

Are highway constructions associated with increased transport incidents? A case study of NSW Pacific Highway construction zones 2011-16

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Key Findings

- We identified 35 traffic incidents within the location of construction zones;
- The incident rate in the construction periods was significantly higher than in non-construction periods;
- There was no difference between the age, injury severity and mortality rate of casualties.

Abstract

Transport incidents are among the major causes of trauma and injury in Australia and worldwide. While improving infrastructure can decrease the rate of incidents, the required construction imposes challenges regarding simultaneous public use of the relevant road sections. This study focused on construction zones along the New South Wales (NSW) Pacific Highway. We aimed to investigate if the rate of people who had major trauma as a result of a transport incident in a construction zone was higher than the rate of people with similar incidents at other times. This was a retrospective study, conducted by screening the data of patients admitted to the trauma services, or who died due to traffic incidents on the NSW Pacific Highway 2011-2016. We identified 35 casualties who experienced

a traffic incident within a construction zone, 19 of these incidents occurred during the construction dates and 16 before or after those dates. The rate of casualty in construction periods was 2.21 per 1000 days, which is significantly higher than the rate in non-construction periods (1.2 per 1000 days, p-value: 0.037). There was no significant difference between the age, injury severity score and mortality rate of casualties who had an incident during the construction dates and those who had an incident in non-construction periods. This study indicated that the rate of incidents increased at NSW Pacific Highway construction zones during construction periods. More investigation is needed to improve the safety of road users during highway road constructions.

Keywords

Injury, trauma, construction sites, highway construction, safety, transport incidents

Introduction

Road traffic incidents are among the major causes of trauma and injury in Australia, and worldwide. In New South Wales (NSW) annually, around 1,400 patients are admitted to the NSW trauma services for major trauma due to transport incidents (NSW Agency for Clinical Innovation, 2018). With 389 lives lost in 2017 on NSW roads, the NSW Government has adopted the target of 'Towards Zero', aiming to reduce the rate of road traffic fatalities by 30% from 2008-2010 levels by 2021, and ultimately have zero fatalities and serious injuries by

2056 (Transport for NSW, 2018). To achieve these targets, the NSW Safer Roads Program, has been undertaken to improve road conditions, which includes improving infrastructure by construction projects (Transport for NSW, 2018). The Pacific Highway upgrade was commenced in 1996 (Road and Maritime Services, 2020). At July 2020, 657km of the highway has been upgraded to four lanes of divided road, while still, 129km are under construction (Road and Maritime Services, 2020).

Undertaking construction works are not without their challenges. Several studies in the United States of America (USA) have reported that construction zones are associated with increased rates of transport incidents (Garber & Woo, 1990; Graham, Paulsen, & Glennon, 1978; Khattak, Khattak, & Council, 2002). There are also conflicting results, where earlier studies indicated rates such as 6.8% increase in the incident rates in USA highway construction roads (Graham et al., 1978), a more recent study reported reduced incidence rates (Jin, Saito, & Eggett, 2008).

Traffic incidents pose hazards for both road users and the people who work in construction zones. The majority of crashes within construction zones have been found to occur in activity area locations (Garber & Zhao, 2002), with rear-end incidents identified as the main types of crashes (Garber & Zhao, 2002; Pigman & Agent, 1990).

Different factors are suggested to be associated with transport incidents in construction zones, such as length and duration of the construction zone (Theofilatos, Ziakopoulos, Papadimitriou, Yannis, & Diamandouros, 2017), poor light condition (Li & Bai, 2009) and drivers' misjudgement on stopping distance or driving too close to other cars (Chambless, Ghadiali, Lindly, & McFadden, 2002; Pigman & Agent, 1990).

In general, contributing factors are human, vehicular, and environmental (Pigman & Agent, 1990). From these, the human factors (driver inattention, following too close, speeding, and failing to yield way) constitute a high proportion of work zone transport incidents (Pigman & Agent, 1990).

