PHASE 2A – DISASTER NETWORKS AND LOGISTICS ANALYSIS

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1. Intent

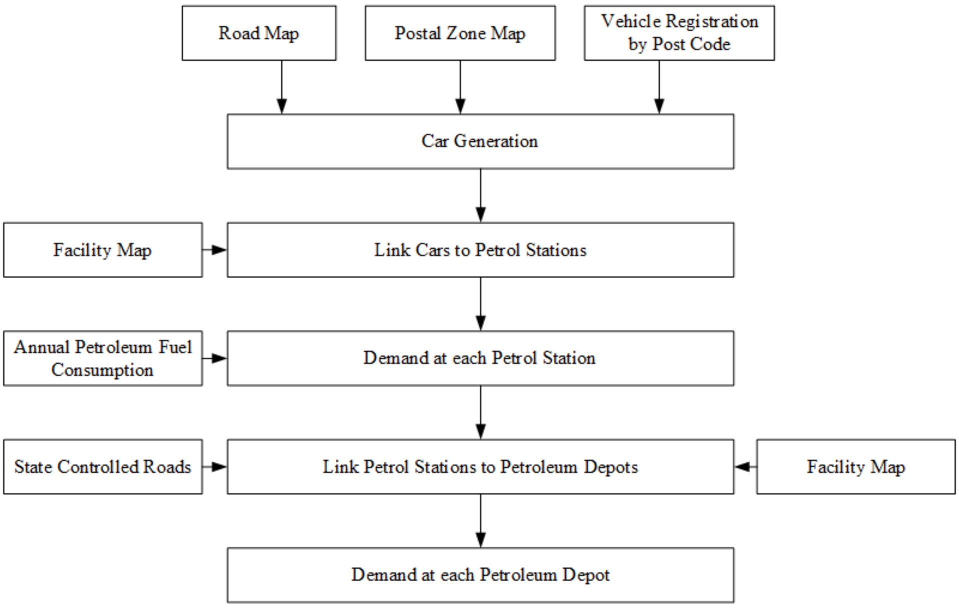
This Phase sought to provide empirical modelling of the case study network in Queensland to identify a set of potential options for management action. We sought to use previous data on transport network closures to explore disaster damage and recovery, and to attempt to model flows of commodities to and through the case study region. This would then be used in network models, to calculate likely impacts and changes under specific disaster scenarios, and to identify possible 'solutions' that may improve outcomes.

2. Data

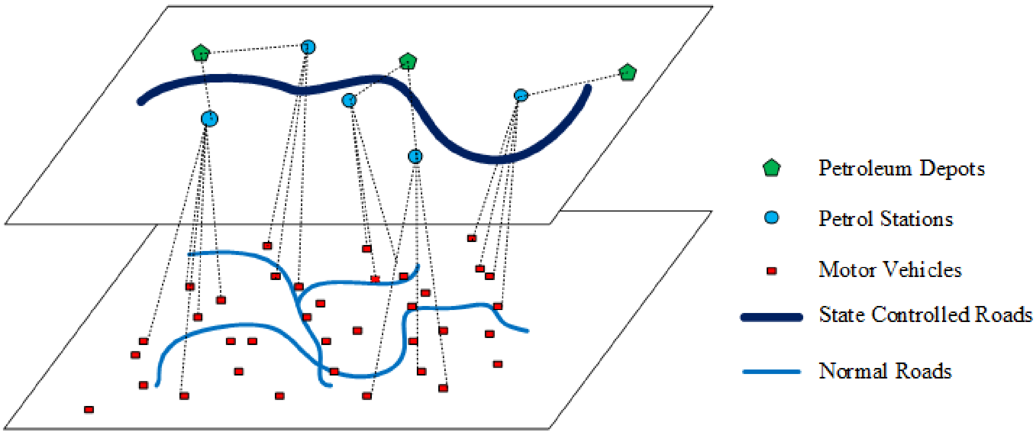
The data available in Australia proved very different to that available in Japan. Useable data (origin, destination and volume) was difficult to source. Time series road closure data was provided by DTMR and a range of other datasets were used to synthesise and replicate commodity flows. A focus was placed on petroleum fuels as a key commodity for which supplies may be problematic at petrol stations across NQ/FNQ immediately after any major disruption to supply from the south. We focused on road transport demand for petroleum fuels (not agricultural or mining) and used Queensland motor vehicle registration data to estimate demand. Geo-coded locations of petrol stations, key depots and road network links were obtained from government sources, allowing a meaningful representation of the fuel supply network.

