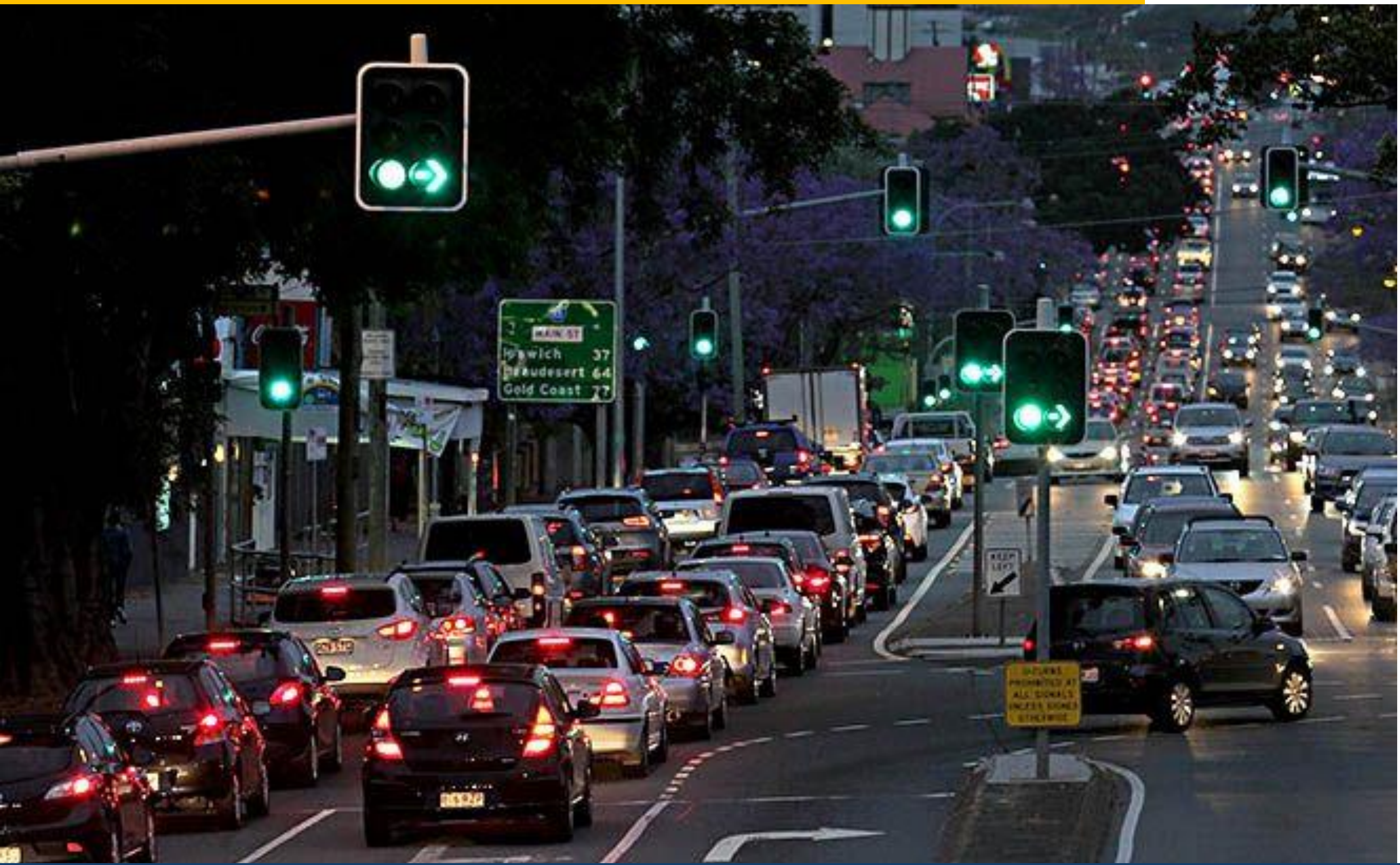

Collision avoidance strategies and controlled failure process for Traffic Signal posts

Progress report - Benefit cost (preliminaries) and crash analysis

Submitted To:

Queensland Department of Transport and Main Roads (TMR)

Queensland Government

Department of Transport and Main Roads

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EXECUTIVE SUMMARY

This project involves proposing and evaluating alternatives for rewiring traffic posts to improve the process and time required to repair them after damage by a crash. Expected benefits include a faster and safer management of the traffic site during the repair of the traffic posts and signals. The work zone required to repair and regain control of the site is expected to last for a shorter period relative to current practice. The associated benefits of a shorter work zone are savings in travel time and its reliability, emissions, vehicle operating costs, and safety among other externalities.

After literature review and discussions with the Queensland Department of Transport and Main Roads (TMR), two alternatives were chosen as described in Section 2 of this report. Parameters and information required to perform benefit cost analysis for transport projects in Australia was collected from multiple sources and it is included in Sections 3.1 – 3.5. Section 3.6 provides a benefit cost analysis of the two chosen alternatives. Results from this analysis the two alternatives considering 20 upgraded intersections are summarized as follows:

First alternative

Life-Cycle Costs:	$0.7 M	**Net Present Value:**	$ 2.67 M
Life-Cycle Benefits:	$ 3.37 M	**Benefit/Cost Ratio:**	4.81

Second alternative

Life-Cycle Costs:	$2.5 M	**Net Present Value:**	$ 0.87 M
Life-Cycle Benefits:	$ 3.37 M	**Benefit/Cost Ratio:**	1.35

In both cases, most of the benefits are attributed to travel time and travel time reliability savings ($ 3.37 M). The overall benefit-cost ratio of the two alternatives, 4.81 and 1.35, denote a very cost-effective project.

Section 4 provides a preliminary crash data analysis with focus on speed limits which were obtained using OpenStreetMaps. The results were as expected, the higher the speed limits, the more likely crashes with traffic posts. Crash and the corresponding traffic flow data is required to perform further statistical analyses. Section 5 completes this report providing conclusions and recommendations.

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1 Introduction

This report proposes and evaluates two alternatives for retrofitting or improving the way traffic signal posts are wired. The operational benefit assessed in this project is expected to be in terms of faster regaining control over the traffic signals relative to current practice in Queensland. That is, a shorter and safer work zone because the new wiring system facilitates the activities required to get the intersection back to normal operation after a traffic crash has damaged a post.

2 Alternatives

Two alternatives were proposed and approved by the Queensland Department of Transport and Main Roads (TMR) for further analysis and benefit cost estimation as follows.

The **First alternative**, a proposed future Business as Usual (BAU) case with some changes which includes:

- Using the existing traffic signal controller cabinets, with
- 42Vac ELV field wiring and aspects, and with
- Existing 36 core cabling,

but with the following changes:

- Relocation of the daisy-chaining din-rail connector from top of traffic pole to a sealed water-proof enclosure in the adjacent pit or pole-base, along with a low core count spur cable up the traffic pole (eg 12 core), and
- Use of retention socket poles for vulnerable single pole signals (but not cantilever masts).

