Wellington City Council (WCC)

Strategic Issues for a Business Case for WCC LED Street Lighting Upgrade

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Final – 31 July 2014

STRATEGIC LIGHTING PARTNERS

1 Introduction

This report has been requested by Deven Singh, Wellington City Council's Manager of Transport Assets, Roading Traffic and Transportation under the supervision of Paul Glennie, Team Leader, Strategic Planning.

The report was commissioned to identify the strategic issues facing Wellington City Council as it considers an upgrade to its street lighting. The scope of work is attached in Appendix 1 where it should be noted that an economic analysis of the issues was not included.

2 Executive Summary

This report strongly recommends that Wellington City Council (WCC) move as quickly as possible to upgrade its street lighting to "LED" (an acronym for Light Emitting Diodes) and together with their control systems, represent a paradigm shift in street lighting. This offers substantial benefits of increased safety and possible reduction in crime as well as material cost savings arising from reductions of electrical energy and maintenance of about 50%. Professor Rune Elvik, arguably the world's most eminent transport economist, suggests that road lighting is the most cost effective road safety measure, but also one of the least recognised.

Unfortunately however, Councillors, senior managers and engineers are unable to rely on any Australian or NZ standard to assist them in mitigating risks associated with setting LED lighting levels as the current standard, AS/NZS 1158 is remarkably out of date. The recent update of the luminaire part of that standard has been stopped (announced 17th July 2014) and the committee responsible for the review of all parts of AS/NZS 1158 is being reconstituted (disbanded and positions re-advertised). In SLP's view the cause of this was that the standard did not sufficiently incorporate best international practice and contained trade restrictive provisions. The AS/NZS luminaire standard (Part 6) is being replaced with an international (IEC) standard, but the social and economic cost of waiting until this and other AS/NZS 1158 updates is far too high so WCC should not delay for any of the updates.

SLP strongly recommend that WCC follows what the City of Los Angeles has done in its conversion of more than 140,000 yellow High Pressure Sodium street lights (a 40 year old technology) to white LEDs. Los Angeles ensures that all LED street lighting is "Better than Before". USA street lighting standards are also out of date and the legal risks and consequences of not following a standard are substantially higher than New Zealand. Thus following Los Angeles as several other US cities are doing has become, in SLP's view, best practice. Furthermore, there are at least 30 other cities in the world currently converting or have completed an upgrade to LEDs and they are also facing similar issues.

LED street lighting is nevertheless new and therefore requires new skills and capabilities. To mitigate against risk caused by this SLP therefore recommends that best practice "Strategic Procurement" processes are used to ensure that the best outcome of the upgrade is brought about. SLP recommend that strong use of commercial warranties and performance guarantees and that a "Financed Performance Contract" model is utilised.

One of the largest risks facing a Council investing in the upgrade of its street lighting is that of a narrow focus on energy and maintenance benefits and thus overlooking the opportunity to improve street lighting practices to systematically reduce traffic accidents at night and reduce crime and provide for other "future proofing" measures. Another high risk is that of regulatory delays to control system implementation and the wrong tendering specifications. These and other risks are covered in section 6 which the reader is encouraged to study.

In SLP's view, the benefits of converting to LED street lighting are so great that any local government body who doesn't do so, is risking failing their duty of care to their stakeholders.

3 The strategic case for greater focus on street lighting

3.1 Introduction

Road lighting has three main purposes: to increase road safety; to decrease crime; and to provide comfort to all road and footpath users. Historical investment and management decisions have accepted the benefits of street lighting without systematically quantifying their effects or their costs. Consequently, the new LED lighting and control technology is seen only as a more energy-efficient and less costly system to maintain. Other more fundamental benefits are generally under-appreciated or ignored altogether.

Wellington City Council does not need to be convinced of the benefits of street lighting. However, an up-grade to LED lighting and controls provides the city with an opportunity substantially greater than just a reduction in energy and maintenance costs. Treating LED lighting as only a technology upgrade would miss a significant opportunity. This section identifies why.

To clarify this strategic opportunity, this section re-visits the scientific basis for the importance of street lighting. The significance of LED lighting and its ability to be controlled provide unprecedented opportunities for a city to increase its liveability at night.

The information presented in this section and the next (on LED lighting) represents a paradigm shift for street lighting infrastructure managers and engineers. At a governance level the evidence presented suggests that a "clean sheet of paper" approach should be taken to obtain the maximum benefit from any investment in street lighting. This suggests big changes and therefore the evidence needs to be presented in detail. For those readers who don't need to be convinced, SLP has provided a summary and conclusions in almost all sub-sections.

3.2 Summary

Although street lighting is accepted as important road safety infrastructure, it has not been managed as if it is. A decision to invest in street lighting is therefore an opportunity to address the fundamental problems that exist, as well as to upgrade the technology to improve liveability for the city's inhabitants and visitors.

Fundamental problems with the status quo are:

a) No priority or strategic direction is provided at national level. No mention has ever been made of street lighting in the rolling 10-year strategic planning document published by Government's[1] "Safer Journeys," which is specifically targeted at "A safe road system increasingly free of death and serious injury."[2] Therefore lighting is also ignored as vital safety infrastructure to be managed by Territorial Authorities to minimise injuries, crime and fatalities, despite the fact that about 40% of all crashes occur at night while only about 25% of all travel takes place at night.

b) The existence of lighting is internationally accepted as an injury- and fatality-reducing road safety measure. The relationship between injuries and the quantity and quality of light is less well understood, but recent NZ and US research provides strong evidence that a WCC conversion to LED lighting will reduce injuries and fatalities at night.

c) Despite the critical role that road lighting plays in safety at night, current practice and AS/NZS standards compliance is only focused on initial construction and installation. There is no emphasis on monitoring or maintenance for the often 20-year lifetime of this vital safety infrastructure, despite the known lighting level deterioration caused by physical and electrical degradation and vegetation encroachment. In this respect street lighting infrastructure appear to be unique.

d) AS/NZS standards have complex engineering requirements that demand each category of road be lit to prescriptive lighting levels. Accordingly, designs must incorporate a large set of "Light

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[1] Ministry of Transport, "*Safer Journeys: NZ Road Safety Strategy 2010 - 2020*", Published on 1 Feb 2013, launched March 2013. Also "*Safer Journeys Action Plan 2013-2015*" published March 2013.

[2] Page 3, Safer Journeys.

