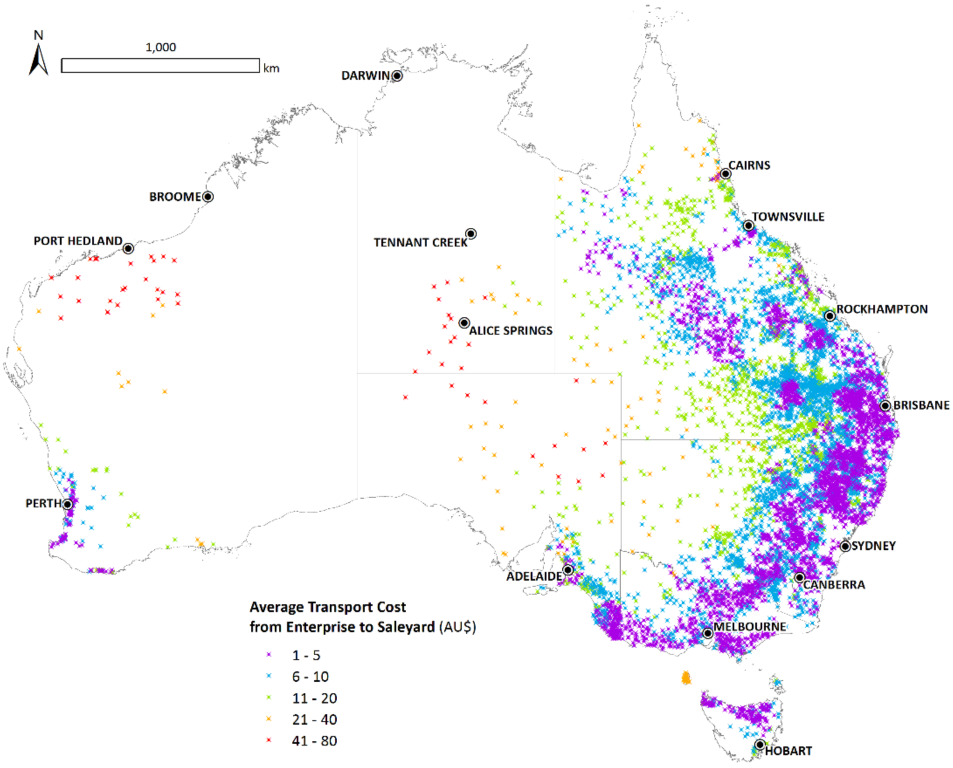

Figure 19 Average cost of transport costs to Saleyards

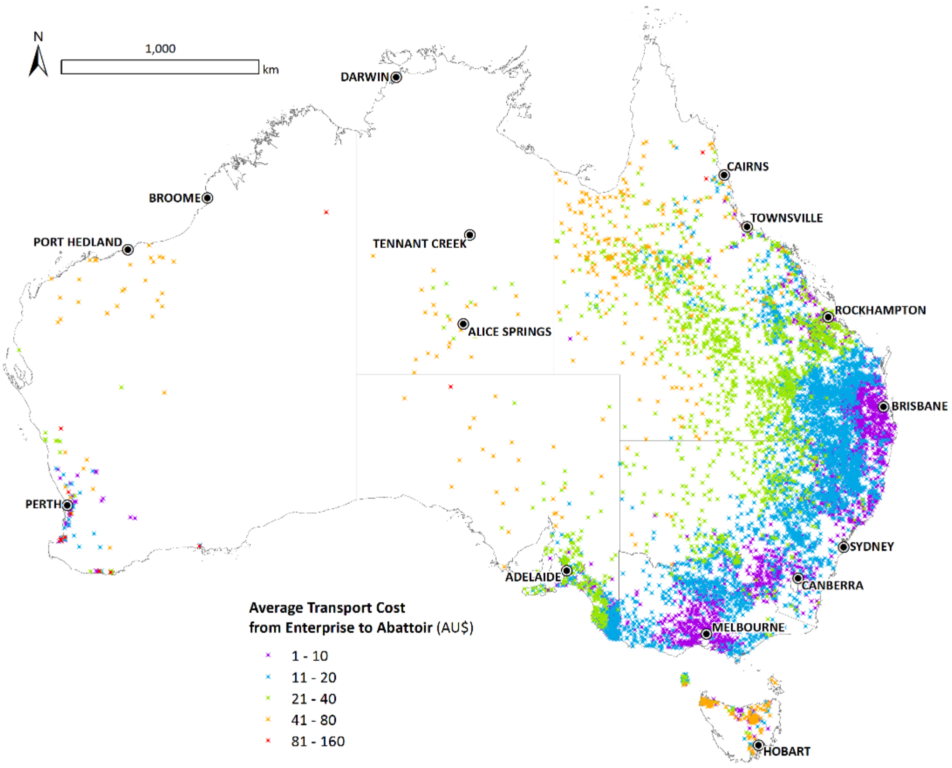

Figure 20 Average cost of transport costs to Abattoirs

References

AusVet Animal Health Services (2006). A review of the structure and dynamics of the Australian Beef Cattle Industry. A Report to the Australian Department of Agriculture, Fisheries and Forestry.

Durr P, Graham K, Eady S. (2010). GIS mapping of cattle market service areas using the National Livestock Identification System. Final Report Submitted to Australian Biosecurity CRC.

Higgins A, Watson I, Chilcott C, Zhou M, Garcia-Flores R, Eady S, McFallan S, Prestwidge D, Laredo L. (2013). Optimising Capital Investment and Operations for the Livestock Industry in Northern Australia. The Rangeland Journal, 35, 181-191.

Higgins A, McFallan S, Laredo L, Prestwidge D, Stone P. (2015). TraNSIT- A model for simulating infrastructure and policy interventions in agriculture logistics: Application to the northern Australia beef industry Computers and Electronics in Agriculture. Computers and Electronics and Agriculture, 114, 32-42.

Higgins AJ (eds). (2013). Livestock Industry Logistics: Optimising Industry Capital Investment and Operations. CSIRO Sustainable Agriculture Flagship.

McFallan S, Higgins A, Prestwidge D, Laredo L. (2013) A GIS model for simulating infrastructure investments in livestock logistics: Application to the northern beef industry. Proceedings of the 2013 MODSIM, Adelaide.