The **Second alternative**, a more significant variation with networked signal control including:

- A traffic signal control cabinet with a new network control "master",
- Greatly simplified intersection wiring using eg four core (two twisted pairs) for ELV power and data,
- Sealed water-proof enclosures with network "slaves" in pits adjacent to signal poles or at the pole base, with short low core count spur cables up the traffic poles (eg 12 core),
- Use of retention socket poles for vulnerable single pole signals (but not cantilever masts).

3 Benefit cost analysis

Benefits and associated parameters required for benefit-cost analysis for transport projects in Australia can be divided into four categories[1]:

- Vehicle Operating Cost (VOC)
- Travel Time Cost
- Crash Cost

- Emissions Cost

These parameters are provided by the Australian Bureau of Statistics and the Australian Transport Assessment and Planning (ATAP). Typically, improving traffic signal posts is part of larger projects where benefits are considered after the implementation is completed. Benefits or disadvantages associated with the work zone required to implement projects are not often considered. However, most of the benefits from the project under study are a consequence of a shorter and safer work zone because of the innovative wiring of the traffic lights. To enable this type of non-traditional benefit cost analysis we have chosen an open-source methodology and software tool that can easily be adapted for Queensland conditions as well as the unique characteristics of the project. The California Life Cycle Benefit/Cost Analysis Model (Cal B/C) methodology is a highly documented, broadly used, implemented in Excel and easy to understand and update (California Department of Transport, 1999). Hence, it has been chosen to perform the required analysis. The methodology provides estimates using relationships from the Highway Capacity Manual.

3.1 Vehicle operating cost

Vehicle operating costs (VOC) include all factors associated with fuel and non-fuel (e.g., car maintenance, insurance, tires, etc) expenses. In this project, the most important factors include lowered costs associated with improving traffic flow throughout the work zone, created to repair damages and regain operational control of the signalized intersection, and/or minimize its duration. Traffic fuel consumption and costs are likely to increase because of the associated reduction in capacity during the work zone. Table 2.1 provides fuel consumption rates per vehicle type. Similarly, Table 2.2 provides consumption rates per fuel type including petrol and diesel. Table 2.3 provides fuel cost per state.

Table 2.1 Average fuel consumption rate for vehicle type in litres (L) per 100 km and L per km

	Fuel Consumption Rates (2020)	
Vehicle Type	**L 100 km^{-1}**	**L km^{-1}**
Passenger Vehicles	11.1	0.111
Motorcycles	6.1	0.061
Light Commercial Vehicles	12.8	0.128
Rigid Trucks	28.6	0.286
Articulated Vehicles (e.g., transport trucks)	53.1	0.531
Non-freight Carrying Trucks	23.2	0.232
Buses	27.8	0.278

Source: Australian Bureau of Statistics (2020)

Table 2.2 Average fuel prices per Australian State for the 2022 calendar year

State	Average Price ($ 100 L^{-1})	
	Petrol	**Diesel**
NSW	184.9	207.7
VIC	184.3	207.5
QLD	184.4	208.3
SA	179.7	205.9
WA	181.9	203.8
NT	199.0	222.0
TAS	191.9	213.2
National	184.2	207.5

Source: Australian Institute of Petroleum (2023)

3.2 Travel time cost

Travel time costs estimates involve how many people on average occupy a vehicle and their average income. Travel time is likely to increase as a consequence of the work zone and its reduction on capacity. Average occupancy and hourly wage (deemed 'value') for occupants of common vehicle types in urban areas is provided in Table 2.4. Table 2.5 provides this information in 2022 dollars using an inflation calculator provided by the Reserve Bank of Australia (2023).

Table 2.3 Average occupancy and wages across Australia (2013)

Vehicle Type	Occupancy Rate (person/vehicle)	Wages per occupant ($/person per hour)
Passenger Vehicles (private)	1.25	14.99
Passenger Vehicles (business)	1.4	48.63
Rigid Trucks (Light and Medium)	1.3	25.56
Rigid Trucks (Large)	1.0	26.19
Bus (driver)	1.0	25.72
Bus (passengers)	20	14.99
Courier Van	1.0	25.41
4WD (mid-size SUV for utility)	1.5	25.41

Source: Australian Transport Assessment and Planning (2013)

3.3 Crash cost

Work zones may alter traffic flow crash risk. Average costs associated with fatal, serious and non-life-threatening or minor (i.e., other injuries) injuries across each state in Australia are included in Table 2.6. Estimations in 2022 Australian Dollars using the inflation calculator provided by the Reserve Bank of Australia are provided in **Table 2.6.**

Table 2.4 Average occupancy and wages across Australia (2022)

Vehicle Type	Occupancy Rate (person/vehicle)	Wages per occupant ($/person per hour)
Passenger Vehicles (private)	1.25	18.44
Passenger Vehicles (business)	1.4	59.81
Rigid Trucks (Light and Medium)	1.3	31.44
Rigid Trucks (Large)	1.0	32.21
Bus (driver)	1.0	31.64
Bus (passengers)	20	18.44
Courier Van	1.0	31.25
4WD (mid-size SUV for utility)	1.5	31.25

Source: Australian Transport Assessment and Planning (2013) updated using an inflation rate of 1.23 (Reserve Bank of Australia, 2023)

Table 2.5 Estimated crash costs across Australia States in 2013 ($AUD)

Region	Fatality ($)	Serious Injury ($)	Other injuries ($)
ACT	9,233,736	567,583	Information not provided
NSW	8,298,633	659,881	
NT	8,780,310	655,048	37,888
QLD	7,955,196	633,652	38,566
SA	7,780,230	611,175	38,110
TAS	7,720,934	563,748	42,488
VIC	8,409,584	594,663	39,848
WA	8,001,286	617,588	43,661

Source: Australia Transport Assessment and Planning (2013)

Table 2.6 Estimated crash costs across Australia States in 2022 ($AUD)

Region	Fatality ($)	Serious Injury ($)	Other injuries ($)
ACT	11,357,495	698,127	Information not provided
NSW	10,207,319	811,654	
NT	10,799,781	805,709	46,602
QLD	9,784,891	779,392	47,436
SA	9,569,683	751,745	46,875
TAS	9,496,749	693,410	52,260
VIC	10,343,788	731,435	49,013
WA	9,841,582	759,633	53,703

Source: Australia Transport Assessment and Planning (2013) updated using an inflation rate of 1.23 (Reserve Bank of Australia, 2023)

Although the above information is available, there is not sufficient reliable data about the impact of the work zone on increasing of reducing crashes. On one hand the added congestion because of a work zone and damaged traffic light is expected to increase the number of crashes. On the other hand, the added congestion will decrease vehicles speed thereby reducing the associated severity of crashes. Hence, the safety benefits of having shorter work zones are assumed to be negligible in this study.