Technical Parameters" (LTPs). However, the lighting levels are set mainly by Average Daily Traffic (ADT) flow and are not directly related to night-time injury and crash frequencies. Additionally, after installation, street lighting is rarely monitored for lighting levels. If occasional monitoring does reveal problems, remedial action is seldom taken, despite the effort required to set the initial levels many years before to comply with AS/NZS standards.

e) The prescribed lighting levels in New Zealand and Australia are significantly below those in US and European standards, and Australian and NZ standards have not caught up with CIE[3] work completed in 2010[4] which incorporated the eye's "mesopic" response to low lighting levels and resulted in de-rating yellow light in favour of white lighting (such as LEDs). This response is discussed further in section 3.6.1. More recent research suggests that in yellow street lighting, human reaction times and corresponding vehicle stopping distances are significantly worse than for white lighting.

f) One of the challenges facing an asset manager of street lighting is the large number and variety of lighting types that exist across a city. Historically it would have been prohibitively expensive to keep account of each light and its support hardware. With the advent of integrated information and control systems this is now possible.

A decision to make an investment in street lighting provides WCC with a major opportunity to strategically change the way it manages road lighting to substantially improve community outcomes and provide additional benefits.

Conclusion: WCC's approach should therefore be to:

i. Avoid relying solely on AS/NZS 1158 for determining lighting levels until it has been fully updated to reflect international best practice;

ii. Upgrade to white LED lighting and controls as soon as possible to "Better than Before standard";

iii. Monitor lighting performance before, and regularly after, the upgrade on significant proportions of street-lit roads, and in all known "hotspots" where crashes, crime and trouble occur to ensure that lighting: location, intensity, quality (including colour), and maintenance matches expectations over the life of this safety infrastructure;

iv. Gather, analyse and regularly update traffic, crash and crime statistics to correlate with lighting performance as measured above, **to actively manage** the reduction of nigh time crashes, fatalities, injuries, and crime;

v. Utilise modern asset management practices, software and integrate them with CMS controls to maintain and replace assets when necessary;

vi. Collaborate with leading research institutes (such as Virginia Tech Transportation Institute (VTTI)) to co-ordinate the previous points above which will provide one of the highest quality night-time city environments in the world.

3.3 Road Safety Economics

Dr Rune Elvik, arguably the world's leading authority on the economics of road safety, suggests that road lighting is the most cost effective road safety measure available and yet remains the least well recognised – even amongst leaders in the field such as the Netherlands, Sweden and Norway. Professor Elvik is the lead editor of the "*Handbook of Road Safety Measures"* and in his presentation to Road Lighting 2014 in Auckland[5] he provided data to support these observations.

Figure 1 below shows the relationship between the benefit-cost ratio for street lighting and annual average daily traffic flows (the standard measure of transport intensity). The graph shows data

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[3] CIE stands for Commission International de L'Eclairage or in English the International Commission on Illumination

[4] "*Recommended System for Mesopic Photometry Based on Visual Performance"*, CIE 191:2010. See ***www.cie.co.at/Publications/index.php?i_ca_id=788*** & *CIE Supplementary System of Photometry*, CIE 200:2011.

[5] Elvik, R, Institute of Transport Economics, Norway, Presentation to Road Lighting 2014, Auckland, March 2014

gathered internationally and demonstrates that even for low levels of traffic flow the benefits quickly overtake the costs.

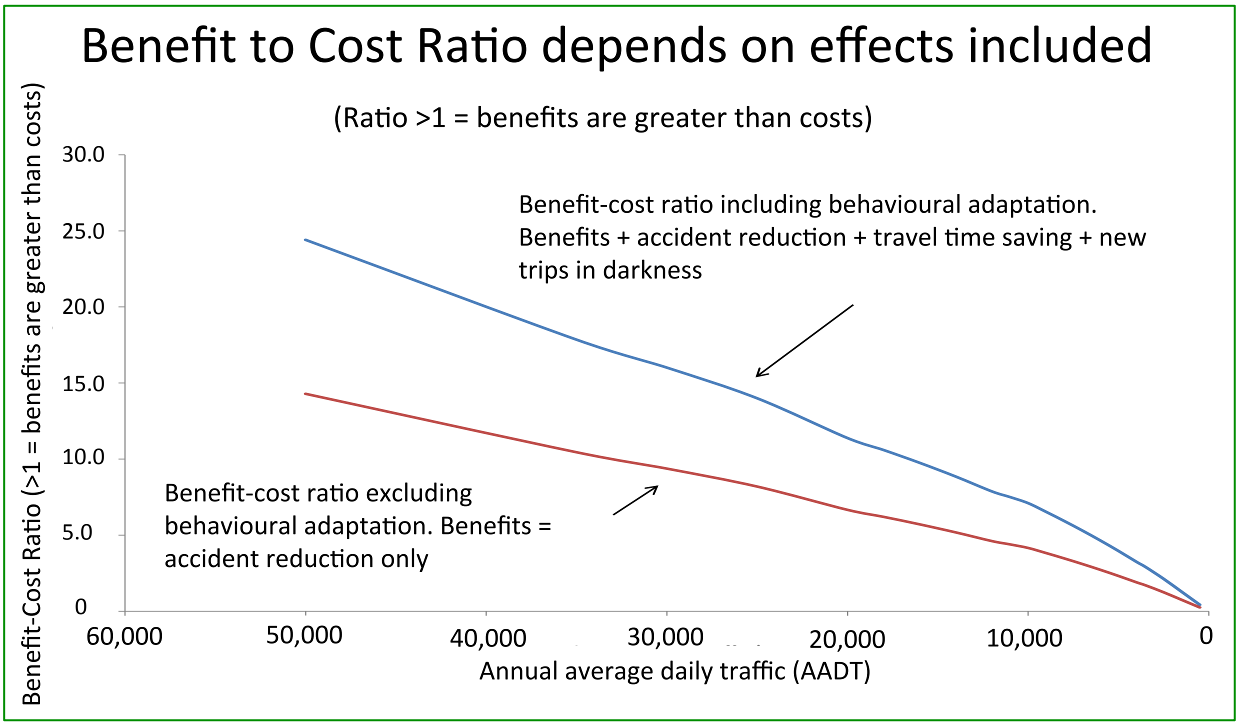

Figure 1 Benefit-Cost ratios for street lighting for a range of traffic flows
(Source: Elvik, R, Institute of Transport Economics, Norway, Road Lighting 2014, Auckland, March 2014)

3.4 Night Road Injuries

Substantial research shows that the **existence** of street lighting produces significant reductions in injuries and fatalities.[6] Consequently NZTA uses a research-based reduction in fatalities of 35% to determine the benefit-cost ratio of road lighting where road lighting currently does not exist[7].

In contrast, there is little research showing **how much** and what type of lighting should be used where it is in place. Road lighting standards are therefore universally silent on research-based lighting levels. In fact, as far as the authors and Dr Gibbons from VTTI are aware, there are only two credible research publications: one done here in New Zealand by Jackett and Frith in 2012[8], and the other by Gibbons in 2013[9].