3. Estimation of Fuel Demand

The demand estimation was performed using a Multi-Agent framework as shown in Figure 1. Vehicle registrations were examined by postcode and synthesized with estimated annual fuel usage. The estimated annual fuel consumption in Queensland in 2010 was 4,014 million, 2,175 million, and 242 million liters, for petrol, diesel, and LPG, respectively (Department of Infrastructure and Transport, 2011).



(a) Analysis Framework



(b) Multi-Agent Relationships in Petroleum Supply Chain

Figure 1 Framework for Estimation of Fuel Demand

From the vehicle registration database (Queensland Government, 2014) each vehicle was assigned to a street in each postal region using Monte Carlo Simulation. More than 4.6 million vehicles were allocated to streets across Queensland. This approach is not perfect, with populations in small town areas less accurately allocated than in larger centres. The generated vehicles were assigned to their potential supply petrol stations considering the distance to each petrol station based on travel impedance. All available petrol stations (with demand still less than capacity) within a 5 km range were identified as possible candidates with the nearer the petrol station, the higher possibility that the station was chosen. Petrol stations in key locations in NSW were also included for this analysis, to ensure no erroneous results along the state boundary. In cases where there was no petrol station available within range, the nearest available petrol station was chosen. Next, the number of customers estimated for each petrol station was used to represent likely fuel demand at each location. The links between petrol stations to petroleum depots was undertaken in a similar way, albeit each petrol station was connected to the nearest depot of the same brand where that information was available. In the latter case, the distance matrix calculated using the state controlled road network was used as the main roads for deliveries by petroleum trucks. The national GIS databases of petrol stations and petroleum depots were utilized to identify the locations. Finally, the demands at each petrol station and each depot were estimated with the results shown in Figures 2 and 3.