3.4 Emissions cost

Vehicles emit gaseous chemicals (e.g., carbon dioxide, nitrous oxides, and carbon monoxide) which can have negative effects on human health and the environment. Work zones at intersections reduce traffic flow and increase or decrease emissions depending on vehicle congestion and speeds. **Table 2.7** provides average amount of CO2 produced by cars and heavy vehicles.

Table 2.7 Average carbon dioxide (CO2) emissions in Australia (2022)

Vehicle Type	**Average CO_2 produced (g km^{-1})**
Passenger cars	146.5
Heavy SUVS, commercial utility vehicles	212.5

Source: National Transport Commission (2022)

3.5 Representative work zone

A small work zone quote from TMR on the Gold Coast from 2022 (Evolution Traffic Management, 2023) was provided to estimate the number of lanes closed, speed reductions around work zones, work zone length and work zone duration. We also had input from personal communications from TMR.

Number of lane closures

The Gold Coast job closed numerous lanes in succession to prevent total blockage of the road. The first job closed off the first 3 lanes at the intersection, the second job closed the next three lanes of the intersection, and the third job close a single lane in the opposite direction. We were advised that the number of lanes is highly specific to the size of the intersection, with small sites generally closing 2 lanes and larger sites with higher posted speeds have multiple lane closures (S. Palmer personal communication; email from TMR).

Work-zone Duration

Traffic light work zone duration may be related to how dangerous the scene is. After a crash, it may take up to four hours for a repair crew to respond to a crash and four hours to repair. However, general operational degradation (i.e., less severe cases not involving a crash) may take 12 to 16 business days to repair, depending if traffic light footing needs repair (S. Palmer personal communication, TMR). The Gold Coast contract required 9 hours of work (Evolution Traffic Management, 2023).

Work Zone Cost

The average cost to repair a traffic signal in 2022 in Brisbane was $21,723 AUD. This cost will vary depending on a few factors. Re-cabling of the traffic light will add an additional 40% to the total cost, repairs done to intersections at speeds larger than 70km/h add 20% to the total cost, and new footing to the traffic light pole adds an additional 50% to the total cost (K. Leskarac personal communication; email from TMR).

Speed Reductions and work zone size

Travel speeds through the Gold Coast project were 40 km/h to ensure enough traffic was able to pass through the work-zone to mitigate congestion (Evolution Traffic Management, 2023). This speed was slow enough for the safety of workers (1.2 m distance between traffic and workers). Traffic coming into the work zone was initially travelling at 80 km/h and had 130m of tapering to reduce speeds and merge out of the blocked lanes (Evolution Traffic Management, 2023). The work zone in the Gold Coast was 20 - 30 m long with an additional 20 m of buffer space for the safety of the works (i.e., enables cars more distance to slow down) (Evolution Traffic Management, 2023).

3.6 Work zone time and cost

This analysis considers only collisions with traffic signal poles that require a pole repair. The analysis does not need to consider the time taken to arrive to the sites, nor the time required to create safe work zones because these times apply to all alternatives; hence the associated disbenefits all cancel out.

For the Business as Usual (BAU) case, a traffic signal pole repair is assumed to require either unwiring the existing multicore cable(s) (one, or two if daisy chained) or cutting the cable(s) immediately below the pole cap or at the pole base depending on damage and length of cable available, followed by cable preparation and then rewiring the new pole-top 36 way multicore cable connector on the new traffic signal pole. Additionally, the traffic lantern wiring will need to be correctly configured for the pole, although this could be accomplished prior to attending site.

For both future alternatives, the greatest benefit would be gained if the low core count (eg 12 core) spur cable in the traffic signal pole is terminated in a waterproof connector with a standard configuration. An example of a suitable range of connectors are the Deutsch DT or DTM series. These are IP68 rated 2-12 way, in-line, flange, or PCB mount connectors used in automotive, marine and industrial applications. Using such connectors would allow the traffic lanterns to be prewired to the connector terminated spur cable at the depot. Electrical work during pole replacement would then only involve unplugging the damaged pole spur cable and plugging in the new pole spur cable. If a connector is not used, but rather the spur cable is hardwired in the sealed water-proof enclosure in the pit or base of the pole, the rewiring task would still be greatly simplified compared to the BAU case.

For all cases, the time saving is expected to be at least two hours per pole. The time and cost of re-cabling will be eliminated if we assume waterproof connectors on the traffic signal pole spur cable can and will detach in a high impact crash which would have required re-cabling in the BAU case.

If a connector is not used, but rather the spur cable is hardwired, the need for re-cabling may still exist in some circumstances. In these circumstances, the second alternative scheme utilising four core power and comms cable would be significantly easier, faster, and cheaper to re-cable in the event that this was required. Retention socket poles should speed up the removal and reinstallation of poles, but this time saving may be marginal. However, retention socket poles should remove the need for new foundations in all but the most exceptional cases.

In summary, for the existing BUA case, physical repair time once on site was estimated to range from six to nine hours. We have assumed that for both alternative cases, the physical repair time once on site will fall to a fairly uniform four hours. This is based on a two hour saving on simple repairs (rewiring only), and five hours saving for previously complex repairs where re-cabling or new foundations were required (as these are assumed to be now very rarely required).

Once all the required technology is available, cost savings are assumed to be reduced to the base cost of approximately $13,000 per repair for all repairs, without the large spread of costs seen for longer and more complex jobs. Cost savings associated with having the repairing crew on site for a shorter period are assumed to be accounted for in these reduced total costs.

The following analysis assumes that the alternatives will be implemented when new intersections are signalised or when existing intersections are repaired using the new proposed technology. Hence, the following benefits are obtained after crashes during the repairing of new signalised intersections and during the second and following repairs of retrofitted signalised intersections.

Summary – time

BAU: Physical repair time once on-site ranges from 6 – 9 hrs.

Future alternatives: Physical repair time once on-site uniform 4 hours, because rewiring traffic signal poles is greatly simplified, and because re-cabling and new foundations become rare.

Summary – costs

BAU: depending on correspondent, $13k base, or $19k median assuming a spread of repair complexities.

Future alternatives: new repairs will cost $13k, because the repair complexities are generally reduced or eliminated, and all jobs see a speed up.

3.7 Benefit cost estimates

The real cost for implementing the alternatives proposed in this study is the investment required for research, development and deployment of the required alternative approaches. It does not change with the number of upgraded or retrofitted intersections. This cost is based on a project to develop and demonstrate a prototype of the first alternative:

- to develop and test a sealed water-proof enclosure with the daisy-chaining din-rail connector relocated from top of traffic pole to the pole base or adjacent pit, including selection of suitable waterproof connectors for the water-proof enclosure (socket) and traffic pole spur cable (plug), and the development of suitable wiring schemes to simplify, speed and where possible standardise traffic pole spur wiring.