An Australian qualitative study found that people who work in road construction activities believe police presence and driver education are the most effective safety measures (Debnath, Blackman, & Haworth, 2015), however, there is limited data in Australia on the effects of highway construction zones on the rate of transport incidents. Access to data related to such incidents can be challenging as not all incidents are reported to police (Blackman, Debnath, & Haworth, 2020). Still, a recent unpublished review of trauma admissions to two NSW regional trauma services, Port Macquarie Base Hospital and Coffs Harbour Health Campus, indicated an unprecedented increase in major trauma admission rates in particular periods. Based on the knowledge of the local healthcare practitioners, it was speculated that these peaks in admission rates might have occurred during the construction times of the NSW Pacific Highway upgrades. However, as there was no evidence to support the observed increase in the rate of injuries being associated with highway construction zones, this study was designed to explore this speculation.

We aimed to investigate if the rate of people who had major trauma as a result of transport incidents in construction zones was higher than the rate of people with similar incidents in other situations. The study aimed to address

two research questions: 1. Was the rate of people who had a transport incident in a highway construction zone higher than when there was no highway construction being conducted? 2. Was there any difference in the mortality rate and level of injuries sustained by people who had a transport incident in a highway construction zone, and those who had a transport incident when there was no highway construction being conducted?

Methods

Data sources

This study was a retrospective data collection of injuries and deaths due to transport incidents on Pacific Highway construction zones. We focused on the construction zones along the NSW Pacific Highway between Herons Creek and Port Macquarie, Port Macquarie and Coffs Harbour, and on the Woolgoolga to Maclean upgrade. More information on the Pacific Highway upgrades can be accessed here: <https://www.pacifichighway.nsw.gov.au/>. Data was collected from the NSW Trauma Registry and the Gold Coast University Hospital. The NSW Trauma Registry is governed by the NSW Institute of Trauma and Injury Management (ITIM), and contains data on major trauma patients from all designated trauma services in NSW (ITIM, 2019). Trauma patient data is entered into this registry if their injury is moderate to severe, as defined by them having an Injury Severity Score (ISS) of greater than 12, an admission to an Intensive Care Unit, or having died during their admission. In the northern areas of NSW, owing to proximity, patients can be transferred to Queensland, therefore we collected data on these patients from the Gold Coast University Hospital.

Patients were included, if the mechanism of injury was 'transport incident', location of injury (incident) was relevant to the study, and the time of injury was between 01/01/2011 and 31/12/2016. Since some road incident casualties might have died on the scene, and this data would not be included in the trauma services data, we accessed coronal files via the National Coronal Information System (NCIS). NCIS is a data system for Australian and New Zealand coronal cases, including all the deaths that are reported to the Coroner (NCIS, 2019). NCIS is managed by the Victorian Department of Justice and Community Safety. We screened NCIS records for reports of death due to transport incidents in the time and location, as earlier indicated.

After identifying the study cohort, records of the included patients were accessed from hospitals to retrieve the exact location of injury that was documented on the ambulance or retrieval case sheets. For those records that had the required location of the incident information, we obtained the case sheets from the retrieval data (the NSW Ambulance and NSW Ambulance Retrieval). Additionally, one of the authors (PL) used local residential knowledge as

well as archived media reports to check the exact location of some incidents. Finally, if the precise location of the incident could not be ascertained after all the attempts, the cases were excluded.

In addition to incident and injury data gathered in this study, external information regarding construction zone locations and periods was obtained from the NSW Roads and Maritime Services (RMS) Pacific Highway project office (Road and Maritime Services, 2020).

Data analysis

For each record included in the study, we collected data to identify whether the patient/or deceased persons were involved in a transport incident, location of the incident, basic demographic data, injury severity and outcomes.

Information obtained from the ambulance notes on the address of incidents was turned into latitude and longitude using the Google maps geocoder (Google, 2019). Hence we identified the exact location of traffic incidents, as well as where construction zones were started and ended. The combination of these data was entered into a geospatial mapping program for a visual demonstration. In the resulted map, we could identify transport incidents that occurred on the construction zones. Then we divided the identified incidents into two groups: those which occurred during the time period of construction and those which occurred at other periods. We then calculated the rate of the transport incidents during construction dates versus non-construction periods to see if the incident rate was higher during the construction dates (research question 1).