Jackett and Frith conclude that the greatest reduction in injury crashes is shown to be in "mid-block" road sections (between intersections) where an increase of 0.5 candela/m^2 reduces injury crashes by 33%. In other parts of the network the decrease in injury crashes is less than this, but there is still a significant reduction. For all sites (including mid-block) an average 19% reduction in crashes would

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6 Elvik, R, Hoye, A, Vaa, T, and Sorensen M (2009), Handbook of Road Safety Measures, Institute, of Transport Economics, Oslo, Norway, Emerald Group Publishing Ltd, 2nd Edition, October 2009.

7 Despite this fact, as previously mentioned road lighting is not mentioned anywhere in the Ministry of Transport's transport safety strategy "Safer Journeys" which leads one to expect that road lighting isn't mentioned in any credible Safety Strategy internationally. (The authors have confirmed this in UK, Australia and in one or two states of USA.)

8 Jackett, M and Frith, W (2012), Quantifying the impact of road lighting on road safety – A New Zealand Study, Australasian Road Safety Research, Policing and Education Conference 2012.

9 Gibbons, R. Guo, F., Medina, A., Terry, T., Du, J., & Lutkevich, P., "Design Criteria for Adaptive Roadway Lighting", Federal Highway Administration (FHWA), Department of Transport, USA, March 2014.

result from that same 0.5 candela/m^2 increase[10]. These results were obtained from a survey of 7,944 crashes so the results have very high confidence levels. This has substantial public policy implications which have yet to be recognised. **The results show that a significant number of injuries and deaths could be prevented simply by increasing street lighting levels in New Zealand**.

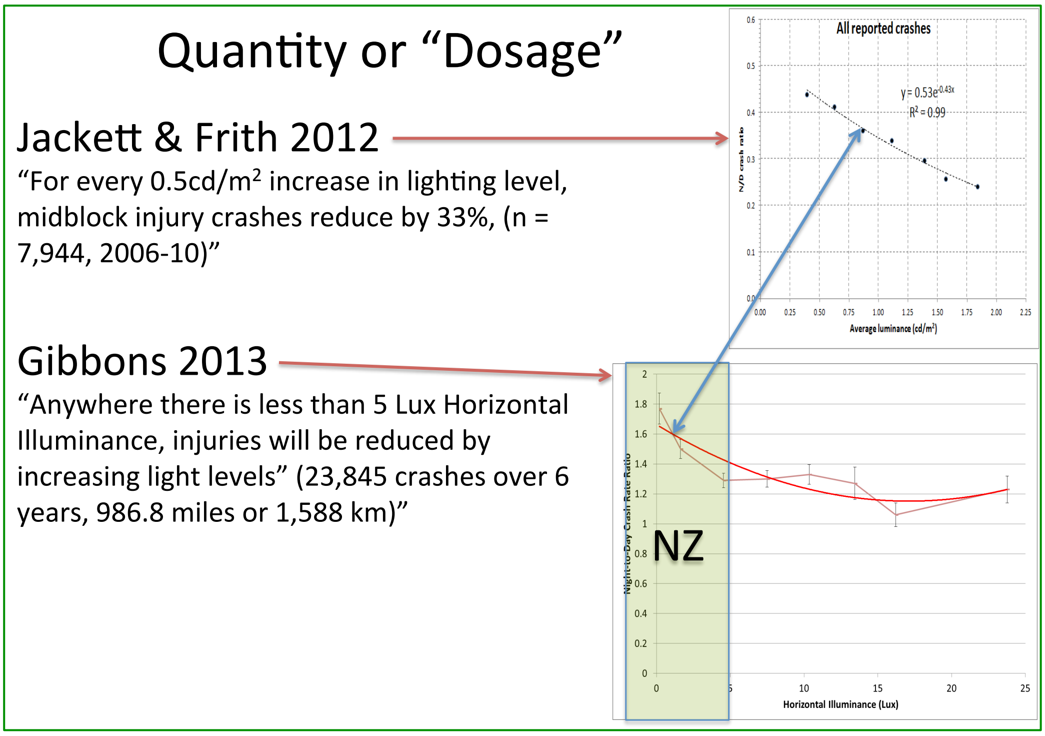

Figure 2 Recent research shows quantity of light reduces injury crashes

(Source: Jackett & Frith[8], 2012, Gibbons et al[9], 2014**)**

This research is corroborated by a large study by Gibbons[9] of 23,845 crashes in four US states in locations where lighting levels were more or less equivalent to those found in NZ. However, in the USA (and Europe) the lighting levels are generally substantially higher than in NZ as discussed in section 3.6.6. Gibbons et al showed that in general, lighting levels above 5 Lux (higher levels than generally found on most NZ roads) had little effect on the incidence of injury crashes.

Both Gibbons' and Jackett and Frith's works were presented at the Road Lighting 2014 conference and their conclusions are illustrated in Figure 2.

3.5 National Guidance

Although the most recent research, conducted by Gibbons and Clanton in 2013, is unlikely to have had policy consequences yet, it is surprising that work published in 2012 and the large body of knowledge accumulated regarding street lighting[6] in the last decade has not found its way into public policy. Neither *Safer Journeys: NZ's Road Safety Strategy 2010-2020* nor *Safer Journeys: Action Plan 2013-2015* ever mention the words "road lighting" or "street lighting." At national policy level road lighting suprisingly has no part to play in preventing injuries or crashes (documents mentioned above are shown in Figure 3).

Neither Jackett and Frith's work[8] in 2012 nor Bridger and King's paper[11] - both presented at the Australasian Road Safety Research, Policing and Education Conference 2012 - were incorporated in the latest safety strategy documents published in 2013. In the authors' opinion this is due to the fact that

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[10] 0.5 candela per square metre is about the same as the lighting level required for AS/NZS1158 subcategory V4 roads (sub-arterial road)

[11] Bridger, G., King, B., "*Lighting the way to road safety – A policy blindspot?*" Australasian Road Safety Research, Policing and Education Conference 2012, 4 - 6 October 2012, Wellington, New Zealand

New Zealand is necessarily and logically a follower of international policy, and this “policy blind spot” exists internationally as well.