This project is estimated to cost $300k. This cost is for a research assistant time, procurement of prototyping materials, fabrication of prototypes, and laboratory testing of these prototypes. There would then be deployment costs, which would include:

- the required documentation and procurement of the new enclosures, connectors systems, and spur cables,
- the required training for field crews to implement or retrofit the new pit or pole-base versus pole-top cabling solution,

- the required documentation and procurement for retention socket poles for vulnerable single pole signals (noting that these have already been trailed), and
- the required training for field crews to implement or retrofit the retention socket poles.

These deployment costs have estimated at $400k.
The sum of these costs is estimated to be $700k.

These costs are for the first suggested alternative solution.

The second solution involving networked controllers would be a natural extension of this first solution, which might be pursued once the first solution had been trialled to assess its associated benefits and issues. The second solution would be best suited to green field installations, and as a means to transition away from multi-core cable to a new networked controller technology approach.

Three networked controller solutions were found in the previous literature review:

- Swarco (Denmark): ITC-3, now Xline;
- Yunex (Siemens) (Germany): Plus+ / ST950 and
- Dynniq (now Swarco) (UK): PTC-1O)

While these solutions demonstrated the technical advances of a networked ELV solution, all appear to be prototypes in nature, and none are considered suitable for immediate deployment due to their immature practical development. Specifically, none demonstrated the required level of environmental protection and suitable wiring termination schemes this report has identified as necessary for long term reliable operation. Further, as none are yet available as products in our market, the vendors could only provide rough price guidance. This makes it more difficult to cost the implementation of a more ambitious solution using these or similar products.

Assuming a suitable networked ELV traffic controller solution was available, the capital cost of deployment in a new intersection could reasonably be assumed to be cost neutral. This is because several opportunities for cost savings (particularly reduced cabling and conduit material and installation costs) are offset by an initial higher capital cost of the network controller components (based on overseas experience).

Once deployed, rewiring of damaged poles would be greatly simplified, and the assumed cost savings in traffic signal impact restorations would be at least equal to, and in some cases significantly better that discussed for the first solution.

The cost of a project to develop and demonstrate a prototype of the second alternative:

- In conjunction with the vendors and TMR, assess the existing networked controller prototypes and select the most suitable for further development, and then
- In conjunction with the vendor and TMR, to the develop and test suitable sealed water-proof enclosures, connectors and daisy-chained wiring systems suitable for deployment of the networked controller in the field in Queensland conditions.

This project is estimated to cost $1.5M over three years. This cost is for a dedicated project officer to take carriage of this project, a dedicated research assistant, procurement of prototyping materials, fabrication of prototypes, and laboratory testing of these prototypes.

There would then be deployment costs, which would include:

- the required documentation and procurement of the new network hardware, enclosures, wiring and connector systems,
- the required training for field crews to implement or retrofit the new pit or pole-base versus pole-top cabling solution,
- the required documentation and procurement for retention socket poles for vulnerable single pole signals (noting that these have already been trailed), and
- the required training for field crews to implement or retrofit the retention socket poles.

These deployment costs have estimated at $1M.

The sum of these costs is estimated to be $2.5M.

3.7.1 Benefit cost estimates for first alternative

Table 3.1 provides benefit estimates when only one intersection if upgraded with the first alternative. Under this scenario the benefit cost ratio is 0.24, denoting a no cost-effective project. However, this scenario (and table) is provided only for comparative analysis because once the required technology is available, it is likely to be deployed in multiple intersections to take advantage and justify the investment. Table 3.2 provides a more realistic and conservative scenario when only 20 intersections are upgraded with the first alternative. As the number of upgraded intersections increases so are the benefits.

Table 3.1 Net present value per intersection using a 7% interest rate and the first alternative

Year	Present Value of Benefits			Present Value of Project Benefits	Present Value of Project Costs	Net Present Value
	Travel Time and Reliability Savings	Vehicle Operating Cost Savings	Vehicle Emission Reductions			
Research and development cost					$700,00	($700,000)
Project open						
1	$12,506	$867	$126	$13,499	$0	$13,499
2	$11,841	$870	$133	$12,844	$0	$12,844
3	$11,212	$798	$124	$12,135	$0	$12,135
4	$10,618	$749	$119	$11,486	$0	$11,486
5	$10,057	$671	$110	$10,839	$0	$10,839
6	$9,527	$688	$117	$10,332	$0	$10,332
7	$9,025	$645	$112	$9,782	$0	$9,782
8	$8,551	$554	$44	$9,149	$0	$9,149
9	$8,103	$568	$44	$8,714	$0	$8,714
10	$7,679	$487	$36	$8,203	$0	$8,203
11	$7,278	$457	$35	$7,770	$0	$7,770
12	$6,900	$429	$33	$7,361	$0	$7,361
13	$6,541	$402	$28	$6,971	$0	$6,971
14	$6,203	$377	$27	$6,606	$0	$6,606
15	$5,882	$321	$21	$6,224	$0	$6,224
16	$5,579	$301	$20	$5,900	$0	$5,900
17	$5,293	$311	$20	$5,624	$0	$5,624
18	$5,022	$258	$15	$5,295	$0	$5,295
19	$4,765	$242	$15	$5,022	$0	$5,022
20	$4,523	$233	$15	$4,770	$0	$4,770
Total						
	$157,104	$10,229	$1,193	$168,525	$700,000	($531,475)

Table 3.2 Net present value for 20 intersections using a 7% interest rate and the first alternative

Year	Present Value of Benefits			Present Value of Project Benefits	Present Value of Project Costs	Net Present Value
	Travel Time and Reliability Savings	Vehicle Operating Cost Savings	Vehicle Emission Reductions			
Research and development cost					$700,000	($700,000)
Project open						
1	$250,110	$17,337	$2,528	$269,974	$0	$269,974
2	$236,813	$17,394	$2,664	$256,871	$0	$256,871
3	$224,247	$15,963	$2,484	$242,694	$0	$242,694
4	$212,370	$14,974	$2,372	$229,716	$0	$229,716
5	$201,144	$13,424	$2,206	$216,774	$0	$216,774
6	$190,533	$13,759	$2,345	$206,637	$0	$206,637
7	$180,502	$12,906	$2,239	$195,647	$0	$195,647
8	$171,020	$11,079	$875	$182,974	$0	$182,974
9	$162,056	$11,356	$873	$174,284	$0	$174,284
10	$153,581	$9,748	$722	$164,051	$0	$164,051
11	$145,567	$9,143	$690	$155,401	$0	$155,401
12	$137,991	$8,576	$660	$147,226	$0	$147,226
13	$130,826	$8,044	$558	$139,427	$0	$139,427
14	$124,051	$7,544	$533	$132,128	$0	$132,128
15	$117,644	$6,420	$411	$124,475	$0	$124,475
16	$111,584	$6,021	$393	$117,998	$0	$117,998
17	$105,852	$6,224	$408	$112,484	$0	$112,484
18	$100,431	$5,161	$307	$105,899	$0	$105,899
19	$95,303	$4,841	$294	$100,437	$0	$100,437
20	$90,451	$4,659	$291	$95,401	$0	$95,401
Total						
	$3,142,073	$204,574	$23,852	$3,370,498	$700,000	$2,670,498

Sensitivity Analysis

The analysis above uses a real discount rate of 7%. A real discount rate is a discount rate that reflects the opportunity cost of money net of the rate of inflation. A sensitivity analysis using a rate of 3% and 10 is often recommended (Infrastructure Australia, 2021).

