An investigation into the safety benefits of flag lighting at NZ state highway intersections

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Flag lighting means one to three lights at a rural intersection

Safety project

- It is known that road lighting has significant safety benefits.
- Overseas evidence suggests that flag lighting reduces crashes – in one study by 39%.
- This project aims to improve our understanding of flag lighting’s impact on night-time crashes.

Linking databases

- We developed a database of state highway intersection crashes and intersection characteristics
- Produced by matching the CAS system of Police reported crashes to a number of databases containing road infrastructure and vehicle flow information.
- The common linkage between the databases and CAS was the State Highway Route Position (RP).
- The databases used were:
- KiwiRAP: Inventory taken from the 2009 SH network video
- SLIM: A Transport Agency database of lighting infrastructure
- MobileRoad: A query-friendly database of road and traffic characteristics produced by the Auckland Motorways Alliance
- Statistical analyses used generalised linear modelling (GLM) and contingency tables.

Caution on linking databases

- Intersection route positions change over time as the State Highway length changes.
- Route positions in transport databases (KiwiRAP, SLIM, and CAS) are updated but on an irregular basis and are often at variance from current day route positions.
- Considerable effort was required to align database route positions with those in current use in CAS.
- Where significant variation occurred sites were simply omitted resulting in a loss of data to the project.

Crashes included

- Those within an RP range of plus or minus 50 metres.
- This served the dual purpose of including crashes on the approach and departure from intersections and increased the chances of capturing the intersection crashes where there was a small error in the RP.
- The +/-50 metres range was selected after a sensitivity analysis.
- Higher values would increase the sample size but also increase the data noise as it became more likely to include crashes from adjacent intersections.
- The study included only intersections with at least one reported crash in the study period.

Major variables used

- No. of lights at the intersection
  - KiwiRAP definitions of unlit, flag lit (<=3 lights), fully lit (>3 lights)
  - SLIM – limited availability
  - Google street view observations
- Lumen package (sum of lamp lumens at the intersection- limited availability)
- SH Traffic volume (available for all data)

Major variables used

- Side road traffic data (available for flag lit sites and a sample of unlit and fully lit sites).
- Intersection geometry (T, Staggered T or Cross intersection).
- Destination signs, advanced signing, and chevron boards (KiwiRAP).
- Crashes:
  - night, day and total
  - by injury severity
  - by movement codes (types of crash)

Generalised linear modelling

- A Poisson multiplicative regression model was used of form:

$$N/T = e^{(a + b A + c B + d C + \ldots) + \epsilon}$$

- Where:
  - N = number of night crashes (dependent variable)
  - T = total number of crashes (day and night)
  - A, b, c and d are parameter estimates of the model
  - ϵ is the random error of the dependent variable
  - A, B, C etc are the independent variables which are being tested
- The structure of the model is log-linear, appropriate for a multiplicative relationship between the dependent variables.

Generalised linear modelling

- In general the impact of a crash countermeasure will depend on the size of the crash problem it is targeting. This situation is best described by such a model where the factors are assumed to act multiplicatively.
- A value of two standard deviations ($p<=0.05$) was adopted in rejecting the null hypothesis that the relevant variable has no impact on the night-to-total crash ratio.
- Three samples were analysed separately in the GLM model:
  - all sites (fully lit, flag lit and unlit)
  - flag lit and unlit sites
  - unlit sites

Generalised linear modelling results (three variable models)

Flag lit and fully lit sites

Variable name	Parameter Value	Implied result for night crash ratio
Lighting present	-0.183*	17% reduction where lighting present
“X” intersection	-0.272*	24% reduction if a cross junction
Advanced Direction Signing	-0.245*	22% reduction where present

Flag lit sites only

Variable name	Parameter Value	Implied result for night crash ratio
Lights per intersection (G)	-0.124*	12% reduction per light (max=3)
“X” intersection	-0.251*	22% reduction if a cross junction
Channelisation	-0.348*	29% reduction if channelisation present

- Reflectorised “Advanced Direction” signing contributes to night time visual guidance at isolated rural intersections.
- Crossroads have inherently fewer crashes at night than T intersections. May relate to the increased turning movements at T intersections compared to crossroads.
- Channelisation adds an additional night time benefit at lit intersections.

Contingency table result

Results by severity of crash

	No of sites	Day crashes	Night crashes	Night / day crash ratio	Crash reduction	Statistically significant?
Injury and Non Injury Crashes						
No Lighting	2856	873	408	0.47		
Flag Lighting	826	758	254	0.34	28%	Yes
Full lighting	485	881	278	0.32	32%	Yes
Injury Crashes Only						
No Lighting	2856	372	153	0.41		
Flag Lighting	826	329	104	0.32	23%	Close
Full lighting	485	336	97	0.29	30%	Yes
Fatal and Serious Crashes						
No Lighting	2856	113	43	0.38		
Flag Lighting	826	95	23	0.24	36%	No
Full lighting	485	93	29	0.31	18%	No

- Fairly similar crash reduction for all crash severities

Results by total lumens from luminaires

Total Lumens per intersection	No of sites	Day crashes	Night crashes	Night/day crash ratio	Crash reduction	Statistically significant?
No lights	2856	873	408	0.47		
Low	354	271	98	0.36	23%	Close
Medium	121	151	38	0.25	46%	Yes
High	53	84	28	0.33	29%	No

- Note: For lumen groups Low =<20 kL, Medium = 20 -36 kL, High =>36 kL
- Crash ratio reduction peaks at Medium lumens (20-36kL)