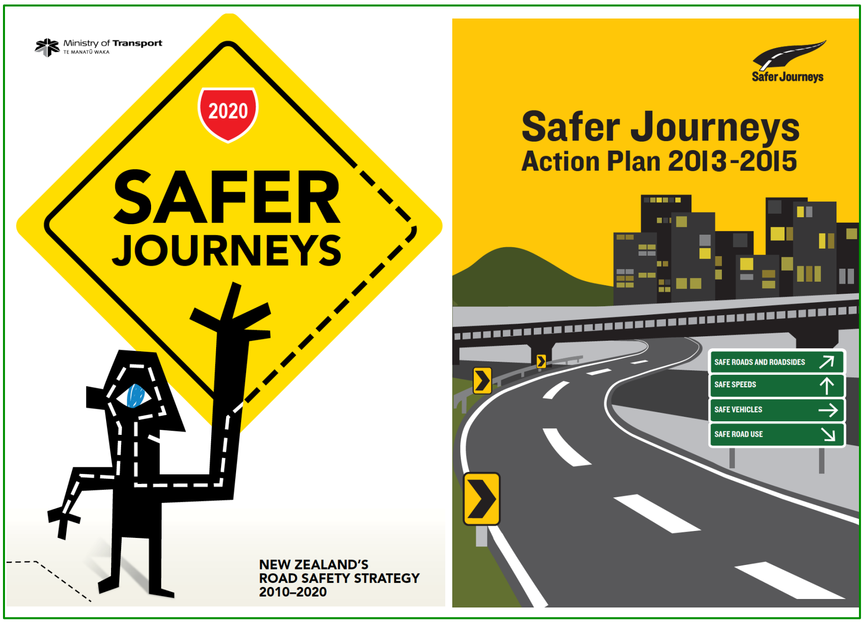

Figure 3 Government Land Transport Safety Policy Documents (Source: Ministry of Transport, 2013)

Without government policy support and explicit NZTA encouragement, local government cannot be expected to lead the way when there are so many other conflicting calls on resources. However, SLP is aware of a fundamental shift in thinking by NZTA (discussed in section 5.6.4) which makes it highly likely that only LED lighting will be funded by NZTA in future. This is a very important development as currently NZTA contributes about half of the funding for all local government road corridor street lighting.

3.6 AS/NZS Standards

A significant consequence of the rapid advancements in technology - and the reliance on legacy road lighting design and construction practices - is that *AS/NZS 1158 Lighting for Roads and Public Spaces* is extremely out of date. It does not currently permit LED or induction lighting, and instead of restricting AS/NZS 1158 Part 6 (Luminaires) to output-based performance criteria it often specifies in detail how the luminaires should be designed and built. This is poor practice, as by doing this it is likely to be generating Technical Barriers to Trade (TBTs), possibly infringing agreements between Standards Australia and Standards NZ and the World Trade Organisation.

SLP understands that it is for these reasons that Standards Australia has announced[12] that the current review of AS/NZS 1158 Part 6 (which would have become AS/NZS 1158.6:2014 had it been “published”) has been stopped. Furthermore, the full LG-002 committee charged with the review of the *whole* of AS/NZS 1158 has been disbanded to be re-constituted again after a robust formal process. The existing AS/NZS 1158.6:2010 (which does not allow LED or induction lighting) will shortly be replaced by the International Standard IEC 60598-2-3 *Luminaires: Particular requirements – Luminaires for road and street lighting*.

Standards Australia have also advised that a “Technical Specification” may be produced. When the new Australian and NZ Standard for luminaires (based on, or identical to, IEC 60598-2) is published in December, the “Technical Specification” (which is likely to be similar to the current discredited Part 6 Standard) will not be required to obtain compliance with the new Standard. This Technical Specification will therefore become just a “guidance document” without the authority of a “Standard”

[12] Standards Australia’s public statement 17 July 2014.

and the necessity for its compliance. In SLP's view this "Technical Specification" is a wise political manoeuvre to avoid too much controversy over why it was drafted like it was in the first place.

Note that some NZ councils and consultants documents have erroneously stated something like "… LED luminaires are to comply with AS/NZS1158.6". This has never been possible under the terms of the prevailing AS/NZS1158.6:2010, because LED lighting is specifically not allowed. Such a technology specific requirement will not be possible in future as IEC 60598-2-3 is an outcome based standard and is technology agnostic, therefore any technology is permissible as long as it performs to the required standard.

Other flaws in the current standards are outlined below.

3.6.1 Mesopic Eye response

As discussed by Bridger and King (2012)[11] "The eye's sensitivity varies according to the colour or the wavelength of the light being observed". With respect to street lighting, "this spectral sensitivity *also* changes according to lighting *levels*. Thus in daylight the eye is most sensitive to yellow-green light. This is scientifically referred to as 'photopic' vision."

At very low levels of light such as those encountered driving at night in a street-lit environment, the human eye observes light "mesopically". In this intermediate lighting level the eye is most sensitive to blue or blue-green light. "The eye perceives light of 600nm[13] wavelength (similar to yellow High Pressure Sodium streetlighting (HPS)) at about 10% of the lighting levels that it perceives blue/green light even though they are the same light level."

For this reason the CIE[3] and their national members' standards bodies "have recently begun to use Scotopic/Photopic ratios ("S/P") that favour white lighting at the luminance levels encountered during night-time driving on highways. These S/P ratios *de-rate* the yellow HPS coloured lights in most use today by up to 75% (at very low background illumination levels of 0.01 cd/m^2), and *up-rate* white lighting such as that produced by modern Metal Halide (MH) and Light Emitting Diodes (LEDs) by up to 101% also at 0.01 cd/m^2 (Table 1 Puolakka 2010)[14]."

While AS/NZS 1158 3.1-2005 A1-3 partially recognises this effect[15] in Amendment A1 dated 27 November 2008, the standard does not reflect the significantly more advanced CIE treatment of 2010.

Conclusion: Unlike their international counterparts, Australian and NZ standards (AS/NZS 1158) do not take these important aspects of the physics of vision into account in the same meaningful way and therefore devalue safer white light.However, it is expected that this will change when the current review of the standards is possibly completed in 2015.

3.6.2 Reaction time

Clanton and Gibbons[16] investigated the colour of road lighting for a US State equivalent of the Energy Efficiency and Conservation Authority (EECA) in New Zealand, and made some remarkable findings. They confirmed older research which showed that white light (also produced by old Mercury Vapour and Metal Halide technology) reduced driver reaction times from those observed in yellow and orange light. Gibbons' 2013 research compared yellow HPS lighting with white LED lighting, which dramatically reduced driver reaction times and stopping distances.

The statement that most aptly summarises these findings is: "*146W LED white light dimmed to 25% of its rated output provided the same stopping distance (due to reaction times) on wet roads compared with full intensity 250W High Pressure Sodium street lighting on dry roads*"

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[13] A nm is a nanometre or a billionth of a metre, also a millionth of a millimetre

[14] Puolakka M., Halonen L (2010), *CIE new system for mesopic photometry*, Proc of CIE Lighting Quality and Energy-Efficiency, CIE x035:2010, p. 457-462, presented at the CIE 2010 "Lighting Quality and Energy Efficiency conference

[15] Clause 2.6, page 15.