Table 3.2 Sensitivity Analysis considering 20 intersections and the first alternative

Discount Rate	**3%**	**7%**	**10%**
Life-Cycle Costs (in millions)	$0.7	$0.7	$0.7
Life-Cycle Benefits (in millions)	$4.81	$3.37	$2.68
Net Present Value (in millions)	$4.11	$2.67	$1.98
Benefit / Cost Ratio	6.87	4.81	3.83

This analysis shows how sensitive the life-cycle cost and benefits are relative to a discount rate of 7%. The B/C ratio significantly changed from 3.83 to 6.87, implying that additional benefits may occur.

3.7.2 Benefit cost estimates for second alternative

The benefits of the first and second alternative are identical because they both provided the same impact in terms of traffic flow effects including travel time and its reliability, vehicle operating cost, and vehicle emissions. This is because the work zone required to repair the signal posts after crashes on average are identical in both cases. Table 3.3 provides the corresponding benefit cost analysis. Given that the cost of the second alternative is significantly higher than for the first alternative, the benefit cost ratio is 1.35 compared to 4.8.

Table 3.3 Net present value for 20 intersections using a 7% interest rate and the second alternative

Year	Present Value of Benefits			Present Value of Project Benefits	Present Value of Project Costs	Net Present Value
	Travel Time and Reliability Savings	Vehicle Operating Cost Savings	Vehicle Emission Reductions			
Research and development cost					$2,500,000	($2,500,000)
Project open						
1	$250,110	$17,337	$2,528	$269,974	$0	$269,974
2	$236,813	$17,394	$2,664	$256,871	$0	$256,871
3	$224,247	$15,963	$2,484	$242,694	$0	$242,694
4	$212,370	$14,974	$2,372	$229,716	$0	$229,716
5	$201,144	$13,424	$2,206	$216,774	$0	$216,774
6	$190,533	$13,759	$2,345	$206,637	$0	$206,637
7	$180,502	$12,906	$2,239	$195,647	$0	$195,647
8	$171,020	$11,079	$875	$182,974	$0	$182,974
9	$162,056	$11,356	$873	$174,284	$0	$174,284
10	$153,581	$9,748	$722	$164,051	$0	$164,051
11	$145,567	$9,143	$690	$155,401	$0	$155,401
12	$137,991	$8,576	$660	$147,226	$0	$147,226
13	$130,826	$8,044	$558	$139,427	$0	$139,427
14	$124,051	$7,544	$533	$132,128	$0	$132,128
15	$117,644	$6,420	$411	$124,475	$0	$124,475
16	$111,584	$6,021	$393	$117,998	$0	$117,998
17	$105,852	$6,224	$408	$112,484	$0	$112,484
18	$100,431	$5,161	$307	$105,899	$0	$105,899
19	$95,303	$4,841	$294	$100,437	$0	$100,437
20	$90,451	$4,659	$291	$95,401	$0	$95,401
Total						
	$3,142,073	$204,574	$23,852	$3,370,498	$700,000	$870,498

Sensitivity Analysis

The analysis above uses a real discount rate of 7%. A real discount rate is a discount rate that reflects the opportunity cost of money net of the rate of inflation. A sensitivity analysis using a rate of 3% and 10 is often recommended (Infrastructure Australia, 2021).

Table 3.4 Sensitivity Analysis considering 20 intersections and the second alternative

Discount Rate	**3%**	**7%**	**10%**
Life-Cycle Costs (in millions)	$2.5	$2.5	$2.5
Life-Cycle Benefits (in millions)	$4.81	$3.37	$2.68
Net Present Value (in millions)	$2.31	$0.87	$0.18
Benefit / Cost Ratio	1.92	1.35	1.07

This analysis shows how sensitive the life-cycle cost and benefits are relative to a discount rate of 7%. The B/C ratio significantly changed from 1.07 to 1.92, implying that the project is cost-effective in all cases.

4 Crash data analysis

Crashes damaging traffic posts from 2007 to 2022 were analysed to determine likely contributing factors. Crash data was provided by TMR in file "extract SIMS collision infrastructure to 15032022 cleaned.xlsx." Additional crash data involving signalised intersections was provided in file "QRAM of Struck Light power pole v3.xlsb." However, no all crashes in the second provided file damaged traffic posts. The current analysis focuses on the impact of the different road speed limits on traffic crashes with traffic posts.

4.1 Descriptive statistics

Crash data involving traffic posts was provided by TMR from 2007 to 2022. The data included crash coordinates which were used to locate the corresponding intersections using OpenStreetMaps. Of the 528 crashes with traffic posts that were provided, 521 were successfully located. There are 8,848 traffic intersections in Queensland. A total of 8,438 intersections did not experience any crash involving a traffic signal, 337 intersections experienced 1 crash, 54 intersections experienced 2 crashes, and 18 intersections experienced 3 crashes or more. Details for the crashes that were located (521) are provided in Table 3.1 below.

Table 4.1 Frequency of crashes across traffic signals

Number of crashes	0	1	2	3	4	5	6	7
Number of traffic signals	8,438	337	54	9	5	2	2	1

4.2 Crash locations

Most crashes (525 of the 528) occurred in Southeast Queensland (SEQ). Only 2 crashes occurred outside of SEQ. Within SEQ, the crashes were well widespread. Figure 3.1 below provides an overview of the crash locations.

4.3 Speed limits at intersections and number of traffic post crashes

Speed limits can influence intersection crashes. The following analysis considers average and maximum speed limits as well as the minimum speed limit among the streets approaching intersections and the difference between their maximum and minimum speed limits.

Table 4.2 provides speed limit statistics over the number of crashes involving traffic posts. The average speed limit is the average of speed limits over all streets approaching intersections. Similarly, the average of maximums and minimums speed limits is, respectively, the average of the maximum and minimum speed limits of the streets approaching intersections. The average of the difference between the maximums and the minimums speed limits is averaged over the difference between the maximum and the minimum speed limit of all streets approaching an intersection. These averages are calculated considering the number of crashes observed in each intersection.