Finally, the severity of injuries sustained and outcomes (mortality), was compared between people who were involved in transport incidents during construction periods versus those who incurred an injury in non-construction periods (research question 2). We used binomial and Poisson mid-p exact tests and corresponding conditional maximum likelihood estimates where appropriate.

Ethics approval

All the collected data was taken from the data already collected as part of the care of patients or for other routine administrative purposes. Therefore, the research did not cause any risk or inconvenience to participants and patients' privacy and confidentiality was protected by the research team. We obtained approvals from the Hunter New England Research Ethics and Governance Office (HREC/17/HNE/475, 7 December 2017), Queensland Department of Justice and Regulation HRE (CF/18/5261, 28 March 2018), and Queensland Public Health Act (RD007265, 20 February 2018). NCIS approval was also received from the Victorian Department of Justice Human Research Ethics Committee (CF/18/5261, 20 March 2018). Also, we obtained three site-specific approvals.

Results

The process of data acquisition is summarised by Figure 1. We initially identified 441 cases with major trauma or death as a result of a transport incident in the postcodes attributable to the NSW Pacific Highway. Based on the NSW Trauma Registry and Gold Coast University Hospital

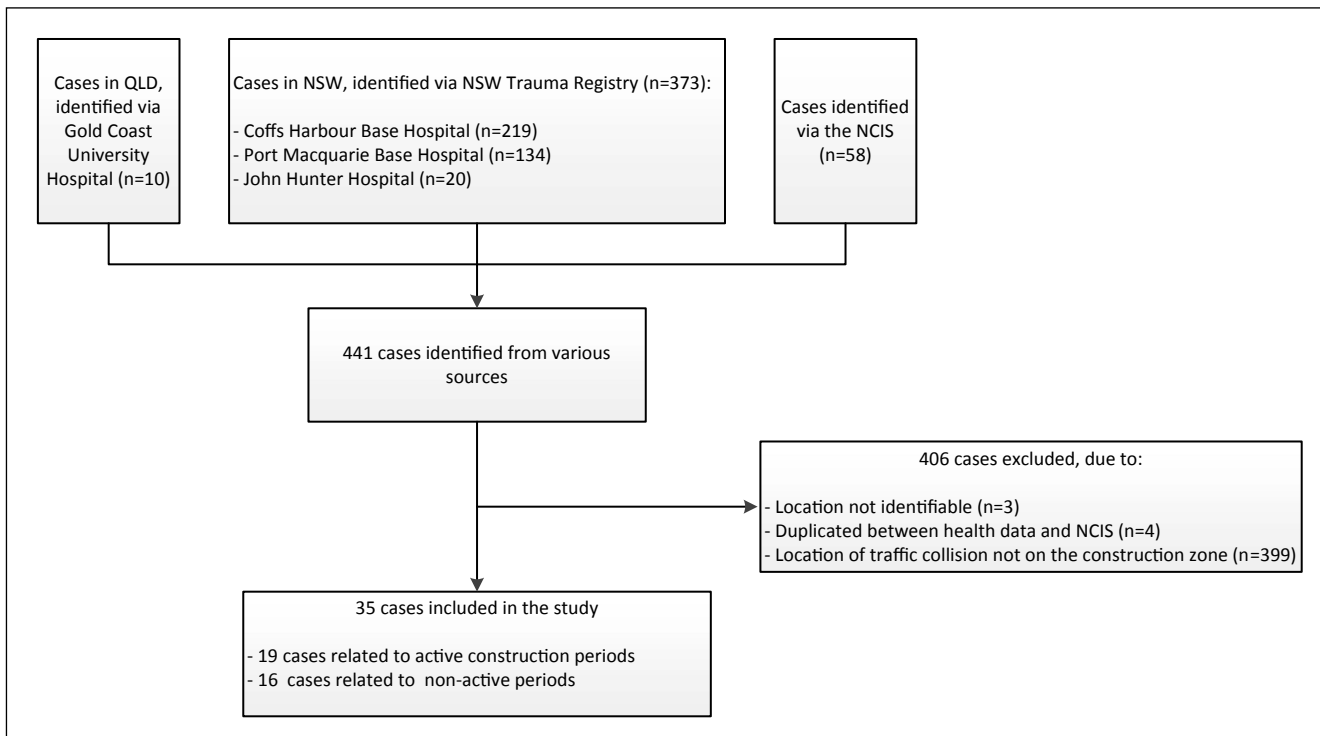


Figure 1: Summary of the data acquisition process

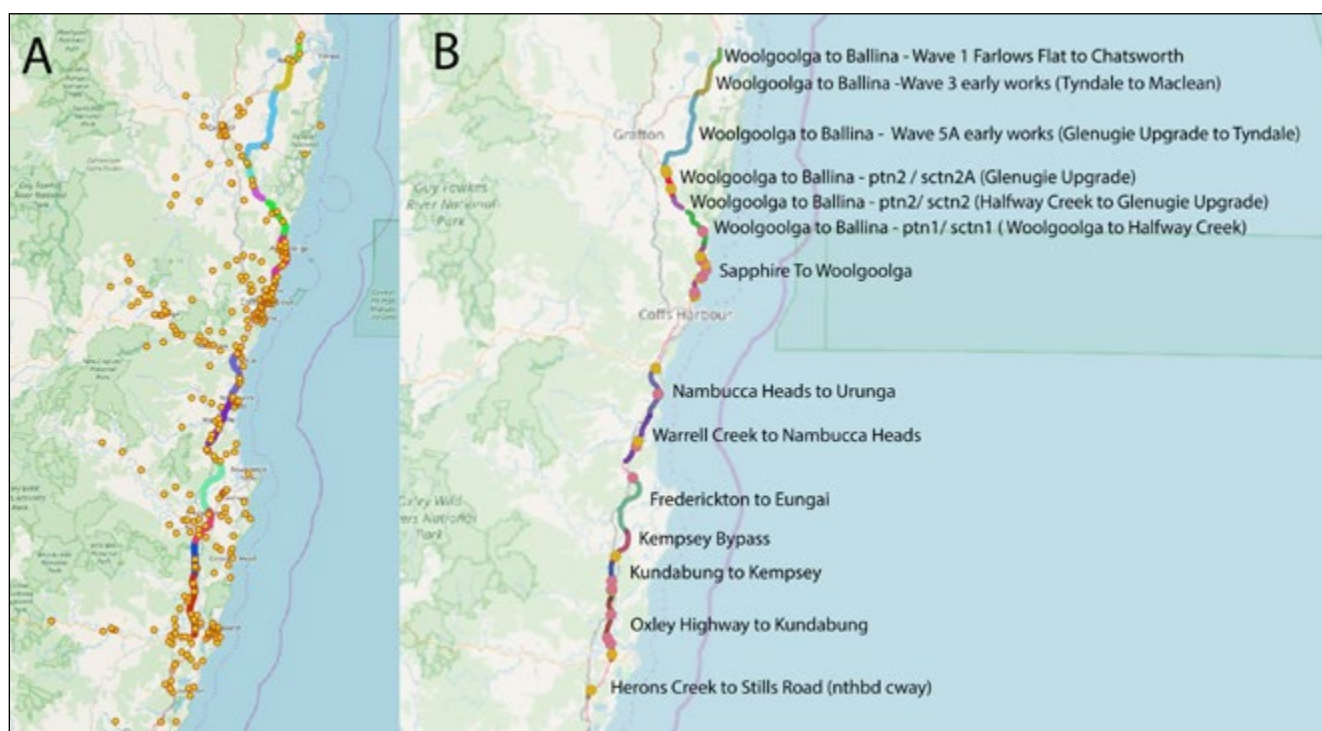


Figure 2: A) Using a Geographic Information System tool, we identified the location of identified cases with moderate to severe injury or death as a result of road traffic incidents during 2011-2016 in the postcodes attributable to the targeted sections of the Pacific Highway. B) After excluding cases that were not on the construction zones, we identified 35 cases who were involved in a transport incident in the construction zones (during construction periods or before or after that).

database, we identified 383 patients. Besides screening NCIS data, we identified 58 cases who died at the scene of a transport incident. Then to access further data on the transport incident location, we checked the hospital records (Coffs Harbour Base Hospital (n=219), Port Macquarie Base Hospital (n=134), John Hunter Hospital (n=20) and Gold Coast University Hospital (n=10)). From the cases identified via NCIS, we could not ascertain the exact location of 3 cases. Also, there were 4 duplicated cases, who died at the Emergency Departments of hospitals, and their data were already included in the hospital data.