[16] Clanton, Nancy, Ronald B. Gibbons, Jessica Garcia and Travis Terry, Visual Quality, Acuity, and Community Acceptance of LED Streetlight Sources, Northwest Energy Efficiency Alliance, REPORT #40385, March 2014

Conclusion: This research has profound policy implications that remain largely un-recognised, certainly in Australia and New Zealand, but also internationally. **The results show that a change to white light road lighting will prevent injury crashes.**

3.6.3 Pavement reflection

Bridger & King[11] also note that "research conducted by Jackett and Frith in 2009[17] suggests that even where the lighting levels are in compliance in New Zealand, they are unlikely to be providing the levels of lighting expected[18]. The reason for this is that AS/NZS 1158 uses pavement reflectance properties in the calculations that have been found by their research to be significantly different to those presumed."

"Their research observes 'The average value found for [reflectance parameter] Qo (0.050) is 44% lower than the value currently used in design. This difference is substantial and suggests that our roads are being lit to a rather lower level of average brightness than had previously been anticipated.' In its executive summary the study suggests that 'using the misaligned r-tables currently specified doesn't just mean that our pavements are less well-lit than previously thought - it also means that motorists are subjected to higher levels of glare than was intended. New Zealand glare levels are already high compared to CIE recommendations, and the increasing age of the driving population draws attention to the need to reduce the effects of glare in road lighting installations. Older drivers suffer greater impairment from glare than younger drivers' (Jackett & Frith 2009)".

Jacket and Frith conclude that "… maintaining the existing lighting levels as defined in table 2.1 of AS/NZS 1158.1.1 and the operating characteristics therein, could have a profound effect on the costs of new lighting schemes. The likely increase in costs for Category V lighting schemes is around 50%".

Conclusion: All calculated "Light Technical Parameters" that depend on reflectance (ie luminance based calculation) used to comply with AS/NZS 1158 **are incorrect**. This also raises the question of what other fundamental flaws exist in the standard. Until AS/NZS 1158 is fully updated, SLP recommend that AS/NZS 1158's provisions to determine lighting levels be set aside for any upgrade and the "Better Than Before"(BTB) approach recommended in section 3.7 is followed.

3.6.4 Focus on asset installation rather than its 20 year life

The AS/NZS 1158 series is detailed, complex and highly cited, but is missing the most fundamental requirements of a standard that provides best practice guidance to management of an asset that reduces transport injuries, fatalities, crime and provides community comfort over the 20 year life of the asset.

The current standard[19] wisely observes that "Significant reductions from the initial values of the light technical parameters will occur in service, primarily as a result of a gradual depreciation in lamp lumen output, an accumulation of dirt on the transmitting or reflecting surfaces of the luminaires and ageing of those surfaces. Recognizing that this depreciation occurs … It is therefore essential that a maintenance regime be determined in conjunction with the client (usually the local government authority) as part of the lighting design and applied throughout the life of the installation so that the installation continues to comply with this Standard for the full duration of each maintenance period."

However, despite these important general observations, the standard provides virtually no quantified guidance on how this can be achieved. While it does provide a lot of very general descriptive guidance and desirable subjective outcomes on long term maintenance, no quantifiable guidance (despite the

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17 Jacket, M., and Frith, W., "Measurement of the reflection properties of road surfaces to improve the safety and sustainability of road lighting", Opus International Consultants, Lower Hutt, NZ, New Zealand Transport Agency research report 383, 2009.

18 For Category V roads. P category roads do not use pavement reflectance values as lighting levels are based on lighting Illuminance, not pavement surface luminance.

19 Clause 2.9.1, page 15 of AS/NZS 1158.3.1:2005

deep attention to quantifiable Light Technical Parameters), is provided other than a table[20] that relates the "Ingress Protection" rating (IP XX[21]) to suggested "cleaning intervals" ranging from 12 to 48 months.

This empirical and qualitative approach, relied upon throughout the standard, uses experience from decades-old techniques, traffic conditions, pollution levels, lighting and vehicle technology to predict the performance of street lighting.

Much has changed since then and there are superior methods available to determine the actual lighting performance of the luminaires across all the roads in a city, not just at a few points. Current practice and the Standard relies instead on predictions based on subjective human visual assessments and "inspection patrols". Modern methods use continuous mapping of lux levels conducted at the maximum speed limit of the road, as illustrated in Figure 4. SLP understands Wellington has trialed the Odyssey Energy system.

Conclusion: Despite road lighting being vital safety infrastructure, techniques for ensuring its fitness for purpose over its lifetime are absent from the current standard – in marked contrast to the complex and detailed calculations and software required for a new street lighting design to be signed off as compliant. This imbalance of detailed focus on initial installation as opposed to the lack of focus on the 20 years that follow, is remarkable. SLP strongly recommends ignoring the sparse maintenance guidelines provided by the standard and replacing them with modern motorised continuous light mapping surveys.

3.6.5 Lack of direct relationship between lighting levels and crash rates

The lighting design sections of AS/NZS 1158 do not refer to any research that relates lighting levels to pedestrian visual acuity or vehicular crash rates. The relevant sections are:

- Part 1.2:2005 Vehicular traffic (Category V) lighting—Performance and design requirements;
- Part 2:2005 Computer procedures for the calculation of light technical parameters for Category V and Category P lighting; and
- Part 3.1:2005 Pedestrian area (Category P) lighting – Performance and design requirements.

The list of references used in the standard are attached in section 11 Appendix 2 – AS/NZS 1158 references. Although SLP have not read all the very old papers identified, many much newer research papers have been investigated which confirm the above statement. Furthermore, this is confirmed by Dr Gibbons, one of the world's experts in the area of the relationships between crashes and lighting levels. As previously stated, there appear to be only two credible scientific papers that do this, Jackett and Frith (2012) and Gibbons (2013).

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[20] Table F1, Appendix F, Luminaire maintenance factors, page 49 of AS/NZS 1158.3.1:2005, and Table 14.4 section 14.4.3, page 63 in AS/NZS 1158.1.2:2010

[21] "XX" is used by AS/NZS1158 to indicate the levels of ingress protection that have been established by other standards. The first X refers to the level of resistance against water, while the second "X" refers to the level of protection against dust.

