ASSESSING MINING IMPACTS ON ROAD TRAVEL CONDITIONS IN AN INTENSIVE COAL MINING REGION IN AUSTRALIA: A CASE STUDY OF THE NORTHERN BOWEN BASIN

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ABSTRACT: Road transport networks are essential for the sustainability of mining activities as well as the liveability of mining communities. This paper examined the impacts of mining activity on road travel conditions in the Bowen Basin region. A pressure-state-impact-response (PSIR) framework was used to identify the impacts of mining activity. Pressure (i.e., development), state (i.e., change) and impacts (i.e., effects) were identified by reviewing environmental impact assessments of selected coal mines' travel trips and commodities flow modelling. Following this a household travel survey was distributed to residents of the Moranbah and Emerald townships in order to explore mining communities' level of satisfaction with their road travel experiences. The study found that the poor pavement condition, safety and congestion was associated with over-dimensional vehicles. Other issues raised included perceptions of poor driver behaviour, particularly in regard to speed, inattention and fatigue. The research identified road user's support for confining the movement of wide loads to low-traffic periods (such as overnight), and introducing carpooling arrangements to reduce congestion and addressing the issues of accidents and driver fatigue. These findings have planning implications to future transport planning in the Bowen Basin region as well as other inland and intensive mining regions.

KEY WORDS: Road travel experience, intensive mining region, Queensland.

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1. INTRODUCTION

Mining projects have significant impacts on transport infrastructure, housing and human services in mining towns (Akbar *et al*., 2013; Miles and Kinnear, 2008). An effective transport network is essential to both ongoing growth of the resources sector, as well as to the sustainability of the regions that host resource development activity. For mining companies, modern and efficient transport infrastructure is necessary in order to move its product from mine to market; to enable easy, safe and effective employee access; and to provide for the non-coal freight supply to both construction and mining operations activities (DTMR, 2013; Kinnear *et al*., 2014). Transport infrastructure is also essential for day to day travel by residents of both rural and mining communities. However, regional communities can be negatively impacted through poor transport conditions and pressures on small businesses (Kinnear *et al.*, 2014). These problems are magnified where multiple mining operations are located in close proximity to mining towns. For instance, about 75 per cent of coal mining operations in the Bowen Basin region are within the proximity of the Moranbah and Emerald townships (DNRM, 2016). This paper aimed to assess the impacts of mining activities on road travel condition within the proximity of these two towns. Furthermore, it will provide some guidelines for regional transport planning in the Bowen Basin region.

2. THEORETICAL DOMAIN AND METHODS

Transport impact assessment is a comparatively new component to the fully-fledged environmental impact assessment process in Australia, especially in the coal mining sector. In Queensland (Qld) currently, transport impact assessment has been considered under the social impacts section of Environmental Impact Statements (EISs) (DSDIP, 2013). There appears to be a paucity of published research that has been undertaken on the impacts of resource development on regional transport systems. This is true both in Australia as well as in other countries experiencing rapid growth in resource development (e.g. Canada, Mongolia, Ghana and South Africa) (Jackson, 2015; Kinnear, 2013). A key challenge in transport impact assessment for major resource projects is to identify a process for impact assessment and mitigation. This can be illustrated with major resource developments in the Bowen Basin in Queensland, where rapid development of new coal mines and changing employment and social patterns has led to varying impacts on existing transport systems. Any development (pressure) makes changes to the current community and social setting (state), the pressures create changes (impacts), and impacts need to be addressed (response) in order to maintain community sustainability. This equation of pressure, state and impact on one side and response on the other side is generally known as the ‘Pressure-State-Impact-Response (PSIR)’ model (Figure 1). This framework is often used for impact identification and estimation (Akbar *et al*., 2013; Svarstad *et al*., 2008; Wolfslehner and Vacik, 2008) as well as impact management to some extent (Bowen and Riley, 2003; Storey and Jones, 2003)

This study used the PSIR framework to identify the mining impacts on road travel condition as well as to identify some guidelines (i.e., response) that may help to minimise the impacts on the mining communities (Figure 1). This study also entailed a case study approach with quantitative methods for data analysis and a focus on illustrating mining transport pressure and perceived road travel effects within the studied mining communities.

The study collected information and data on mining vehicles and road travel items from the EISs of sixteen mining projects, for which EISs were available online. This information was then organised into construction and operation phases of the mining project. Following this categorisation, a discussion of the potential impacts on the current road travel system is presented. Data on wide load vehicle movements, fatigue and accidents in a selected highway (the Capricorn Highway) was collected from the Queensland Department of Transport and Main Roads (DTMR). This study used spatial interaction theory, specifically a gravity model (see details in Rodrigue *et al*., 2013), in order to identify current and future trip generations (i.e., state and pressures described in Figure 1) between the towns within the northern Bowen Basin, based on the journey to work (JTW) data.