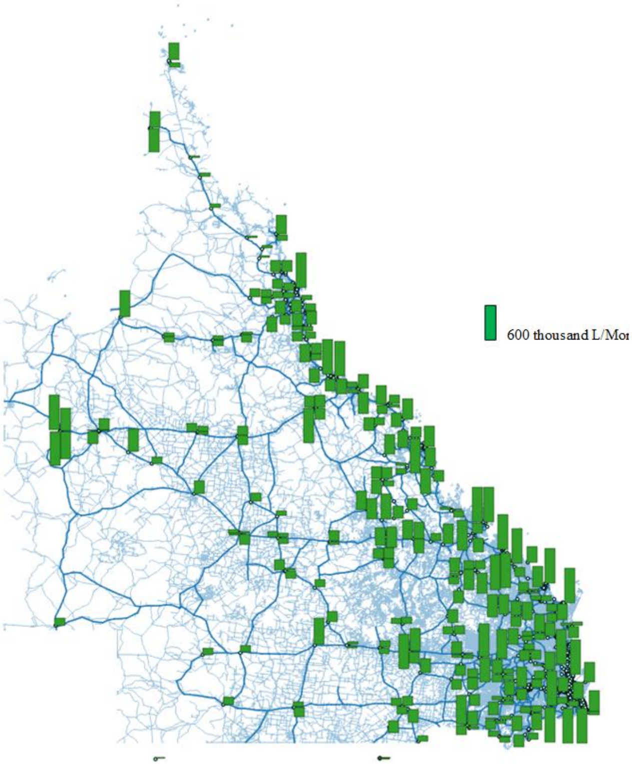


Figure 2 Estimated Fuel Demand at Each Petrol Station

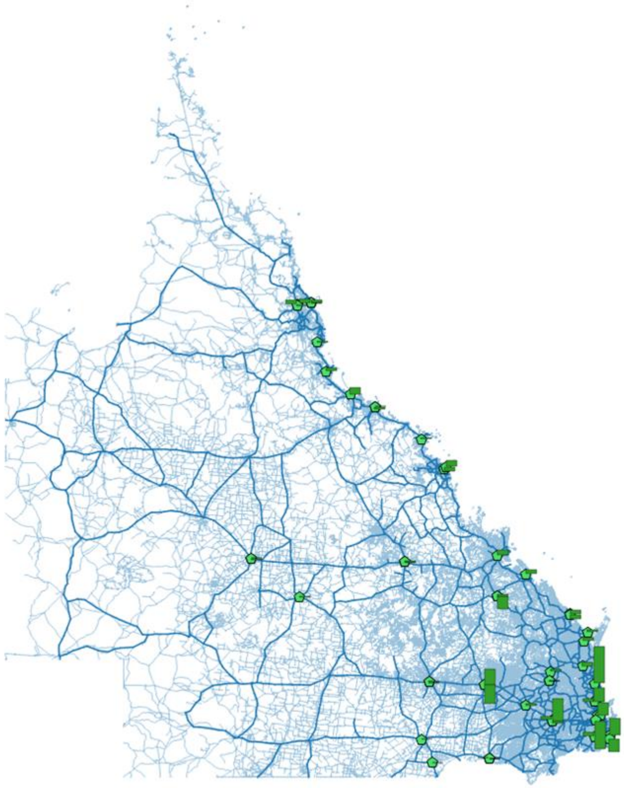


Figure 3 Estimated Fuel Demand at Each Petroleum Depot

4. Road Failure Analysis

The rate of link failure can be estimated based on the history of road closures from 2009-2014. Here, only a closure of more than 3 days is considered since the storage of fuel at petrol stations is generally at least 3 days regular supply. Failure probability of each link is calculated using the following equation:

$$P_{ij} = 1 - e^{-\lambda d}$$

Where, P_{ij} is the failure probability of link *ij*, λ is the rate of failure of link *ij* for more than 3 days [times/month], and d is time duration [month]. *d* equals to one for the monthly failure probability. Estimated link failure probability is shown in Figure 4. The value indicates the probability that each link will be closed for more than 3 days at least once in a month. The links are divided into 3 groups according to the estimated probability: blue ranges from 0-20%, orange from 20%-50%, and red from 50%-80%.

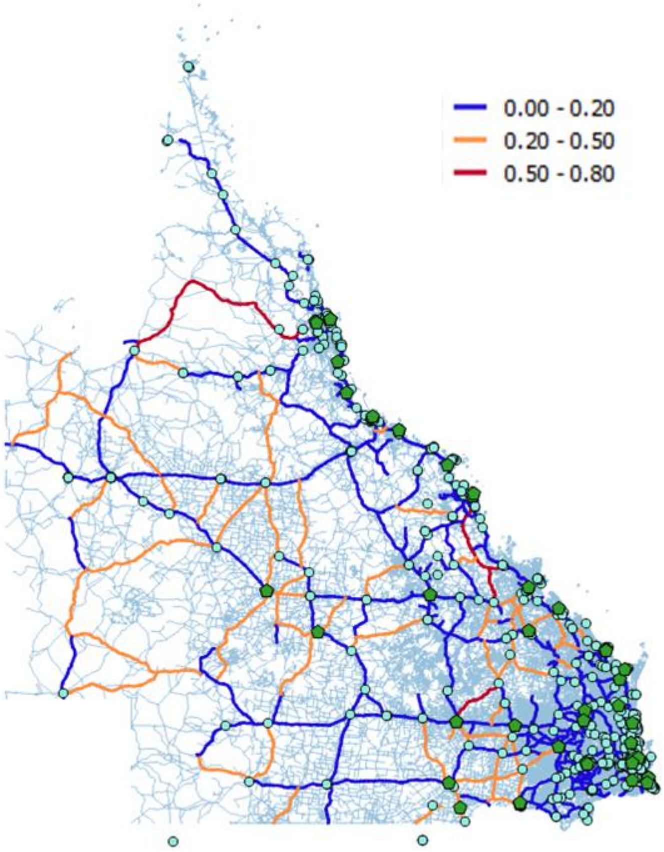


Figure 4 Monthly Link Failure Probabilities

5. Analysis of Flood Impact

The 2011 GIS flood extent was overlaid on the road network and the locations of petroleum depots and petrol stations. Figure 5 shows the locations of flooded roads, petrol stations, and petroleum depots. Although other petrol stations were not flooded but some petrol stations were cut-off due to flooded roads and were prevented from accessibility for the delivery from petroleum depots. All the inaccessible petrol stations and petroleum depots and flooded petrol stations and petroleum depots due to the 2011 flood are as shown in Figure 6.