Results related to crash movements

Intersection type crash movement codes (G, H, J, K and L)					
	No of sites	Day crashes	Night crashes	Night/day ratio	Crash reduction
No lighting	2854	319	55	0.17	0
Flag lighting	826	406	64	0.16	9%
Full lighting	485	496	96	0.19	12% increase
Single vehicle crash movement codes (C and D)					
No lighting	2854	335	230	0.69	0
Flag lighting	826	173	140	0.81	18% increase
Full lighting	485	144	112	0.78	13% increase
General crash movement codes (A,B,E,F,M,N,P and Q)					
No lighting	2854	219	123	0.56	0
Flag lighting	826	179	50	0.28	50% *
Full lighting	485	241	70	0.29	48%*

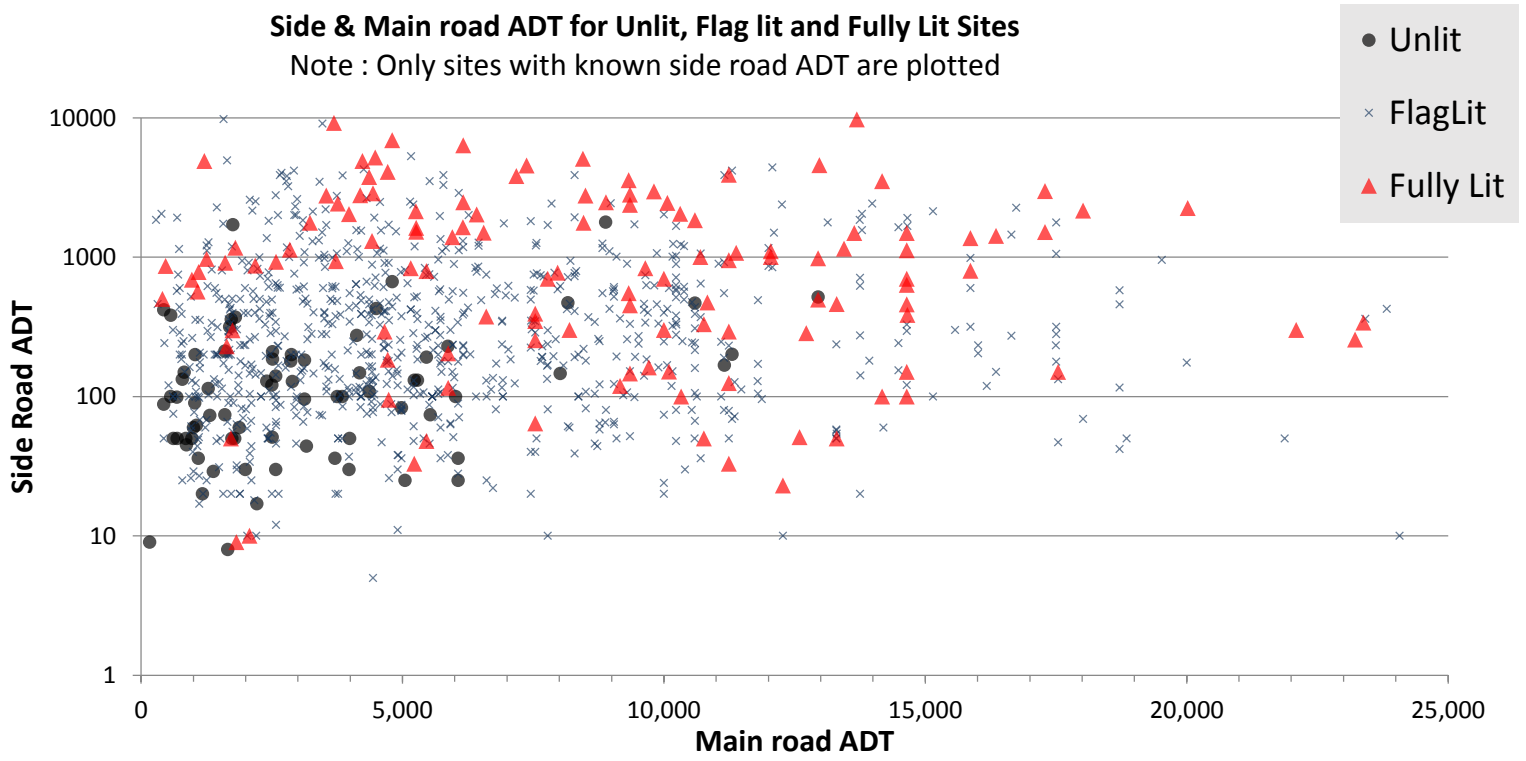
small increase

big decrease

*statistically significant

- Flag lighting most effective for crashes involving hazards, rear end and manoeuvring crashes.
- Flag lighting is not effective in reducing single vehicle lost control type crashes.

Guidance for flag lit sites



- Tendency for more highly trafficked sites to be fully lit or flag lit.
- Data is dispersed suggesting different implementation criteria in different areas.
- More consistent practice could result by having guidance with a volume related component.

Conclusions

- Flag lighting is an effective safety measure if targeted at appropriate intersections.
- Multiple flags lights (typically two) at an intersection achieve better safety than just one flag light.
- In assessing the suitability of lights (including LED lights) for flag lighting the lumen package and the number of lights provided appear to be important factors.
- Destination signing at intersections in itself appears to reduce night time crashes and especially so where the intersection is unlit.

Conclusions

- Channelization in conjunction with flag lighting or full lighting seems to provide additional night time safety improvements but channelization in the absence of any intersection lighting seems to reduce night time safety.
- Chevron signs at intersections appeared to have little influence on the proportion of crashes at night.
- There was much variation in the traffic flows at the intersections where lighting was installed. This along with an economic imperative to install lighting only when other passive measures are inadequate indicates consideration of national guidance for flag lighting.
- Flag lighting should not be used as a countermeasure for loss of control/off road crashes and is most effective against rear end/obstruction type crashes.

Acknowledgement

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