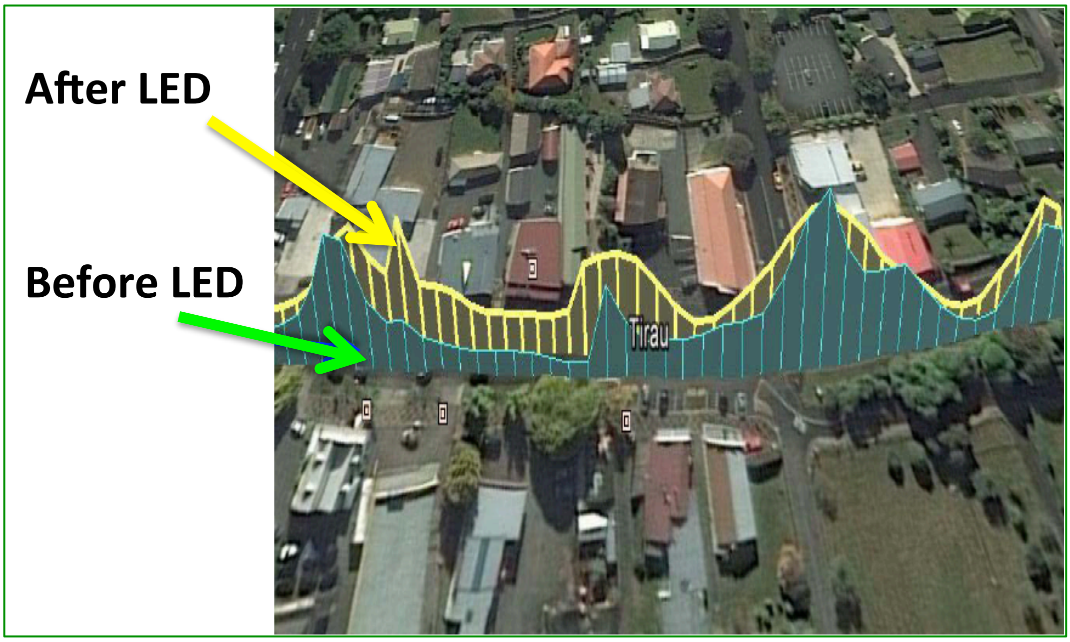

Figure 4 Mapping actual continuous street lighting performance instead of estimating it at single points (Source: Odyssey Energy**)**

While there is significant logic in varying lighting levels according to traffic flow, the original benchmark lighting level chosen appears to have been set according to common lighting practice at the time without any reference to research. This is an understandable approach for a small country that could not afford to increase its lighting levels to those used in larger economies in Europe and USA (with higher population densities). The problem is that the chosen lighting levels are now described by a highly technical standard that provides a strong impression that these levels have great basis in research. **They do not.**

The current standard appears to use arbitrary legacy lighting levels, set decades ago probably for good economic and pragmatic reasons, and then logically varies them according to traffic flows. Unfortunately the sophistication of the lighting design process has masked the arbitrary nature of the original lighting level selection process.

Conclusion: A substantial upgrade in street lighting across a city to white LED lighting should not be held back by AS/NZS 1158 lighting level considerations. A WCC upgrade of the type envisaged by SLP would take into account the most recent published research available.

3.6.6 Lower lighting levels in NZ than Europe and USA

As mentioned previously, New Zealand and Australian lighting levels for roads of corresponding traffic density are substantially less than in Europe and USA. This is probably largely due to simple pragmatic economic and legacy reasons from a period when NZ could not afford to invest to keep up with the high lighting levels of more wealthy economies. Figure 5 shows the AS/NZS standard lighting levels as a percentage of those in Europe, and an important question raised by the diagram is why the *difference* in lighting levels is so much greater for residential standards than for highways.

SLP has not discovered the reason but given the observations above and elsewhere in this report, it is unlikely to be scientific, as all the indications point to pragmatic cost-saving. If this is correct, it makes no logical sense to have a standard that is complex, requires rigid adherence, but is patently out of date.

Conclusion: With the large improvements arising from white LED lighting, current lighting levels may be quite sufficient (and US/European ones may be too bright) so SLP recommend that AS/NZS 1158's provisions to determine lighting levels be set aside for any upgrade and the "Better Than Before" approach recommended in section 3.7 is followed.

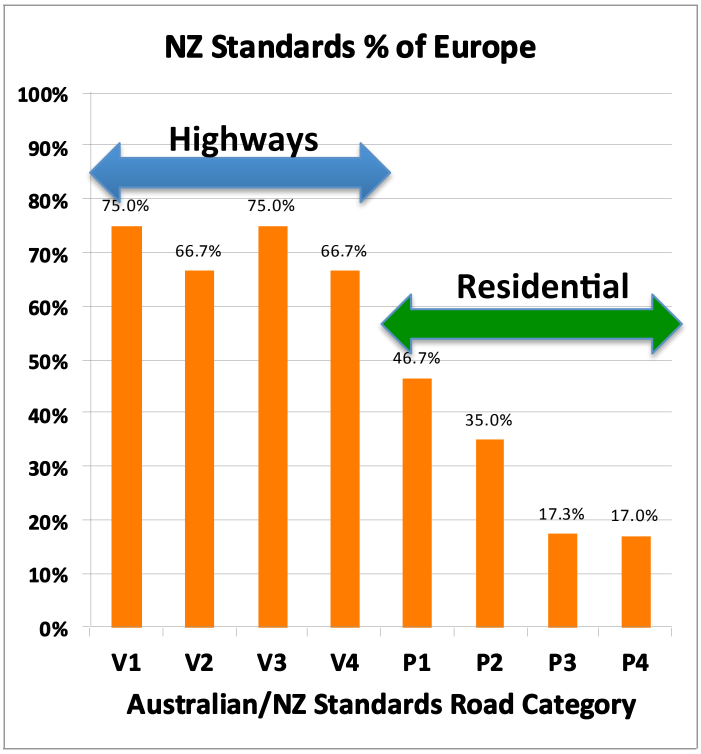

Figure 5 NZ Lighting level standards as a % of European Standards (Source: SLP from relevant standards - AS/NZS, and EN**)**

3.6.7 Reliance on software that removes design engineers from technical understanding and introduces significant risks of poor outcomes

AS/NZS 1158 Part 2:2005 Computer procedures for the calculation of light technical parameters for Category V and Category P lighting is 58 pages long and covers the calculations required to design street lighting in great detail. The standard even requires specific authorized software to do this and a screen shot of this is shown in Figure 6. This particular software is called STANSHELL. The commercial version that has been widely used for many years for compliance calculations is called PerfectLite. These were both developed many years ago with a Fortran base and are cumbersome, limited in scope and inflexible.

Several issues arise from this legacy approach.

If new and improved software is being developed, its accuracy needs to be assessed and approved. This is handled by the AS/NZS LG-002 Standards Committee. It is unknown whether any initial procedures (20-25 years ago) to certify the original software's accuracy are on record, although some committee members think that procedures may have existed at the time.
In Australia and NZ a commonly used commercial lighting design software package is AGI32. There have been several unsuccessful attempts to gain AS/NZS road lighting compliance acceptance for this, with material differences between STANSHELL/Perfectlite and AGI32 being detected. There has been a reasonable degree of software QA, but this has been largely internally referenced with little international benchmarking.