As expected, the number of crashes, in general, increased with the average speed limit, the average of maximums speed limits, the average of minimums speed limits. Similarly, the average difference between the maximum and the minimum speed limit is larger for intersections with 1 or 2 crashes (1.30kph and 1.88 kph) than for intersections without crashes (1.28 kph).

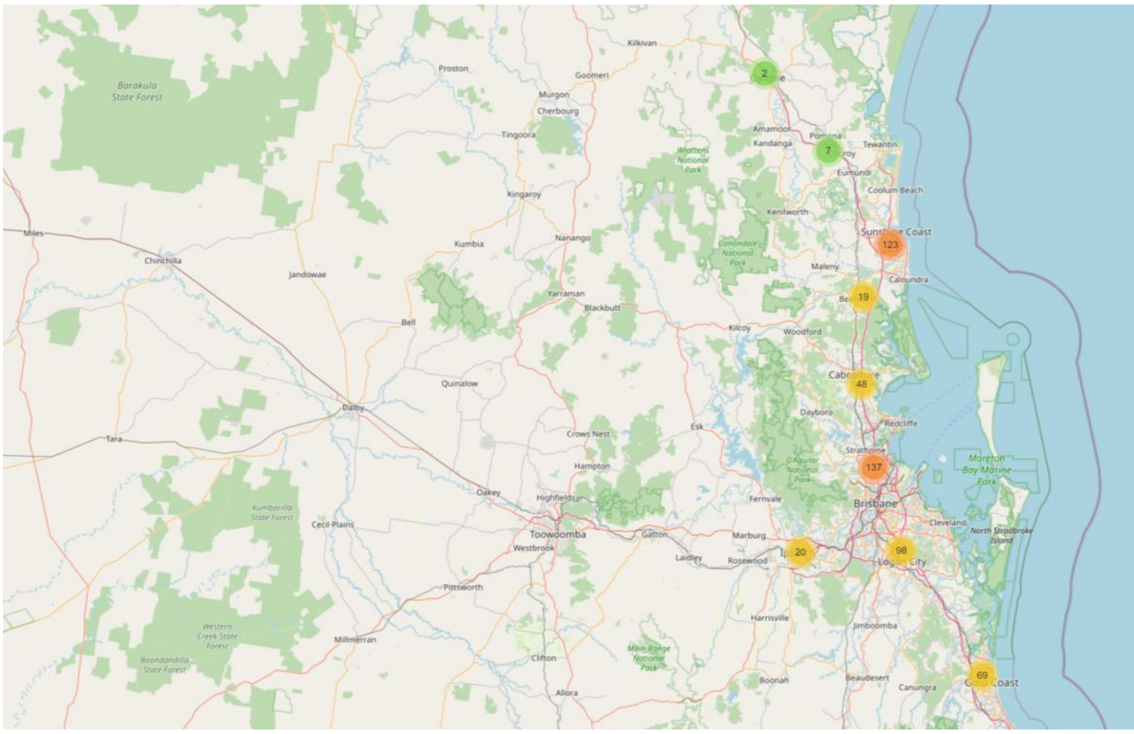

Figure 3.1 Location of crashes from 2007 to 2022 involving traffic posts in Queensland

Table 4.2 Speed limit statistics over the number of crashes involving traffic posts

Number of crashes involving traffic posts	0	1	2	3+
Average speed limit	60.05	62.11	63.49	62.5
Average of maximums speed limits	60.62	62.68	64.38	63.12
Average of minimums speed limits	59.33	61.39	62.5	61.88
Average of the difference between the maximums and the minimums speed limits	1.28	1.30	1.88	1.25

4.4 Statistical analysis

This section presents statistical analyses using a Negative Binomial functional form to evaluate how speed limits can influence the number of crashes involving traffic posts. The general equations for crashes with traffic posts is:

$$Ln(\theta) = \beta_0 + \beta_1 X \quad (1)$$

where,

- $Ln(\theta)$: Logarithm of the number of crashes involving traffic posts.
- β_0: Constant
- β_1: Parameter/coefficient associated with potential crash contributing factors X
- X: Average speed limits as listed in Table 3.2

Table 4.3 provides results testing independently (columns 1-4) each speed limit variable listed in Table 4.2. In all cases, Negative Binomial models were estimated to evaluate the effect of the speed limits. All average speed limits were statistically significant, which indicate a strong influence in crash likelihoods.

With the absence of data, this report focuses on the likely impact of speed limits on crashes involving traffic posts. This preliminary analysis indicates that the higher the speed limits, the more likely are crashes with traffic posts, as expected. Standard crash and traffic data is required to complete a statistical analysis.

Table 4.3 Effect of average speed limits on crashes involving traffic posts

Response variable: crashes involving traffic posts	**(1)**		**(2)**		**(3)**		**(4)**	
Explanatory Variables	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
	z	**Prob**	**z**	**Prob**	**z**	**Prob**	**z**	**Prob**
Constant	-2.71***	0.06	-2.71***	0.06	-2.71***	0.06	-2.67***	0.06
	-48.96	0.00	-48.99	0.00	-48.93	0.00	-45.81	0.00
Average speed limit	0.00***	0.00	-		-		-	
	6.48	0.00						
Average maximums speed limits	-		0.00***	0.00	-		-	
			6.48	0.00				
Average minimums speed limits	-		-		0.00***	0.00	-	
					6.48	0.00		
Average difference between maximum and minimum speed limit	-		-		-		0.00***	0.00
							6.36	0.00
Dispersion parameter (α)	8.17***	0.87	8.17***	0.87	8.17***	0.87	8.19***	0.87
	9.44	0.00	9.44	0.00	9.43	0.00	9.44	0.00
No. of parameters (K)	3		3		3		3	
Log Likelihood	-1906		-1906		-1906		-1906	
AIC	3818		3818		3818		3819	
BIC	3839		3839		3839		3840	

5 Feedback from other Jurisdictions

On 6 July 2023, an email was sent to ten representatives of the various Australian and NZ state government departments responsible for traffic signalling to seek their feedback on our report to Qld TMR. In the three weeks that followed, only two substantive responses were received; which are summarised below. Others forwarded the email internally, and we followed up with phone calls, however no other substantive replies were received. The Appendix includes all email communication regarding this task.

Vincent Vong, Manager, ITS Solutions Development of the Victorian Department of Transport and Planning, Summary of response:

- Victorian intersections operate a 51 core ring circuit which loops from the traffic controller cabinet to each traffic signal pole before closing the loop back to the traffic controller. In the event of damage to a pole, the pole cables can be isolated while the remaining poles and thus the intersection is quickly returned to full functionality. The site can remain operational while the work is carried out.
- Replacing a pole sometimes requires re-terminating the 51 core cables but can often just require disconnecting the terminal strip from the UMA (upper mounting assembly) and pulling the still terminated cables down the pole. If re-termination is required, it may be time consuming, but are argued to neither be difficult nor error prone. They are not aware of arcing problems caused by diesel fumes in the cable termination area.
- DTO Victoria canvased internally, other road authorities, and industry some years back seeking potential alternatives to the current arrangement. They did not identify a feasible alternative.
- They believe the use of underground terminations is not considered feasible due to the amount of rain we receive. To date, there has not been a 'waterproof' termination housing that works. They have always suffered water ingress.
- They have looked at the retention socket pole which appears to be a very good option to replace current Type 2 poles. They intend to trial, but have not done so yet.
- VicRoads had an operating 'networked traffic controller', or distributed switching, in Mulgrave many years ago. Efforts at the time to create interest in other states have failed.