Metang (2010). Feasibility of Establishing a Northern Western Australian Beef Abattoir. RIRDC Publication No. 10/214.

Appendix A Brisbane Workshop Agenda

Cost of Transport and Regulatory Constraints in Cattle Supply Chains Stakeholder Meeting

Date: 15th August 2014

Time: 12:00pm

Venue: MLA Brisbane office. Board Room.

Attendees: To be confirmed from Cattle Council, Australian Lot Feeders Association, Red Meat Advisory Council, AgForce, DAFF Queensland, Livestock and Rural Transporters Association, MLA and CSIRO.

Goals and Desired Outcomes

- Participants gain a clear understanding of how the logistics tools can benefit the livestock industry
- Identify priority infrastructure and/or policy scenarios for analysis, with a nominated champion and action plan (data needs, others to consult, timelines) for each scenario to progress it.

Time	***Topic***	***Presenter***
12:00 pm	Lunch – catering provided	
12:30 pm	Welcome, Introduction and context to the meeting	Paul Fry
12:45 pm	Livestock Logistics tools and baseline analysis - Overview of tools developed to date - Demonstration - Outline of proposed work	Andrew Higgins
1:30 pm	Identify priority transport infrastructure and regulatory scenarios, including specific geographic based scenarios. - Shortlist - Actions for outlining requirements to evaluate each scenario - Coffee break	Paul Fry and Andrew Higgins
3:30 pm	Next steps - Identify contacts for ongoing development of case studies - Communication plan	
3:45 pm	Close	

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