Conclusion: Reliance on industry to self-police quality assurance on software that performs complex and difficult-to-verify design calculations is not a convincing foundation for high value infrastructure that is designed to save lives and reduce injuries. On the other hand, adopting robust field measurement techniques (ie light mapping) to economically and reliably measure and compare "actual to calculated performance" and actual performance over time is required to replace the current legacy approach.

(Disclosure of Interest - Bryan King has been a member of Standards Australia LG-002 AS/NZS1158 committee since 2007)

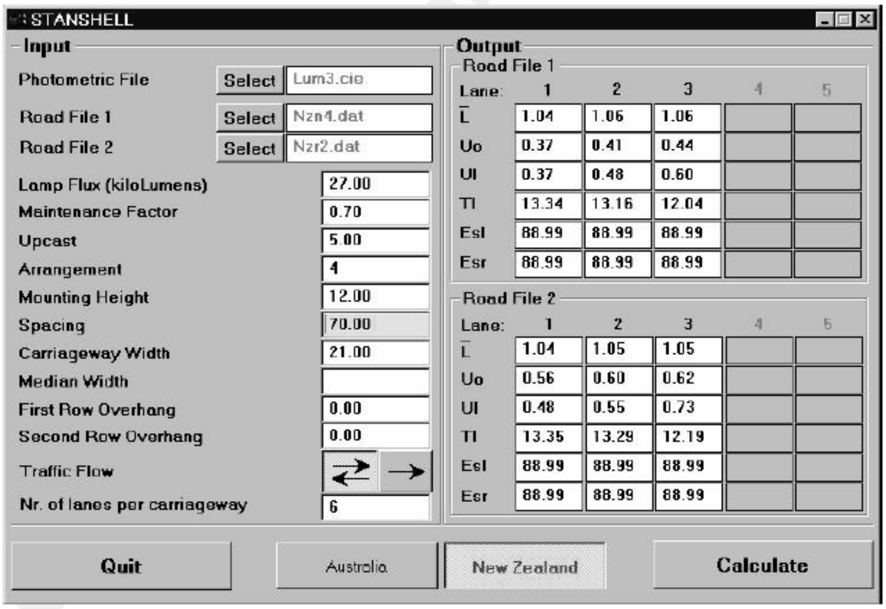

FIGURE A2 SAMPLE SCREEN FOR 'IN NEW ZEALAND' MODE

Figure 6 Example of Software output identified in AS/NZS 1158 Part2:2005

3.7 So what lighting levels should be used?

One of the critically important issues that arise, given the lack of research-based content in AS/NZS 1158 as guidance for lighting the nation's roads, is what are the right lighting levels to use?

Although Australia and New Zealand each have special physical infrastructure circumstances, this question is relevant to most places in the world because standards have lagged behind technology everywhere. In Los Angeles, where litigation is a much greater risk than it is in New Zealand, the strategy has been simple: replace existing luminaires with LED luminaires that provide the same or better lighting performance than was there before. This pragmatic approach is aided and supported by the fact that the colour of the light has been changed from low quality (ie low CRI) yellow light to high quality white light: public perception is that illumination levels have been significantly increased and that visibility is improved, and perceptions of safety have been enhanced.

This is the only strategy that makes practical sense until more credible work has been completed to address the fundamental "standards lag" issues raised in this section.

3.8 Collaboration with Virginia Tech Transportation Institute (VTTI)

SLP recommends that at the same time as upgrading Wellington's street lighting to white LED and CMS systems, internationally recognised researchers from VTTI together with local NZ research collaborators be "embedded" in the process. This will provide internationally credible results that will also be highly "visible" and promotable to the rest of NZ and the rest of the world. VTTI are actively seeking to internationalise their research programme by working with real-world applied research partners. To the authors' and Dr Gibbons' knowledge, no other city has contemplated this, despite USA and Europe's leadership in LED road lighting. This is an additional opportunity for Wellington that carries many reputational co-benefits with little cost and little risk.

3.9 Conclusions

As a result of the observations made in this section SLP recommends that Wellington City Council's approach should therefore be to:

i. Avoid relying on AS/NZS 1158 for determining lighting levels until it has been fully updated to reflect international best practice;

vii. Upgrade to white LED lighting and controls as soon as possible to “Better than Before standard”;

viii. Monitor lighting performance before, and then at regular intervals after the upgrade on significant proportions of street-lit roads, and in all “hotspots” where crashes, crime and trouble occur to ensure that lighting: location, intensity, quality (including colour), and maintenance matches expectations over the life of this safety infrastructure;

ix. Gather, analyse and regularly update traffic, crash and crime statistics to correlate with lighting performance as measured above, **to actively manage** the reduction of nigh time crashes, fatalities, injuries, and crime;

x. Utilise modern asset management practices, software and integrate them with CMS controls to maintain and replace assets when necessary;

xi. Collaborate with VTTI to co-ordinate all the issues above which will provide one of the highest quality night-time city environments in the world.

4 LED Street Lighting Technology

4.1 Introduction

The shortcomings in street lighting practice mentioned in the previous section are fortuitously largely largely overcome by the introduction of the new arguably "revolutionary" new LED lighting technologies.

The first practical Light Emitting Diodes or LEDs were developed by General Electric (now called GE) in 1962 as low-power sources of light for control panel status indication. Since then LEDs have been developed for high power applications in vehicle lighting and more recently for road lighting. As a result of their significant advantages over existing road lighting technologies they are now penetrating the market 40 times faster than Compact Fluorescent Lamps (CFL) did (see Figure 7 below).

Noted international strategy consultancy McKinsey and Company say in their report[22] "The penetration of LED technology just described is driving a far-reaching change to the industry's structure.... **Upstream industry is experiencing a radical shift, with LED expected to capture a huge share of general lighting** [their emphasis]. LED production methods are very different from those used for traditional lamps, where electrical filaments or plasma with bulky glass covers are used. This is leading to the emergence of an entirely new industry and the upheaval of traditional industry structures" (McKinsey 2011[12]).

The physics on which LEDs are based is fundamentally very different to that of preceding lighting technologies. This is recognised in the scientific category name "Solid State Lighting" and results in substantial advantages over alternative technologies. One of the most fundamental benefits is the efficacy of the LED as a light source. This is illustrated in Figure 8, where each technology's efficacy in lumen output per electrical watt input is plotted against time to show the technology's improvement over the decades. Although this is one of several benefits over other technologies, this advantage alone is likely to make the older technologies obsolete fairly quickly in a world where energy is likely to become more expensive.