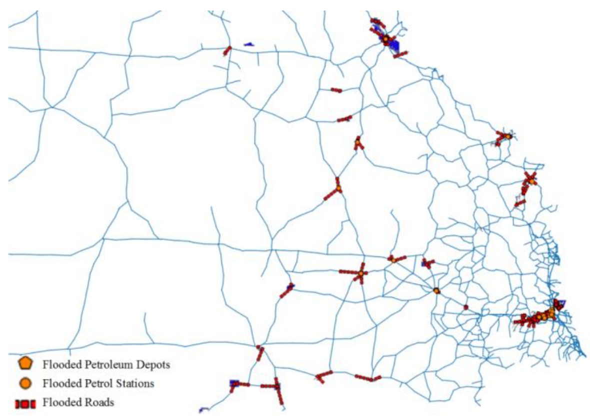


Figure 5 Impact of the 2011 Flood

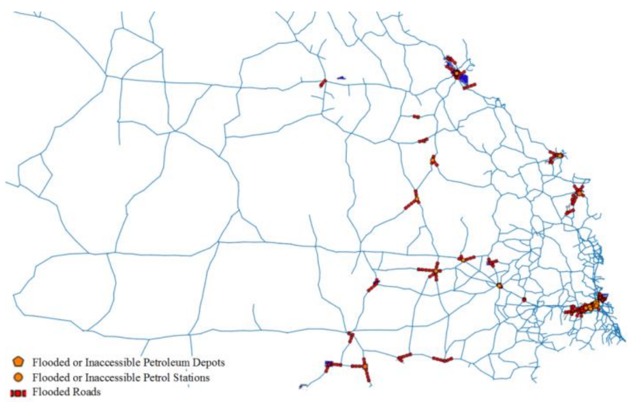


Figure 6 Flooded and Inaccessible Petrol Stations and Fuel Depots due to Road Closure

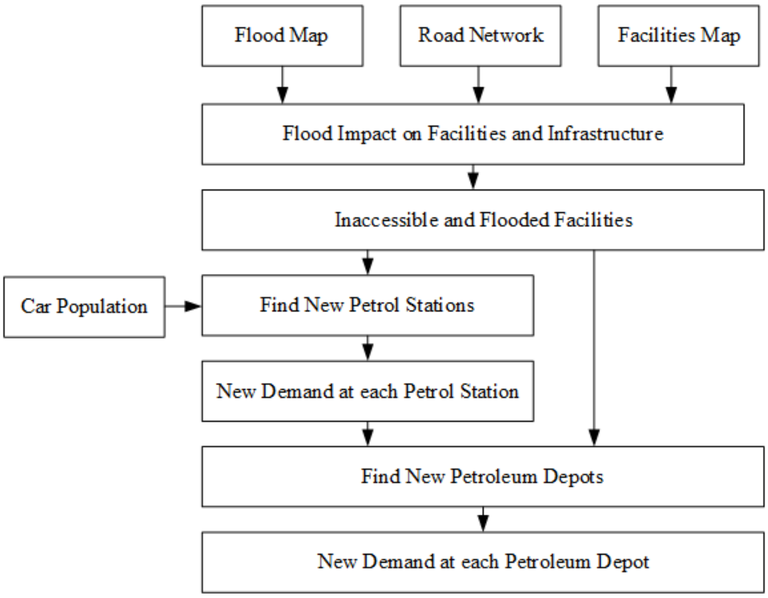


Figure 7 Analysis Framework on Flood Impact

Table 1 Flooded Impact on Petrol Demand

Petrol Stations		#Cars	7 days (1000 Liters)			14 days (1000 Liters)		
Impact	Number		Petrol	Diesel	LPG	Petrol	Diesel	LPG
Flooded	26	107,403	1,801	945	108	3,601	1,889	217
Inaccessible	110	473,648	7,940	4,166	478	15,881	8,332	956
Total	136	581,051	9,741	5,111	587	19,482	10,221	1,173

From the analysis 26 petrol stations were in ‘flooded’ locations and approximately 110 petrol stations became inaccessible (using our definitions) for resupply of petroleum fuels. Table 1 summarizes the impact of the 2011 flood on petroleum fuel demand. As 136 petrol stations were flooded or became inaccessible, we estimate around 580,000 vehicles were impacted. These vehicles would have required around 9.7 million, 5.1 million, and 0.6 million liters of Petrol, Diesel, and LPG respectively for 7 days, and 19 million, 10 million, and 1.2 million liters of Petrol, Diesel, and LPG respectively for 14 days.