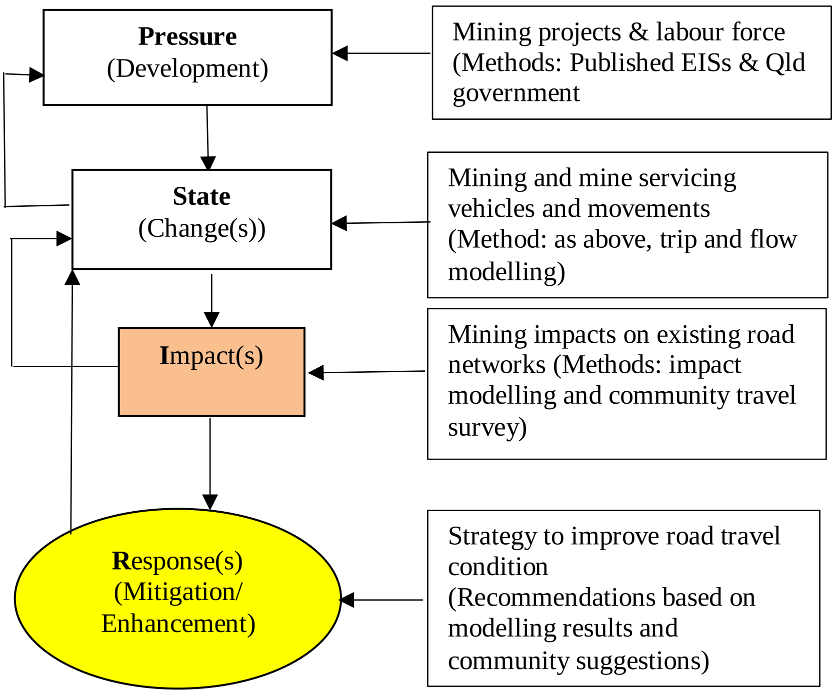

Figure 1: PSIR Model and its Application in Assessing Mining Impacts on Road Travel Condition. Source: Based on Akbar *et al*. (2009), Storey and Jones, (2003) and Svarstad *et al*. (2008).

A household travel survey was conducted to understand the community's perceptions about the mining transport impacts on two mining communities, Emerald and Moranbah (Figure 2). A simple random sampling method was used to determine the sample size from a total household number (i.e., the sampling frame) of 7 540 i.e., total resident householders in Emerald and Moranbah (OESR, 2013). Under a 90 per cent confidence level, a sample size of 112 was determined and targeted for this study by adopting an online survey. This survey was made available for participants to complete online from late November 2013 until late February 2014. To maximise the participation rate, an incentive prize pool was made available; project information was disseminated through various professional and regional networks; a social media campaign was conducted through CQUniversity's Facebook, Twitter and LinkedIn accounts; and a public media campaign was used, including print and radio coverage across the broader Central Queensland region.

Despite this combination of awareness about the survey, the number of respondents (i.e., 76) was lower than the targeted sample size of 112 (less than the 90 per cent confidence level) but higher than the sample size of 69 (the 80 per cent confidence level). Therefore, the survey findings must be interpreted with caution due to sample size and confidence level. A total of 70 out of 76 responses from households was used.The survey attracted a diverse profile of respondents, summarised briefly below:

- by occupation, participants ranged from entry-level retail and trades roles (newsagent, labourer), through to paraprofessional and professional roles (paramedics, doctors, accountants);
- the average length of (residential) stay was 9.2 years, with the maximum recorded being 44 years;
- the average reported household size was 3.2 people, with a maximum of 7 people;

With respect to transport data, participants indicated that the average number of vehicles per household was 2.4, with the maximum being eight in a single household. Overwhelmingly, participants and/or their household members appear to travel using private modes, with only five instances of public bus travel being reported across all participating households.

A Chi-square test and logistic regression model were used to ascertain the likely effects of independent variables on the dependent variable (i.e. respondent's satisfaction with the road condition). Responses from the open-ended questions (used in this survey) supported by the findings from EIS review, trip and flow modelling, were then used to prepare strategies to improve road travel condition.

3. PRESSURE AND STATE OF MINING ON THE ROAD TRANSPORT SYSTEMS: NORTHEN BOWEN BASIN

The Bowen Basin is an area of coal reserves and mining related communities that extends over approximately 60 000 square kilometres of Central Queensland (CQ), Australia. In 2014-15, it represented 80 per cent of the Queensland's saleable coal production and about 80 per cent ($1.61b) of the mining royalties paid to the state were attributable to coal sales (DNRM, 2016). The Capricorn highway connecting the east and west boundary of the Bowen basin divides the area into two subregions: the southern region, which is a mix of mining and agricultural land use and the northern Bowen Basin, which is an intensive coal mining region (Figure 2).