Utilising QGIS (Quantum Geographic Information System), a Geographic Information System tool, we located the identified cases geographically (QGIS, 2019) (Figure 2- part A). After excluding those cases that were not on the construction zones, we identified 35 cases involved in a transport incident in the construction zones. From these cases, 19 were related to transport incidents during the construction periods, and 16 were related to transport incidents during non-construction periods (Figure 2- part B).

We calculated the rate of casualties to the time during construction and non-construction periods in each construction zone. Non-construction periods were calculated based on the subtraction of the construction period from the total time of the study. Then we calculated the casualty rate per 1000 days (table 1). Total time of the study was 2,192 days (between 1/1/2011 till 31/12/2016).

The earliest time considered for construction zones was 1/1/2011, even if the construction zones started earlier, and the latest end date for the study was 31/12/2016, even if the construction zones continued afterwards. In the following construction zones, there were no transport incidents, nor at the construction, neither the non-construction periods.

- Woolgoolga to Ballina - ptn2/ sctn2 (Halfway Creek to Glenugie Upgrade)
- Woolgoolga to Ballina - Wave 5A early works (Glenugie Upgrade to Tyndale)
- Woolgoolga to Ballina -Wave 3 early works (Tyndale to Maclean)
- Woolgoolga to Ballina - Wave 1 Farlows Flat to Chatsworth

Addressing research question 1, we identified that the rate of casualty per 1000 days in the construction dates was 2.21, while on the same locations at non-construction times, this rate was 1.2 (table 1). The corresponding rate ratio, 1.84 (95% confidence interval based on the mid-p exact test: 0.94-3.63), was significantly higher than one based on one-tailed mid-p exact test (p-value: 0.037).

The average age of those included in the study (n=35) was 44.7 years old, and there was no statistically significant difference between the average age of casualties of incidents during non-construction and construction periods (47 years old, n=16 versus 43 years old, n=19, T-test,

Table 1: Calculation of casualty rates in construction and non-construction periods

Construction zones	Number of casualties during construction periods	Duration of construction periods (days)	Rate of casualties per 1000 days during construction periods	Number of casualties during non-construction periods	Duration of non-construction periods (days)	Rate of casualties per 1000 days during non-construction periods
Oxley Highway to Kundabung	4	822	4.87	1	1370	0.73
Kundabung to Kempsey	2	791	2.53	3	1401	2.14
Frederickton to Eungai	1	1004	1.00	0	1188	0.00
Warrell Creek to Nambucca Heads	1	761	1.31	1	1431	0.70
Nambucca Heads to Urunga	3	994	3.02	2	1198	1.67
Sapphire To Woolgoolga	6	1306	4.59	5	886	5.65
Woolgoolga to Ballina - ptn1/ sctn1 (Woolgoolga to Halfway Creek)	1	579	1.73	1	1613	0.62
Kempsey Bypass	0	1010	0.00	1	1182	0.85
Herons Creek to Stills Road (nthbd cway)	0	920	0.00	1	1272	0.79
Woolgoolga to Ballina - ptn2 / sctn2A (Glenugie Upgrade)	1	404	2.48	1	1788	0.56
Total	19	8591	2.21	16	13320	1.20

p value=0.53). All the 16 casualties in non-construction periods survived, while out of 19 cases of casualties who were involved in a transport incident during construction periods, 3 cases were deceased. Nevertheless, the difference in the mortality rate of construction and non-construction groups was not statistically significant (odds ratio: 0, 95% CI: 0-2.29; mid-p exact test, p value=0.18). Moreover, the difference between the average Injury Severity Score of non-construction (ISS: 24.2) and construction periods (ISS: 21.4) was not statistically significant (T-test, p-value: 0.51). Therefore, addressing research question 2, we did not identify any statistically significant differences between the outcomes of the two groups.