Gavin Leng in the Roads ACT Traffic Signals group summary of response:

- Apart from some legacy sites, the ACT uses 51 core cables. (No further discussion)
- The long-term integrity of sealed water-proof enclosures in pits will always be an issue, and the routine inspection burden in assuring this would probably be a net loss in productivity compared to rectification times involved with the current pole mounted setup.
- The idea of traffic signal controllers based on intelligent networked signal lanterns / aspects has been floating around for a long time, but apart from certain individual engineers/technologists I am not aware of any jurisdiction that is heavily invested in this as a group.

6 Discussion and recommendations

The benefit-cost ratio for upgrading 20 traffic signal posts with the proposed first and second alternatives are 4.8 and 1.35, respectively, with a 7% discount rate. Hence, the first alternative is a great investment, attributable to the shorter work zones during future repairs of traffic signals that get posts damaged by road crashes. The majority of the savings will be in terms of travel time savings and vehicle operating cost savings. This analysis shows the cost effectiveness of an investment with benefits for transport users and non-users; it is not exactly a monetary return on investment. The estimates are conservative because other aspects that were not considered in this analysis will also generate benefits including but not limited to reductions in noise, stress, anxiety, transit travel time savings, secondary crashes, and crew safety. These aspects were not included because lack of required data or models to estimate the corresponding benefits. In addition, the second alternative, which involves signals using network traffic controllers, will introduce further advantages such as simpler installations, particularly for large intersections with many approaches and cabling requirements. Considering the conservative estimates in this study, we recommend TMR to pursue the development of the technology required to implement the proposed alternatives to improve traffic signal posts.

Appendix

Original email:

From: Geoff Walker

Sent: Thursday, July 6, 2023 3:49 PM

To: Siju.Pulickal@transport.nsw.gov.au; mana.z.tavahodi@tmr.qld.gov.au; tai.dinh@sa.gov.au; yolanda.zhao@sa.gov.au; vincent.vong@roads.vic.gov.au; gavin.leng@act.gov.au; marcus.hamill@stategrowth.tas.gov.au; scott.mckay@nt.gov.au; deryk.whyte@nzta.govt.nz; cory.ross@mainroads.wa.gov.au

Cc: Alexander Paz <alexander.paz@qut.edu.au>; Kruno Leskarac <Kruno.Z.Leskarac@tmr.qld.gov.au>

Subject: Seeking feedback on traffic signal pole impact & rectification research project for QLD QUT TMR iMove project

Good afternoon Siju, Mana, Tai, Yolanda, Vincent, Gavin, Marcus, Scott, Deryk and Cory.

Kruno Leskarac from Qld TMR has provided your contact details. Thanks in advance for your time and engagement.

We (QUT) are concluding an iMove CRC research project in collaboration with Qld Transport and Main Roads (TMR).
The research title: Traffic signal post impact and rectification – a design review.

One goal was to investigate methods to improve rectification times when traffic signal posts are damaged.

Re-terminating and sometimes replacing the 36 core multicore cable which daisy chains from traffic signal post pole-top to pole-top is a significant portion of the rectification time.

Two solutions were proposed which should reduce the rectification times; one incremental, and one more radical in nature:

Soln 1: Retain the existing 36 core cable, but relocate the daisy-chaining din-rail connector from top of traffic pole to a sealed water-proof enclosure in the adjacent pit, along with a low core count spur cable up the traffic pole (eg 12 core terminated in IP68 connector), and the use of retention socket poles for vulnerable single pole signals (but not cantilever masts).

Soln 2: Change traffic signal controller to one based on intelligent networked signal lanterns / aspects. This would allow greatly simplified intersection wiring using eg four core (two twisted pairs) for ELV power and data to daisy chain or star connect to all traffic signal poles.

My question – do you have any relevant experience with the rectification of traffic signal posts, and/or with considering alternative wiring arrangements for traffic signal posts and/or lanterns.

More generally still – are there any other "treatments" you have implemented or considered in this space (reducing impacts with traffic signal posts, and speeding rectification time when they do occur)?

Please feel free to contact me by phone if this is a faster way to communicate your feedback.
ph 07 3138 4861 or mob 0403 435 386

FYI and for further context, Below and attached is the presentation and follow up email from our interim workshop with TMR in November when we discussed some of the issues and possible solutions.

With many thanks,
Geoff.

Assoc Prof Geoffrey Walker | Power Engineering
School of Electrical Engineering and Robotics
Faculty of Engineering | Queensland University of Technology
Rm S837 S Block, Level 8, Gardens Point
ph +61 7 3138 4861 | mob +61 403 435 386 | email geoffrey.walker@qut.edu.au
CRICOS No 00213J

Siju Pulickal	Transport for NSW	NSW	Intelligent Transport Systems | Technology and Innovation | Customer, Strategy and Technology	M 0430 730 290	Siju.PULICKAL@transport.nsw.gov.au
Mana Tavahodhi	Department of Transport and Main Roads	QLD	Manager (ITS Device Technologies)	P: 07 3066 8284	mana.z.tavahodi@tmr.qld.gov.au
Tai Dinh	Department for Infrastructure and Transport	SA	A/Team Leader ITS	P: 08 8343 2166	tai.dinh@sa.gov.au
Yolanda Zhao	Department for Infrastructure and Transport	SA			yolanda.zhao@sa.gov.au
Cory Ross	Main Roads Western Australia	WA	A/Manager ITS Operations Network Operations / ITS Operations	P: 08 9323 4845 M: 0413 959 354	
Vincent Vong	Department of Transport	VIC	Manager ITS Solutions Development Intelligent Transport Systems	P: 03 9091 1738 M: 0476 838 308	vincent.vong@roads.vic.gov.au
Gavin Leng	Transport Canberra and City Services Directorate	ACT	Senior ITS & Traffic Signals Officer	P: 02 6207 3086 M: 04 6601 2169	Gavin.Leng@act.gov.au
Marcus Hamill	Department of State Growth	TAS	ITS Team Leader - Traffic Operations	P: 03 6166 4933	marcus.hamill@stategrowth.tas.gov.au
Scott McKay	Department of Infrastructure, Planning and Logistics	NT			Scott.Mckay@nt.gov.au
Deryk Whyte	NZ Transport Agency	NZ	Transport Technology Specialist	M: 04 (0)21 449 510	deryk.whyte@nzta.govt.nz

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From: Cory Ross <cory.ross@mainroads.wa.gov.au>
Sent: Thursday, July 6, 2023 3:55 PM
To: Geoff Walker <geoffrey.walker@qut.edu.au>
Cc: Steven Howells <steven.howells@mainroads.wa.gov.au>
Subject: Fwd: Seeking feedback on traffic signal pole impact & rectification research project for QLD QUT TMR iMove project

Hi Geoff

After reading your email, I believe that Steve Howells is the best person in Main Roads to assist you. Steve is the Manager of Electrical Asset Management which deals with this area.