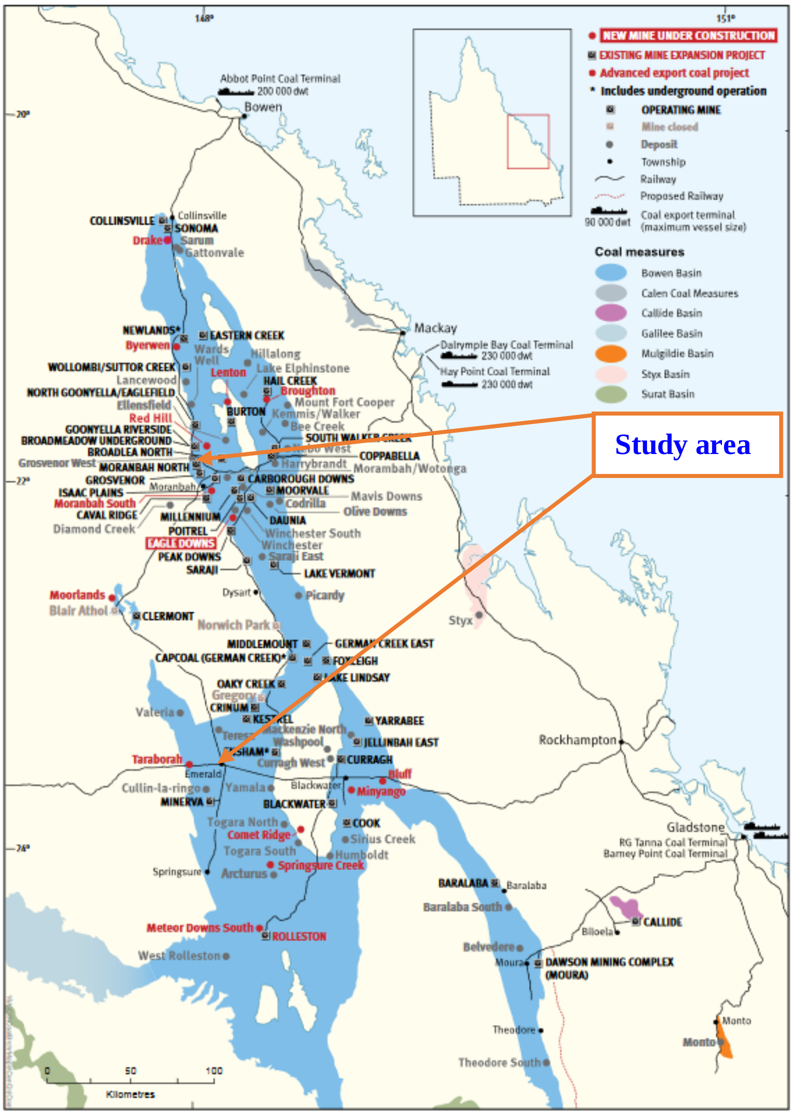

Figure 2. Queensland Coal Mines and Advanced Projects – Bowen Basin. Source: DNRM (2016).

In this study, the northern Bowen Basin region was chosen as a case study to represent mining intensive regions in Australia, as well as to capture information on region-wide transport impacts that mostly arise from coal mining activities.

As indicated above, a desktop review, targeting EIAs lodged since 2009 for the region of interest, was undertaken to identify the nature of the road and transport impacts. A total of nine EIAs for coal development projects in the northern Bowen Basin region were reviewed in this study. Three coal projects in the Galilee Basin were included because these were expected to impact on the Capricorn highway. At the time of the research being conducted, there were also four additional coal projects that had EIS documents approved which were also included in this research. In addition, a further five were in the initial stages of EIS preparation. A total of sixteen coal mining projects out of 42 (DNRM, 2017), i.e. 38 per cent of the total coal mines in the northern Bowen Basin, were included in the study. Thus, it is expected that the findings from this EIS review would capture most road transport related pressures and states within the case study region, and that the pressures would be indicative of those experienced in other intensive mining regions in Australia.

Over-Size and Over-Mass (OSOM) Loads

Estimates for the number of over size and over-mass (OSOM) loads expected for a site were prepared based on projections for the supply of equipment and materials. For example, in the construction phase, this may include deliveries of vehicles and equipment (e.g. earthmoving, cranes and water trucks), building supplies (including modular units used to administration buildings), fuel, concrete and steel. In the operational phase, OSOM loads may include periodic transport of ongoing supplies such as oil, fuel and waste removal.

An analysis of OSOM estimates for resource development sites in the Northern Bowen Basin shows that the number and type of loads varies greatly across the different sites (Table 1).

Table 1. Summary of the Heavy Vehicle Loads Associated with Resource Development Sites in the Northern Bowen Basin.

Mine site and total production per year	Construction Phase	Operations Phase
Caval Ridge (5.5 mtpa)	Average 3 881 deliveries by Type 1 Road Train and Single articulated vehicle. Average 2 100 deliveries by concrete transit vehicle. Oversized vehicles: Not determined to date.	1 175 annual deliveries by single articulated vehicle.
Daunia (4mtpa)	Approximately 60 oversize loads, delivering indivisible construction and mining equipment; with primary load origin being Brisbane (20%) or Mackay (80%). 16 deliveries per day of construction materials/ infrastructure modules, through a combination of eight over-dimensional, semi-trailer and single unit truck loads.	5 to 10 semi-trailers per week. No further information regarding ODL was provided.
Galilee Coal (40 mtpa)	290 heavy vehicle movements per day.	180 vehicle movements per day.
Kevin's Corner (30mtpa)	Average of 8 ODVs per day.	Average of 2 ODL movements per day.
Alpha Washpool (30 mtpa)	8 single truck units daily. 8 articulated vehicles daily. Pilot escorted oversize vehicles: approximately, 65 construction loads and 47 mining fleet loads in total. Police escorted oversize vehicles: Approximately 36 construction loads and 35 fleet load in total. Approximately 200 general loads in total.	8 single truck units daily. 14 articulated vehicles daily. Oversize vehicles may be required during operations, but no specific figures were provided.
Codrilla (4mtpa)	Up to 10 truck (heavy vehicle) movements daily. Proponent indicated it would obtain relevant permits for OSOM vehicles, but no specific figures given.	Up to 3 truck (heavy vehicle) movements daily Proponent indicated it would obtain relevant permits for OSOM vehicles, but no specific figures given.
Drake (10mtpa)	239 semi-trailers/year. 40 tankers/year. 1000 mixer (concrete)/year. 273 AB-triple/year. 210 general truck/year.	408 tankers/year. 210 general trucks/year.
Eagle Downs (7mtpa)	Not available.	Not available.

Note: ODV = over-dimensional vehicle, ODL= over-dimensional loads, and OSOM= over size and over-mass. Source the Authors using data from EIS documents.

Table 1 (Continued). Summary of the Heavy Vehicle Loads Associated with Resource Development Sites in the Northern Bowen Basin.