Discussion

This study aimed to identify if the rate of people who had major trauma as a result of transport incidents in construction zones was higher than the rate of people with similar incidents in non-construction periods, providing landmark research on the effects of highway construction zones on the rate of road transport incidents in NSW. To achieve that aim, we used routinely collected data to explore the rate of casualties in Highway Pacific construction zones and compared casualties during construction periods versus dates before or after constructions. Our results indicated that the rate of transport incidents had increased during the construction periods. We did not identify any differences between the average age of casualties or their injury severity score and mortality rate. Our finding supports the concept that

construction zones could have contributed to the increase in the major trauma admissions to local trauma services. It also aligns with studies undertaken in the United States of America (Graham et al., 1978; Khattak et al., 2002; Pigman & Agent, 1990), despite the differences between the countries transport rules and conditions. However, reduced transport incident rates are reported in a more recent study, which attributes the reduction to improved safety procedures (Jin et al., 2008).

While due to the small sample size in this study, we could not compare construction zones, differences among various construction zones have been reported (Graham et al., 1978). Studying seven different states of USA, Graham et al. (1978) observed that the incident rate decreased in 31% of construction projects and increased in other 24% of these projects, however the overall transport incident rate increased when considering the whole data.

This study has shed light on the potential risk that highway construction zones have for road traffic safety; it is crucial to understand the reason for the increase in incident rates. While the international evidence is not necessarily transferable to the Australian context, it is notable that human, vehicular and environmental factors have been identified to be associated with transport incidents in the construction zones, such as poor light condition (Li & Bai, 2009; Pigman & Agent, 1990) and drivers' misjudgement (Chambless, Ghadiali, Lindly, & McFadden, 2002; Pigman & Agent, 1990). In addition, based on an Australian study, police presence and driver education were perceived as effective safety measures (Debnath et al., 2015). It is crucial to investigate these factors in the current Australian roads.

Construction related incidents are preventable, and observance of standard work procedures are suggested as being instrumental in improving the safety level of the construction zones (Jin et al., 2008). While previous works reported higher crash rates in construction zones, Jin et al. (2008) reported lower rates, most likely due to the observance of standard procedures by contractors. Technological tools might also help, for example, augmented speed warnings are reported to effectively improve drivers' compliance in construction zones (Whitmire II, Morgan, Oron-Gilad, & Hancock, 2011). Since transport incidents on construction sites are preventable, it is important to follow-up the findings of this study by further research studies and projects that explore the bigger picture including minor injuries and also the causation of such transport incidents.

Limitations

While it is imperative to analyse the underlying factors for such association further, we did not have access to detailed information such as the exact time of the incidents. Also, our sample size did not permit further statistical analyses. Otherwise, it could be useful to identify the difference

between fatal and non-fatal collisions (Li & Bai, 2008), between collisions occurring in night versus day time (Arditi, Lee, & Polat, 2007), or to explore the effects of seasons on incident rates (Graham et al., 1978). Also, it would also be essential to compare the accident rate before construction time and after to explore the efficiency of construction zones in improving the safety of the roads. With access to data related to vehicular crashes, it would be possible to undertake case studies and to determine the characteristics of transport incidents. For example, previous studies identified 'activity area' as the primary location of crashes in highway construction zones, rear-end type as the main type of crashes and following other cars too closely as the leading cause of crashes (Garber & Zhao, 2002; Pigman & Agent, 1990).

Other limitations of this study were that we explored major injuries and fatalities only and we did not have access to data of transport incidents that were not leading to casualties or were the cause of minor injuries (ISS<12). Therefore, we were not able to capture a potentially more substantial number of cases with minor injuries or incidents with no injuries. Having access to different sources of data would be ideal. In the USA, a discrepancy is reported between different sources of data on the number of incidents in highway construction zones (Graham & Migletz, 1983).

Future studies

Considering the importance of these incidents and injuries for people's lives and health care system, further studies should aim to explore the association between highway constructions and road traffic injuries and understand what factors contribute to such collisions. Having access to detailed data will support such investigations. This knowledge will enable related authorities to work further on prevention and enhancing road safety surrounding construction zones and times. Also, trauma and emergency health services can have a better opportunity for planning and preparation for similar occasions.

Conclusions

Results of this study suggest that construction zones were associated with a higher rate of transport incidents. Further studies are required to explore the association, including underlying causes and solutions.