Steve is cc'd on this email, and I'll leave you in his capable hands.

Kind regards
Cory

From: Scott Mckay <Scott.Mckay@nt.gov.au>
Sent: Thursday, July 6, 2023 4:07 PM
To: Geoff Walker <geoffrey.walker@qut.edu.au>
Subject: Automatic reply: Seeking feedback on traffic signal pole impact & rectification research project for QLD QUT TMR iMove project

I am currently out of the office and will return on 10th July. If you require any assistance, please contact Traffic Section on 08 8999 4402 or Traffic.NTG@nt.gov.au.

Kind Regards

From: Deryk Whyte <Deryk.Whyte@nzta.govt.nz>
Sent: Friday, July 7, 2023 4:34 AM
To: Steen Bohanna <Steen.Bohanna@nzta.govt.nz>; Bruce Kassir <Bruce.Kassir@jtoc.govt.nz>
Cc: Geoff Walker <geoffrey.walker@qut.edu.au>
Subject: FW: Seeking feedback on traffic signal pole impact & rectification research project for QLD QUT TMR iMove project

Hi Steen and Bruce

I received this email from Geoff yesterday, where he is seeking inputs to a research project titled "Traffic signal post impact and rectification – a design review".

As this is not my area of expertise/experience, would you be able to co-ordinate a Waka Kotahi response to Geoff's questions etc please?

It would be great if you could let Geoff know if you are able to assist and provide the feedback sought.

Many thanks to you both.

Deryk

Deryk Whyte
Transport Technology Specialist
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From: Vincent H Vong (DTP) <Vincent.Vong@roads.vic.gov.au>

Sent: Monday, July 10, 2023 3:15 PM

To: Geoff Walker <geoffrey.walker@qut.edu.au>

Cc: Mana.Z.Tavahodi <Mana.Z.Tavahodi@tmr.qld.gov.au>; Kruno Leskarac <Kruno.Z.Leskarac@tmr.qld.gov.au>; Arthur Drepas (DTP) <Arthur.Drepas@roads.vic.gov.au>; Stephen Purtill (DTP) <Stephen.Purtill@roads.vic.gov.au>; Zoltan Szasz (DTP) <Zoltan.Szasz@roads.vic.gov.au>

Subject: FW: Seeking feedback on traffic signal pole impact & rectification research project for QLD QUT TMR iMove project

Hi Geoff,

Please find details below comments from my team in response to your questions as follows:

- DTO Vic do not use a daisy chain arrangement as Queensland do.
- The 51 core ring circuit was introduced in Victoria for improved safety as it provides power to remaining poles if one pole is deactivated.
- While replacing a damaged pole and terminating the 2 X 51 core cables may take longer than a single cable, the safety benefits of keeping the site operating while the work is carried out, in my view, outweighs the time factor.
- Replacing a pole sometimes requires re-terminating but can often just require disconnecting the terminal strip from the UMA and pulling the still terminated cables down the pole.
- We canvased internally, other road authorities, and industry some years back seeking potential alternatives to the current arrangement. We did not identify a feasible alternative.
- The use of underground terminations is not considered feasible due to the amount of rain we receive. To date, there has not been a ‘waterproof’ termination housing that works. They have always suffered water ingress.
- A single cable to each pole could result in 20 or more cables running back to the controller. This is not feasible as the conduits would not have the capacity nor would the controller.
- We have looked at the retention socket pole which appears to be a very good option to replace current Type 2 poles. We did try to have some installed as a trial, but so far this has not happened.
- We do not agree with the multicore cable issues identified on page 9 of the PDF. Stripping and terminating cables is not difficult. Each core is numbered. We are not aware of arcing problems caused by diesel fumes. We do not generally have many spare cores these days with the complexity of sites. The ring circuit we use means the site continues to operate even if one pole is removed.

- VicRoads had an operating 'networked traffic controller', or distributed switching, in Mulgrave many years ago. Efforts at the time to create interest in other states have failed.

Kind Regards

Vincent Vong MEngSc (civil), RPEng
Pronouns: he/him/his
Manager ITS Solutions Development
Intelligent Transport Systems
Network Operations
Department of Transport and Planning
110 Maroondah Highway, Ringwood, VIC 3134
M 0476 838 308
E Vincent.Vong@roads.vic.gov.au
W dtp.vic.gov.au

From: Leng, Gavin <Gavin.Leng@act.gov.au>
Sent: Tuesday, July 11, 2023 11:40 AM
To: Geoff Walker <geoffrey.walker@qut.edu.au>
Cc: Glassford, Cameron <Cameron.Glassford@act.gov.au>; Bunnik, Chris <Chris.Bunnik@act.gov.au>
Subject: RE: Seeking feedback on traffic signal pole impact & rectification research project for QLD QUT TMR iMove project

Hi Geoff,

Apart from some legacy sites, the ACT uses 51 core cables. Both of the proposed solutions have been thought about for a long time, with their own problems:

Soln 1: The long term integrity of sealed water-proof enclosures in pits will always be an issue, and the routine inspection burden in assuring this would probably be a net loss in productivity compared to rectification times involved with the current pole mounted setup.

Soln 2: The idea of traffic signal controllers based on intelligent networked signal lanterns / aspects has been floating around for a long time, but apart from certain individual engineers/technologists I am not aware of any jurisdiction that is heavily invested in this as a group.

My colleague @Glassford, Cameron has more direct experience with the rectification of traffic signal posts, traffic signal post/lantern wiring arrangements and such issues in this space.

Regards,
Gavin Leng
Traffic Signals / Roads ACT / TCCS

Tai Dinh 08 8343 2166 -> Got the message bank of Phil Stratton 11:27 28/07/2023
Dept of Infrastructure and Transport SA.

Marcus Hamill 03 6166 4933 -> Message bank of Peter Clark 11:30 28/07/2023
Dept of state growth TAS ITS team leader

Siju Pulickal mob 0430 730 290 - left a message
Transport for NSW

Scott McKay → NT public holiday

Mana Tavahodhi 07 3066 8284
TMR Qld – Manager ITS -
She forwarded to David Jones – 3066 8689

I have already received excellent feedback some months back from David Jones. This has already been shared.

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