Grosvenor (7mtpa)	Approximately 90 ODVs to deliver machinery and materials to site.	A limited number of deliveries of large indivisible materials and equipment.
Middlemount Stage 2 (1.8 mtpa)	Estimated range of 0-4 vehicles per day between 2011- 2019; overweight/hazardous goods movement unknown	Estimated 4 heavy vehicles daily.
Minyango (9mtpa)	16 heavy vehicles per day (materials). An undetermined number of escorted ODVs.	12 heavy vehicles per day (materials). An undetermined number of escorted ODVs. Road transport task of 50 000 tonnes per year (t/year) of ROM coal to the Cook Colliery.
Springsure Creek (9mtpa)	Total 1 182 trucks over the 24 month construction timeframe, equivalent to 1.6 heavy vehicles per day. Approximately 80% originate from the local area.	Total 51 077 heavy vehicles over the anticipated 40- year life of the mine, equivalent to 3.5 heavy vehicles per day. A large proportion is expected from non-local destinations.
Eaglefield (5.2 mtpa)	Range of 580 - 7528 heavy vehicle movements per annum. Of 14 movement categories, approximately 10 are oversized vehicles, ranging from one per month up to 15 per week depending on construction phase.	Approximately 54 heavy vehicle movements per week, for the life of the mine.
Newlands Expansion (11 mtpa)	Not available.	Not available.
Foxleigh (3.2 mtpa)	Not available (project mothballed).	Not available (project mothballed).
Millennium Expansion (5.5 mtpa)		38 oversized movements in 2011, then 22 oversized per year, 780 hazardous movements per year.

Note: ODV = over-dimensional vehicle, ODL= over-dimensional loads, and OSOM= over size and over-mass. Source the Authors using data from EIS documents.

It was also noted that EIS documents themselves varied widely in terms of the depth of detail provided for transport activities and impacts. For example, it would have been particularly useful to be able prepare an estimate of the likely number of heavy loads, standardized to production tonnages, as this value could then be used as an indicative guideline in future planning. However, this kind of exercise was frustrated by the variation in the level of detail provided by each proponent, and by differences in the ways that the information was presented. For example, some statements quoted daily or weekly movements, whereas others referred to peak activity periods, values for the overall construction and/or operational phases, and/or figures for the overlap period between construction/operation. Details on expected liquid loads (e.g. transport of ongoing fuel supplies) were mentioned in only some of the EIS documents. It was difficult to distinguish these movements from other heavy-vehicle traffic (such as that required for waste removal or other general supplies). In several instances, the potential use of over-dimensional vehicles to transport indivisible pieces of plant and equipment were flagged, but no specific figures were provided except to mention that negotiations with police escort and/or commercial pilot vehicles would follow as more details came to hand. Therefore, the size and number of mining vehicles may have been linked with substantial pressure on the existing road system and consequent low to high level of impacts such as accidents and fatalities, delays and congestion in the road travel system, especially in the Capricorn Highway (Kinnear *et al.*, 2014).

Workforce Transport

All EIS documents are required to estimate the vehicle movements generated by resource sector employees, across both the construction and the operational periods. As might be expected, these also varied widely, according to the location and nature of the sites and the employment strategy being proposed. The latter included the split between residential and non-residential employees as well as the overall proportions of company and contractor/subcontractor personnel. As was observed for the wide-loads estimates, it was very difficult to scan across sites and develop any ‘average’ measures relating to workforce transport, because of the genuine differences in the workforce approach used at each site, as well as variation in the reporting style used (Table 2).

Table 2. Summary of Workforce Transport Figures for Resource Development Sites in the Northern Bowen Basin (data current as at date 2013).

Mine site	Construction Phase	Operations Phase
Caval Ridge	Approximately 5 128 two-way bus movements per annum. Bus service for 80% of workforce, remaining 20% by private/company vehicles.	165 two-way private vehicle movements daily. Bus service for 70% of workforce, remaining 30% by private/company vehicles. Less volume of personnel noted for maintenance shutdown periods.
Daunia	106 daily light vehicle (private car) trips. 14 bus trips. Mix of private cars and buses (80% buses). Average occupancy 1.5 persons per vehicle.	Average 134 daily light vehicle trips, concentrated in morning and evening shift change periods. Off-site workforce to travel to/from site by light vehicle (50%) and two provided shuttle buses (50%). Average occupancy 1.5 persons per (light) vehicle.
Galilee Coal	1450 vehicles per day.	900 vehicles per day.
Kevin's Corner	69 light vehicles (workforce plus materials transport).	33 light vehicles (workforce plus materials transport).
Alpha Washpool	4 chartered bus, 15 private vehicles (on-shift). 307 private vehicles (shift change).	5 chartered bus, 48 private vehicles (on-shift). 170 private vehicles (shift change).
Codrilla	Between 7 and 12 minibus vehicles daily. 10 private light vehicles daily.	Between 5 to 9 bus vehicles Up to 6 private vehicles daily.
Drake	5 buses daily (one way). 33 light vehicles (3 persons per vehicle).	7 buses daily (one-way). 43 light vehicles (3 persons per vehicle).
Eagle Downs	Not available.	Not available.

Source the Authors using data from EIS documents.

Table 2 (Continued). Summary of Workforce Transport Figures for Resource Development Sites in the Northern Bowen Basin (data current as at date 2013).