Acknowledgments

Authors acknowledge data custodians that supported the study, including NSW Trauma Registry, governed by the NSW Institute of Trauma and Injury Management (ITIM) and the National Coronial Information System (NCIS), which is managed by the Victorian Department of Justice and Community Safety. We are also grateful of Roads and Maritime Services for providing data regarding construction zone location and times.

References:

- Arditi, D., Lee, D.-E., & Polat, G. (2007). Fatal accidents in nighttime vs. daytime highway construction work zones. *Journal of Safety Research*, 38(4), 399-405.
- Blackman, R., Debnath, A. K., & Haworth, N. (2020). Understanding vehicle crashes in work zones: Analysis of workplace health and safety data as an alternative to police-reported crash data in Queensland, Australia. *Traffic injury prevention*, 21(3), 222-227.
- Chambless, J., Ghadiali, A. M., Lindly, J. K., & McFadden, J. (2002). Multistate work-zone crash characteristics. *Institute of Transportation Engineers. ITE Journal*, 72(5), 46.
- Debnath, A. K., Blackman, R., & Haworth, N. (2015). Common hazards and their mitigating measures in work zones: A qualitative study of worker perceptions. *Safety Science*, 72, 293-301.
- Garber, N. J., & Woo, T.-S. H. (1990). *Accident characteristics at construction and maintenance zones in urban areas*. Virginia Transportation Research Council
- Garber, N. J., & Zhao, M. (2002). Distribution and characteristics of crashes at different work zone locations in Virginia. *Transportation Research Record*, 1794(1), 19-25.
- Google. (2019). Google Maps API Geocoder. Retrieved from <https://google-developers.appspot.com/maps/documentation/utils/geocoder/>
- Graham, J. L., & Migletz, J. (1983). Collection of work-zone accident data. *Transportation Research Record*, 933, 15-18.
- Graham, J. L., Paulsen, R. J., & Glennon, J. C. (1978). Accident analyses of highway construction zones. *Transportation Research Record*, 693, 25-32.
- ITIM. (2019). NSW Institute of Trauma and Injury Management. Retrieved from https://www.aci.health.nsw.gov.au/networks/itim/Data/nsw_trauma_registry_system
- Jin, T. G., Saito, M., & Eggett, D. L. (2008). Statistical comparisons of the crash characteristics on highways between construction time and non-construction time. *Accident Analysis & Prevention*, 40(6), 2015-2023.
- Khattak, A. J., Khattak, A. J., & Council, F. M. (2002). Effects of work zone presence on injury and non-injury crashes. *Accident Analysis & Prevention*, 34(1), 19-29.
- Li, Y., & Bai, Y. (2008). Comparison of characteristics between fatal and injury accidents in the highway construction zones. *Safety Science*, 46(4), 646-660.
- Li, Y., & Bai, Y. (2009). Highway work zone risk factors and their impact on crash severity. *Journal of Transportation engineering*, 135(10), 694-701.
- NCIS. (2019). National Coronial Information System Retrieved from <http://www.ncis.org.au>
- NSW Agency for Clinical Innovation. (2018). *Major Trauma in NSW: 2016-17*. Sydney: ACI
- Pigman, J. G., & Agent, K. R. (1990). Highway accidents in construction and maintenance work zones. *Transportation Research Record*(1270).
- QGIS. (2019). QGIS, A Free and Open Source Geographic Information System. Retrieved from <https://www.qgis.org/en/site/>
- Road and Maritime Services. (2020). Pacific Highway Upgrade. Retrieved from <https://www.pacifichighway.nsw.gov.au/>
- Theofilatos, A., Ziakopoulos, A., Papadimitriou, E., Yannis, G., & Diamandouros, K. (2017). Meta-analysis of the effect of road work zones on crash occurrence. *Accident Analysis & Prevention*, 108, 1-8.
- Transport for NSW. (2018). *Road Safety Plan 2021*. Sydney: Centre for Road Safety
- Whitmire II, J., Morgan, J. F., Oron-Gilad, T., & Hancock, P. (2011). The effect of in-vehicle warning systems on speed compliance in work zones. *Transportation research part F: traffic psychology and behaviour*, 14(5), 331-340.