If 580,000 impacted cars had to find new petrol stations instead of the flooded or inaccessible ones, and assuming they travel to their nearest ‘available’ petrol station, Figure 8 shows the increase in demand of petroleum fuel at each of the accessible petrol stations. In order to avoid confusion, this figure shows only the petrol stations expected to have more customers.

Similarly, the accessibility from petroleum depots to petrol stations is also impacted by flooding. Two depots were either in flooded locations or inaccessible; forcing impacted petrol stations to find new supply depots, or to seek supply from the nearest available supply depots regardless of the brand owner. As a result, some depots receive more demand during such an event. Figure 9 shows the increased requirement of petroleum fuel demand at each of the accessible depots estimated by our methods. Similarly, only the depots expected as having more demand are presented.

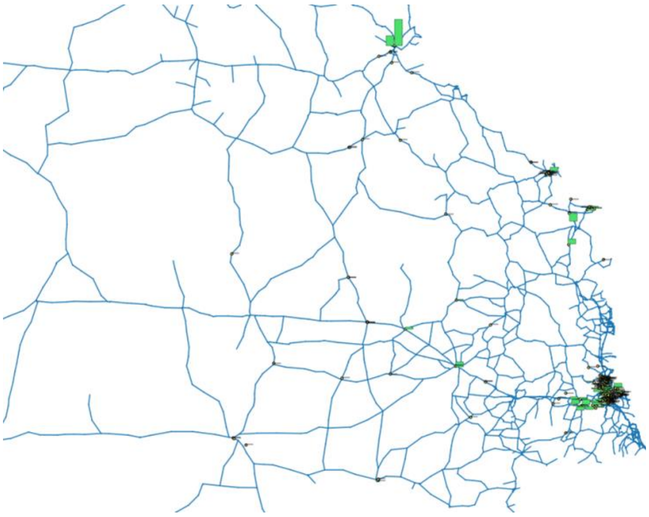


Figure 8 Increased requirement of petroleum fuel at each of the accessible petrol stations

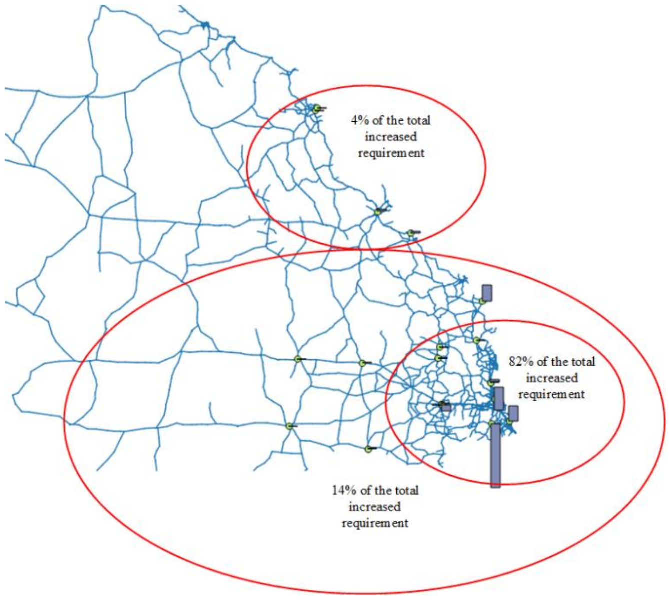


Figure 9 Increased requirement of petroleum fuel at each of the accessible petroleum depots

6. Next steps

Scenario forecasts based on these methods for alternative disaster scenarios are being developed. The methods are being written up in a broader project report so that government or industry colleagues may follow our approach or extend this work to other commodities. The analysis also continues with the research team now looking at what would be required to make use of real-time flood sensor data to make it useful for disaster logistics response. Preliminary assessment suggests that this is a long way from being feasible. An entire sequence of models is required to transform a projected flood event into longer lead times for freight forwarding, and more effective response. Without effective commodity flow models, which are just not possible in Australia except within the tight confines of private industry, a system triggered by flood sensor levels will be sub-optimal. A set of more rudimentary preparedness settings based on likely disaster impact models are likely to have more value for both industry and government. Systematic disaster impact forecasting for road and rail networks remains the priority.

References

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