Grosvenor	Not stated.	24 one-way daily bus movements. 178 one-way private vehicle movements per day
Middlemount Stage 2	Varies according to year of construction, but with a range of 0-10 private vehicles daily and 0-6 shuttle bases daily, between 2011 and 2019.	5 private vehicles daily, 8 shuttle buses daily
Minyango	18 bus movements and 12 light vehicle movements per day	12 bus movements and 59 light vehicle movements per day
Springsure Creek	3 buses and 30 light vehicles daily (dayshift) 2-3 buses and 17 light vehicles daily (night shift) Overall total of 135 vehicles per day including workforce and service vehicles	6 buses and 59 light vehicles daily (dayshift) 6 buses and 34 light vehicles daily (night shift) Overall total of 2 vehicles per day including workforce and service vehicles
Eaglefield	1 bus daily 2 light vehicles daily	4 buses daily, 9 light vehicles daily
Newlands	Not available^	Not available^
Foxleigh	Not available (project mothballed)	Not available (project mothballed)
Millennium Expansion	4-6 shuttle buses and 4 light vehicles (95% BIBO and 5% private light vehicles)	12 bus movements and 8 light vehicles (95% BIBO and 5% private light vehicles)

Source: the Authors using data from EIS documents

Road Traffic and Trips

As mentioned earlier, current and future trips were estimated by a spatial gravity model based on ABS' JTW data, in order to depict the changes (i.e., state) in road traffic conditions within the northern Bowen Basin. Mackay was predicted to experience the highest number of daily trips by 2021, followed by Rockhampton, Gladstone, Moranbah, Emerald and Blackwater (Table 3). Table 4 also presents the predicted increase in trips under three growth scenarios (i.e. low, medium and high) within the six towns in the CQ region. Even under the low growth (conservative) scenario trips within these six towns will be increased by 10.9 per cent in 2016 and 21.6 per cent in 2021. Under the medium growth scenario, which is considered the most likely of the scenarios to be realised, those increases will be 14.2 per cent and 27.9 per cent respectively by 2016 and 2021.

Coal exports are already high in Australia, and production increases are continuing although construction is waning; it is thus not expected that CQ will experience the high growth scenario within the short period of time. However, should this eventuate, the number of daily trips may be increased up to 35 per cent by 2021. It should also be noted that the table of information predicts only passenger trips; if freight and other commercial journeys are included (based on the proportion AADT counts by vehicle types on a segment in Capricorn Highway, see Queensland Government 2013a), then the expectation is that the number of trips will increase by a further 28 per cent. Furthermore, it should be acknowledged that up to one-quarter of vehicle trips are already generated by wide load, heavy and commercial vehicles, and that this traffic profile may continue to pressure the regions' road transport infrastructure, should this trend continue.

Table 3: Number of Daily Passenger Trips Generated in Six Towns in and Around the Northern Bowen Basin Region.

Towns	2011	Low		Medium		High	
		2016	2021	2016	2021	2016	2021
Rockhampton	21 706	23 347	886	23 684	25 724	24 153	26 762
Gladstone	15 235	17 273	988	18 125	20 850	18 897	22 225
Blackwater	3 672	4 105	4 503	4 204	4 740	4 315	4 969
Emerald	6 352	7 100	7 790	7 272	8 200	7 463	8 595
Mackay	***21 816***	***24 190***	***539***	***24 912***	***28 112***	***25 698***	***29 573***
Moranbah	4 930	5 748	6 235	6 008	6 677	6 262	7 255
Total	73 711	81 763	941	84 205	94 304	86 788	99 378

Source: Authors estimated from ABS (2008; 2012).

Table 4: Daily Passenger Trip Increase (%) in Six Towns within the CQ Region, 2016 to 2021.

Towns	Low		Medium		High	
	2016	2021	2016	2021	2016	2021
Rockhampton	7.6	14.6	9.1	18.5	11.3	23.3
Gladstone	13.4	24.6	19.0	36.9	24.0	45.9
Blackwater	11.8	22.6	14.5	29.1	17.5	35.3
Emerald	11.8	22.6	14.5	29.1	17.5	35.3
Mackay	10.9	21.6	14.2	28.9	17.8	35.6
Moranbah	16.6	26.5	21.9	35.4	27.0	47.2
Total	10.9	20.7	14.2	27.9	17.7	34.8

Source: Authors estimated from ABS (2008; 2012).

4. MINING IMPACTS ON ROAD TRAVEL CONDITION

Information obtained through identification and predictions of traffic and commodities flow, accidents and ODV movements from DTMR data; as well as community's road travel experiences obtained from household travel surveys were utilised to illustrate the mining impacts on road travel condition.

Commodity Flows, ODV Movements and Accidents

The Capricorn Highway, linking eastern and western boundary of the Bowen Basin, currently carries large volumes of freight (Figure 3). In total, there are three different directions of commodity flows: the first is the outbound flow of coal from the mining areas to the ports, which is efficiently transported by rail. However, outbound freight also includes meat and livestock as well as grains and cereals, which is generally moved by road transport. The second is the inbound flow of petroleum products to the region, which is within the production systems as well as for household consumption. The third is the two- way flow of general freight, which includes both inbound and outbound forms (Figure 3).

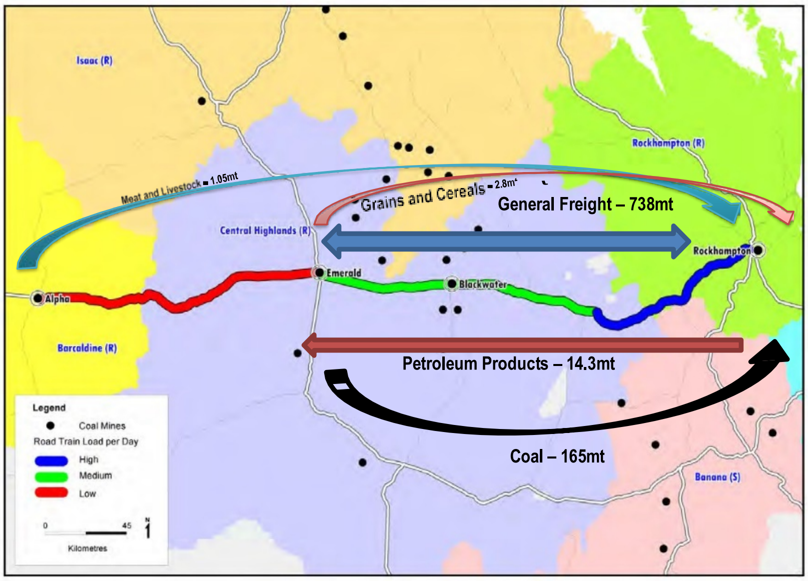

Figure 3. Freight Movement along the Capricorn Highway between Alpha and Rockhampton (2012). Mt = Million Tonnes.
Data source: Queensland Government (2013a and b).

