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Quantifying the impact of road lighting on road safety — A New Zealand Study

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ABSTRACT

It is well known from the literature that road lighting has significant safety benefits. The NZTA Economic Evaluation Manual (EEM) quotes a 35% reduction in crashes as the effect of upgrading or improving lighting where lighting is poor.
However, no well-established dose–response relationship to lighting parameters exists from which one can deduce benchmark levels of lighting for safety.
This study looked at a sample of street lighting installations spread over the urban areas of nine territorial local authorities. Standard street lighting parameters were measured in the field using a variety of instruments including illuminance meter, luminance meter and digital camera. Field measurements were related to the ratio of night-time to day time crashes as a measure of night time safety vis-a-vis daytime safety.
A statistically significant dose–response relationship was found between average road luminance and safety across all traffic volume groups, with an indication that the relationship may be stronger where more serious crashes are involved.
Threshold increment was also a significant variable but not so longitudinal uniformity or overall uniformity. The results related to luminance will allow practitioners to better estimate the safety benefits of different levels of lighting resulting in better targeting of expenditure.

1. Introduction

This paper seeks to improve our understanding of how the quantity and quality of road lighting (as measured by standard CIE[1] lighting parameters) influence the frequency of night time crashes relative to daytime crashes. It is well known that road lighting has significant safety benefits. Before and after studies both here and overseas indicate reductions in crashes of around 30% or more where lighting has been improved. (e.g. Elvik [1], Wanvik [2] Section A6.6 of the NZTA Economic Evaluation Manual (EEM) quotes a 35% reduction in crashes as the effect of upgrading or improving lighting where lighting is poor. However, there is no accompanying definition of "poor" or what constitutes an acceptable improvement. This is because there is no well-established dose–response relationship between safety and lighting parameters from which one can deduce benchmark levels of lighting for safety and thus no objective means to prioritise safety related lighting schemes against other uses of road safety funds. The estimated social cost of night time crashes under category V (safety related) lighting in urban areas is around $310 M per year, around 8% out of a nationwide total of around 3.8 billion per year. With the advent of LED technology in road lighting new opportunities have arisen to allow for an increase as well as a decrease in the level of lighting throughout the night. Benchmarking the level of lighting to specific road safety outcomes will be critical as this technology expands. This study seeks to better define the relationship between road lighting levels and safety to assist in the provision of this benchmarking.

2. Method

The study followed what is known as a relation methodology. Values for the CIE light technical parameters were measured under existing lighting in situ and the results matched with the five year crash history for the same section of road. Regression methods were

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[1] The CIE (Commission Internationale De L'Eclairage) is the international body that deals with lighting and illumination. It has membership of some 40 countries (including New Zealand and Australia).

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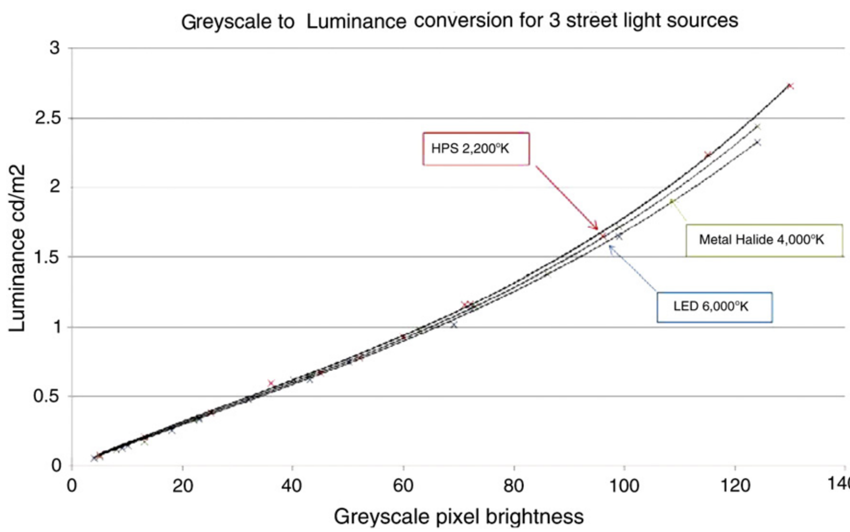

Fig. 1. Conversion scale for photographic measurement (1/50 s, f/3.2, ISO3200, WB = daylight) measured in greyscale pixel values to luminance measured in candela/m^2.

then used to establish the most important predictor variables of the night to day crash ratio. The relation method was chosen as it allowed a much larger sample size than the traditional Before and After study and avoided the need to make adjustments to crash frequencies to compensate for variations in reporting rate.

The parameters measured in the project were:

Average luminance (L_{avg}): Average luminance is the brightness of the road surface as seen by a driver. In Australia and New Zealand the lighting sub-categories V1, V2, V3, and V4 etc. define average luminance groups.

Overall uniformity (U_o): Overall uniformity is a measure of how evenly lit the road surface is. The overall uniformity is established by dividing the minimum value of luminance (L_{min}) by the average luminance (L_{avg}).

$$Uo = L_{min}/L_{avg}$$

Longitudinal uniformity (U_l): Longitudinal Uniformity is a measure to reduce the intensity of bright and dark banding on road lit surfaces. In design it is expressed as the ratio of the minimum to maximum luminance within the lane of travel.

$$Ul = L_{min}/L_{max}$$

Threshold increment (TI): Threshold increment is a measure of the loss of contrast a driver suffers because of light shining directly from the luminaire into the driver's eye. The effect is commonly referred to as disability glare. The physiological effects of glare increase with driver age and consequently glare is a concern in any country with an aging driving population.

2.1. Field measurement

Field measurement will capture the actual light conditions seen by motorists when driving in the street. Road lighting designs make assumptions about road surface reflectivity which may not be accurate and local factors such as vegetation and road alignment also influence the final result.

The disadvantage of field measurement is that it represents the performance of the system at one particular point in time. When the lamps are replaced (3 to 5 year cycle) light output can increase by as much as 30%. Unless the position in the maintenance cycle is known at the time of measurement there will be an error of some + − 15% from the mean value. This increases the noise in the data and consequently the need for a larger sample. The crash data used covers 5 years so could be expected to include at least one maintenance cycle.

2.2. Photographic measurement

A number of field measurement options were explored and a photographic method was chosen as the best all round option. Technological advances have made digital single-lens reflex cameras a viable option for measuring road lighting technical parameters.

The camera's exposure settings and white balance were standardised (1/50 s, f/3.2, ISO3200, WB = daylight). Pixel to luminance calibrations were made using grey scale targets with a calibrated luminance meter [Minolta LS110] under the light sources commonly found in New Zealand road lighting. The calibration curves shown in Fig. 1 indicate that the camera's spectral response is already quite close to the CIE photopic curve and requires only minimal additional adjustment for the different light sources found in the study. To utilise the linear section of the curve photographs were required to be slightly underexposed.

The photographic method has the following advantages over the hand held meter method:

- The measurement area and grid points are more accurately identified.
- Field measurement time is reduced — typically only a few minutes per site.
- Repeatability is improved and a permanent record obtained.

Photographic luminance measurements were made at midblock locations to typify the overall level of lighting along the route. The measurements were made during 2010/2011 and included nine Road Controlling Authorities (RCAs).

2.3. Site selection

Site selection used crash and road asset data to select road lengths which:

- had at least 10 injury + non injury crashes, 2006–2010[2]
- had no significant road lighting changes in the period 2006–2010
- had a similar level of lighting along their length
- had places to stop safely and measure the lighting.

[2] Some sites were subsequently shortened, subdivided or deleted to improve homogeneity.