The route from Rockhampton to Emerald through to Alpha carries a large volume of road train load, particularly along the Capricorn Highway Corridor (Figure 4). The heavy road train load per day particularly between Emerald and Rockhampton is often recognised to disrupt or slow down the traffic flow, cause transportation delays and bottlenecks, or potentially result in damage to road infrastructure. Furthermore, there is also an elevated risk of road accident or fatality with increased utilisation of road infrastructure for freight. As Figure 4 shows, a high loading of road trains per day tended to co-occur with an increased number of accidents per month along the Capricorn Highway corridor during 2012. However, there is currently insufficient data to draw any causal link between these two, and there may also be a range of confounding factors: for example, the higher number of accidents closer to Rockhampton could also be associated with higher traffic volume (e.g., commuters).

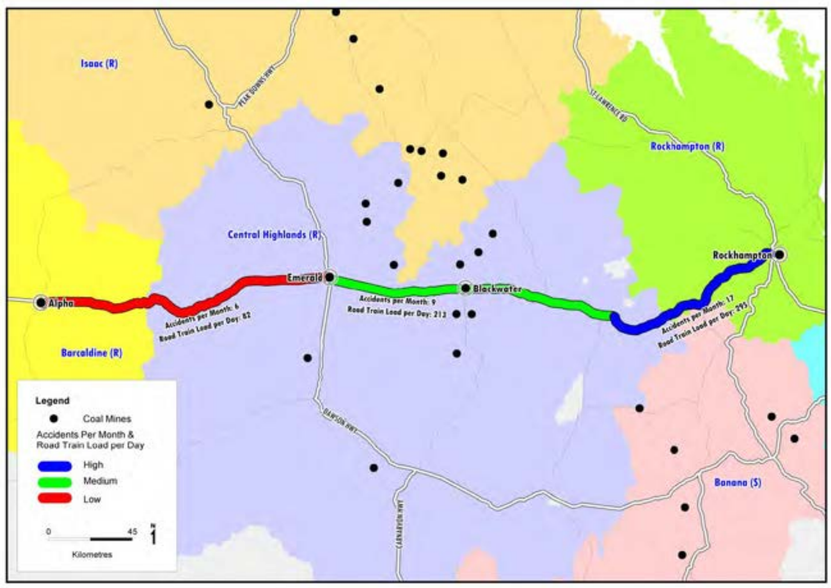

Figure 4. Road Train Load (per day) and Frequency of Road Accidents (per month) along the Capricorn Highway During 2012.
Data source: RAAG (2012; 2013).

Perceived Quality of Road Transport Condition

A mix of responses were recorded regarding participants' levels of satisfaction regarding their road travel experience in the Bowen Basin (Figure 5). Overwhelmingly, the principal issue that was raised with respect to road travel was that of road quality, with participants citing problems with potholes, narrow shoulders, inadequate signing, line marking and lighting, inadequacy in the number of passing lanes, the unsatisfactory quality of road works, and the delay that road work activity caused to travel time. Many participants reported experiencing damage to private or company-owned vehicles as a result of poor road quality. Other concerns included safety and congestion issues associated with over-dimensional vehicles; and perceptions of poor driver behaviour, particularly around speed, inattention and fatigue.

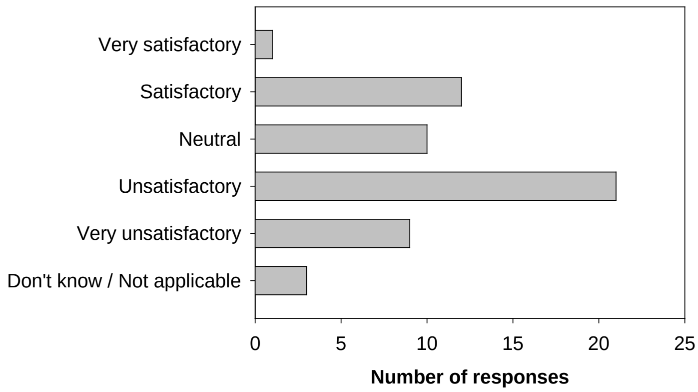

Figure 5. Respondents' Level of Satisfaction with Road Experiences in the Bowen Basin. Source: the Authors.

A detailed statistical analysis of the satisfaction data was undertaken, to detect whether there were any significant factors underpinning residents' satisfaction with the quality of road condition in Emerald and Moranbah. This was conducted by way of cross-tabulations accompanied by Chi-Square testing; however, to meet the statistical assumptions, some variables were collapsed into smaller groups. This was necessary due to the relatively small sample size of the resident's group.

The five original satisfaction levels (from 'very satisfied through to very dissatisfied') were converted into a binary variable (either 'satisfied' or 'dissatisfied'). This allowed the satisfaction of residents to be compared across different socio-demographic categories and the travel-related characteristics of survey participants. However, this exercise revealed that satisfaction with the roads was significantly influenced only by employment status, occupation and the number of journeys per week (Table 5). In particular, residents were more likely to be dissatisfied with the roads if they worked in trade occupations, if they worked full-time, and/or if they used the roads more frequently (e.g. 5 trips or more per week).

Table 5. Data Summary: Correlates of Residents' Levels of Satisfaction with the Road Travel Experience in the Northern Bowen Basin.

Socio-demographic and travel related variables	Groups	Satisfied	Dissatisfied
Gender			
χ2 = 0.001 df = 1, p = 0.974, Insignificant	Male	42.1	57.9
	Female	41.7	58.3
Age			
χ2 = 868.00 df = 2, p= 0.648, Insignificant	18-44 years	46.0	54.0
	45-54 years	33.3	66.7
	55 years and above	33.3	66.7
Household Income			
χ2 = 0.02. df = 1, p = 0.969, Insignificant	Less than or equal to 100 000	43.8	56.3
	More than 100 000	43.2	56.8
Occupation			
χ2 = 2.73. df = 1, p = 0.0098, Significant	Trade persons and labour work	42.9	57.1
	Others	39.1	60.9
Employment			
χ2 = 2.735 df = 1, p = 0.0095, Significant	Full-time	55.2	74.4
	Others	44.8	25.6
Household type			
χ2 = 0.01 df = 1, p = 0.977, Insignificant	Singles and Couples	42.9	57.1
	Other households	42.5	57.5
Work containment			
χ2 = 1.44 df = 1, p = 0.230, Insignificant	Within the postcode	39.7	60.3
	Outside the postcode	60	40
Length of living in the area			
χ2 = 0.194 df = 1, p = 0.660, Insignificant	Less than or equal to 5 years	39.5	60.5
	More than 5 years	44.8	55.2
Travel time			
χ2 = 1.51. df = 2, p = 0.469, Insignificant	Less than 16 minutes	39	61
	16-30 minutes	37.5	62.5
	More than 30 minutes	58.3	41.7
Number of journeys per week			
χ2 = 7.99 df = 2, p = 0.0018, Significant	Less than 5 trips	47.4	52.6
	5 trips	55.2	44.8
	More than 5 trips	12.5	87.5
Overall Sample (70)		**41.4**	**55.7**

Source: the Authors.

These findings were also corroborated by an alternative statistical approach: logistic regression analysis. Here, a logistic regression model was fitted to the dichotomous variable of 'satisfaction' to ascertain the likely effects of independent variables on the chances of some event occurring while controlling for a variety of different influences. The model produces a set of coefficients that allow for the prediction of a logit, that is, the natural log of the odds of being a 'satisfied' (coded with 1) or 'dissatisfied' resident (coded with 0) with road condition in the Bowen Basin area. The model is specified as:

$$\text{logit}(p) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \text{---} + b_kX_k \text{-----(Equation 1)}$$

where p is the probability that a resident is 'satisfied' or 'dissatisfied' with road conditions. The coefficients b_1, $b_2 \ldots b_k$ are estimated using a maximum likelihood procedure via SPSS software.

Five groups of variables representing socio-demographic and economic variables of survey participants (i.e. gender, age, household income, occupation, household type, occupation) were added to the right hand side of the equation. Other travel-related variables in the model which distinguish journey-to-work patterns of residents include: self-containment (commuting within or outside the place of residence); number of journeys per week, and travel time. The detailed categories for these independent variables from the original survey data were collapsed into two or three groups to eliminate bias arising from a small sample size. This resulted in sufficient observations in each of the groups.

Similar to the Chi-square test results, the regression indicated that people engaged in full-time employment in trade-related occupations or labourers, and who required more frequent travel, are more likely to be dissatisfied with the road condition (i.e. the negative coefficients in Table 6). This effect was particularly strong for trade workers, who were 2.4 times more likely to be dissatisfied with road conditions than non-trade occupations. Interestingly, the time spent on travel to work had no significant effect on satisfaction levels, possibly because most of the survey participants reported travelling within a 30-minute range.

The Cox & Snell R^2 value indicates that the independent variables in the logistic model together account for 31 per cent of the variation in 'satisfied' or 'dissatisfied' responses. Column B in the above table presents the coefficient estimates; a positive value indicates that the variable increases the logit transformation of the probability that a resident is satisfied with road condition. The model distinguished the variables well, with 80 per cent of responses predicted accurately by the coefficient for the variable.

Table 6. Data Summary: Results of the Logistic Regression Analysis Relating to Residents' Levels of Satisfaction with the Road Travel Experience in the Northern Bowen Basin.

	B	**Standard Error**	**Significance**	**Exp(B)**
Constant	0.022	2.220	0.992	1.022
Household Income	1.494	1.054	0.156	0.445
Employment Status	-3.031	1.117	0.007	1.48
Age				
18-44 years			0.601	
45-54 years	0.997	1.275	0.434	1.711
55 years and above	0.138	1.476	0.926	1.148
Occupation (Others, Trade workers and labourers)	0.895	0.943	0.342	2.448
Number of Journeys				
Less than 4 trips			0.189	
5 trips	0.700	1.216	0.564	2.015
More than 5 trips	-1.891	1.102	0.086	6.624
Travel Time				
Less than 15 minutes			0.583	
16-30 minutes	-1.374	1.331	0.302	0.253
More than 30 minutes	-1.328	1.696	0.433	0.265
Containment (within, Outside)	-0.073	1.375	0.958	0.930
Number of Vehicles (One, more than one)	-2.348	1.197	0.050	1.956
Gender	0.540	0.967	0.577	1.715

Here, Chi-square Statistic = 2023.52 d.f. = 8; -2 Log Likelihood = 135935.71; Cox & Snell R^2 = 0.310, Nagelkerke R^2 = 0.416; and Hosmer and Lemeshow Chi-square = 165.07 at 0.05 level of significance.
Source: the Authors.

5. DISCUSSION AND STRATEGIES TO IMRPOVE ROAD TRAVEL CONDITION

The EIS review, trips and flows modelling, accident analysis and mining community's experiences about road travel in the northern Bowen Basin identified a number mining impacts on the road travel condition: increased traffic volumes, overload and over size vehicle movements and their associated impacts to risk profiles, pavement damage, and other social and economic impacts (Table 7). Communities indicated that these are particularly noticeable when there are a significantly increased number of vehicle interactions, especially those involving heavy vehicles; being particularly evident on shared, higher-order routes (e.g. commonly used highways and arterial roads).

In addition, the northern Bowen Basin has a complex multidirectional flow of commodities, in terms of both bulk and containerised freight. This necessitates the development of an efficient transport system that links key mining areas with intermodal nodes such as ports and airports. However, some of the key arterial road networks are increasingly under pressure from the growing demand from inbound and outbound freight such as plant and machinery, petroleum products and building and construction materials (Queensland Government 2013b).

There is a paucity of published materials on the impacts of mining on road travel condition and therefore a comparison of these findings with other studies is very challenging. Nevertheless, the previously mentioned study conducted by Jackson (2015) found air pollution impacts from the heavy vehicle movement in a Mongolian mine, which is a very similar concern to that which was identified in this study. In addition, Gudes et al (2017, pp. 243) found "… *articulated heavy vehicles crashes occurred in the vicinity or within the Perth metropolitan area* …", which is very similar findings to this study (Figure 4) and this would occur because of heavy traffic movements at the beginning of highways (i.e., from a major city centre) compared to the end of highways (i.e., towards remote township). Therefore a multilane and wider road transport system is desirable at the beginning of the highways that originate from major cities. Some of the Western Australian intensive mining regions such as the Pilbara, Kimberly and Mid-West, are also facing the same type of road transport impacts from the mining activities; however, population density in these region are lower than that of the Bowen Basin region, therefore the communities might feel lesser impacts compared to that of the Bowen Basin.

Table 7. A Summary of Mining Impacts on Road Travel Condition: Northern Bowen Basin.

Pressure and State	Impacts
Increased traffic movements and incidents	• Congestion, leading to increased travel time and associated losses in productivity/amenity. • Increased need for emergency services to respond to road accidents due to congestion, fatigued driving, and transportation of fuel/ODL. • Increased need for police patrols and calls for services to deal with traffic and other offences. • Dust pollution from vehicle movements on unsealed roads. • Impacts on the movement of farming and farming equipment during harvesting (due to congestion). • Obstructed movement of stock/congestion at stock crossings.
Movement of police-escorted ODL	• Pressure on existing police resources, as vehicles are required for escort duties.
Transportation of hazardous and/or dangerous goods	• Increased incidence of spills, fires or explosions.
Increased traffic delays	• Disruption of school bus and other public transportation activities. • Increased number of accidents.

Source: the Authors.

This study also asked survey participants to provide suggestions regarding ways in which the current road transport situation might be improved. Participants were asked to volunteer ideas outside of infrastructure solutions, as it had been acknowledged that such items typically involved decadal planning and investment periods, especially those led through state and Commonwealth Government. Rather, the objective was to obtain information about short-term and 'grassroots' responses to road transport concerns. Their responses are summarised in Table 8, with the aid of the supporting findings from the trip and flows modelling and EIS reviews conducted for this study.

Table 8. Strategies to Improve the Road Transport Situation in the Bowen Basin.

Non-infrastructure based	**Infrastructure related**
Investigate alternative/confined hours for wide loads passage (particularly evening).	Confining road works to evening or low-traffic periods.
Incentivise use of rail for freight; encourage back- loading of empty coal trains.	Increase road maintenance and road upgrades.
Increased police presence to address driver behaviour.	Create more highway rest areas.
Increase public transport (buses); increased provision of 'company transport'; carpooling program (including dedicated lanes for vehicles with 2 or more occupants).	Place retail facilities in smaller centres to negate the need for travel.
Increased speed limit on some sections of highway (to 110 km/hour).	Increased towers to address lack of mobile phone reception (safety issue in relation to calling for help in case of road accident).
Introduce direct flights (Mackay-Cairns).	Increased number of overtaking lanes and road widening.
Reduced focus on DIDO/FIFO employment models.	Establish the Eton and Walkerston bypass roads.

Source: the Authors.

There was support for confining the movement of wide loads to low-traffic periods (such as overnight); and several participants commented on the need for carpooling arrangements to reduce congestion and issues of driver fatigue. Many participants cited reckless driving behaviour as a key problem on the region's roads. It is also of note that a recent review by the Queensland Department of Transport and Main Roads recorded strong support for reducing speed limits on the Capricorn Highway (e.g. between Emerald and Dingo townships) (DTMR, 2014).

6. CONCLUSION

This study identified that there were increased traffic volumes and heavy vehicles movements in the northern Bowen Basin. The Capricorn Highway is a heavily used road corridors in the northern Bowen Basin region. Full time workers, trade-persons and frequent travellers are mostly dissatisfied with the road conditions within the northern Bowen Basin region. The frequency of road accidents is higher on the Capricorn Highway between Rockhampton and Blackwater. Respondents are looking for more non-infrastructural solutions to the problem in the short term compared with infrastructural solutions in the long term. The Queensland Government has already undertaken several road improvements and widening programs within the region. However, non-infrastructure solutions such as alternative/confined hours for wide loads passage (particularly evening) may improve the current traffic condition, especially when dealing with wide and heavy load trucks, and accidents. These solutions can be replicated to other mining intensive regions in Australia and elsewhere, albeit with some cautions as economic and demographic variables may vary between various mining intensive regions.

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