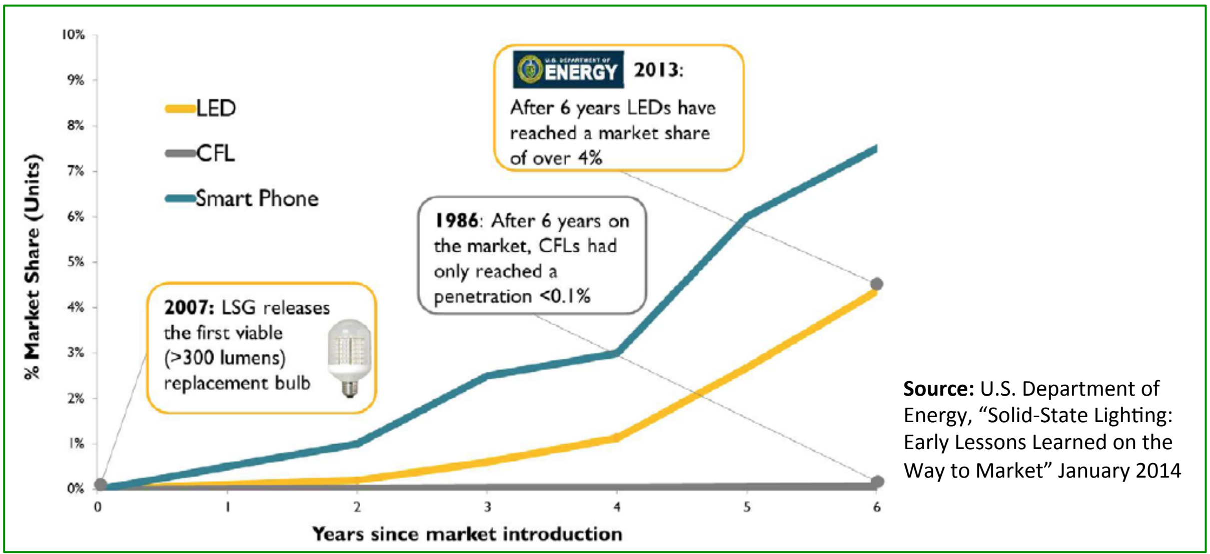

Figure 7 LED Market Penetration comparison (**Source:** Department of Energy, USA, 2014)

The predominant street lighting technology in use today is the "gold" or yellow coloured HPS lamp (shown as the "High Wattage" orange line in Figure 8), because until LEDs arrived, HPS was the most efficient and cost-effective lighting source. In New Zealand it is estimated to make up 80-95% of the lighting stock, and in Wellington it was 93% in 2012[23] as shown in Figure 9.

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22 Lighting the Way: Perspectives on the global lighting market, July 2011

23 Thessman, M., Project Manager – Street Lighting, Wellington City Council, e-mail 30/4/2012

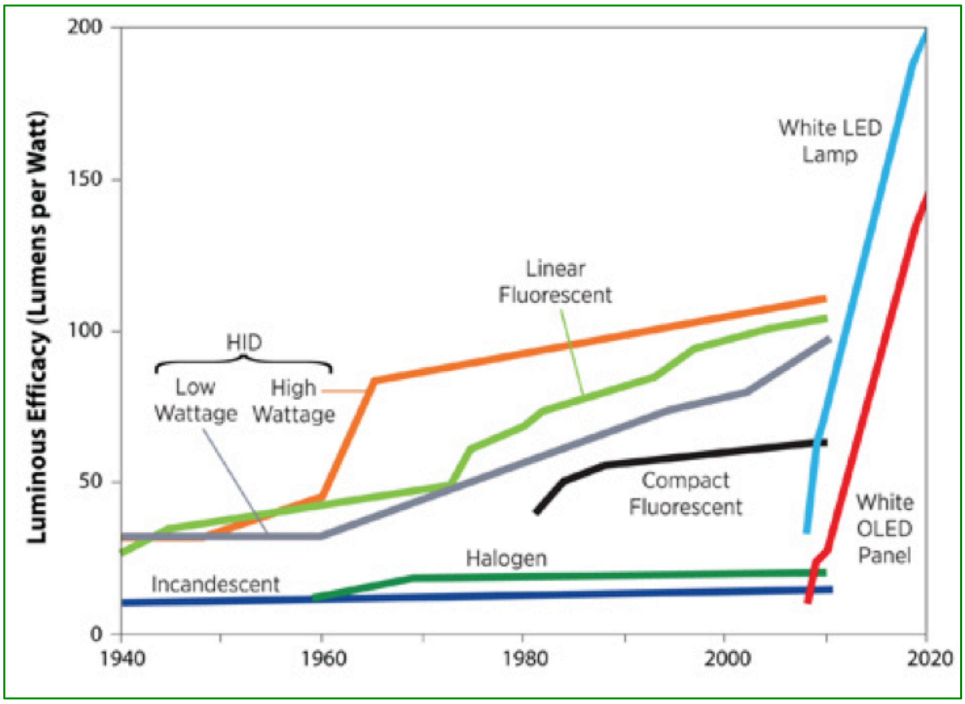

Figure 8 Comparison of Efficacy of conventional lighting technologies with LED (Source: US department of Energy via Digital Lumens[24])

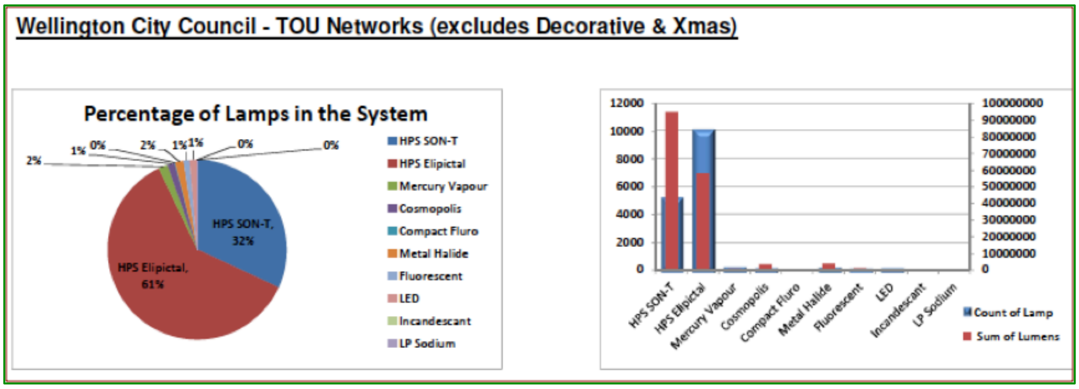

Figure 9 Types of street lighting in Wellington City Council in 2012 (**Source**: WCC, 2012)

24 ***http://www.digitallumens.com/resources/webinars/*** "The Future of Intelligent Lighting"

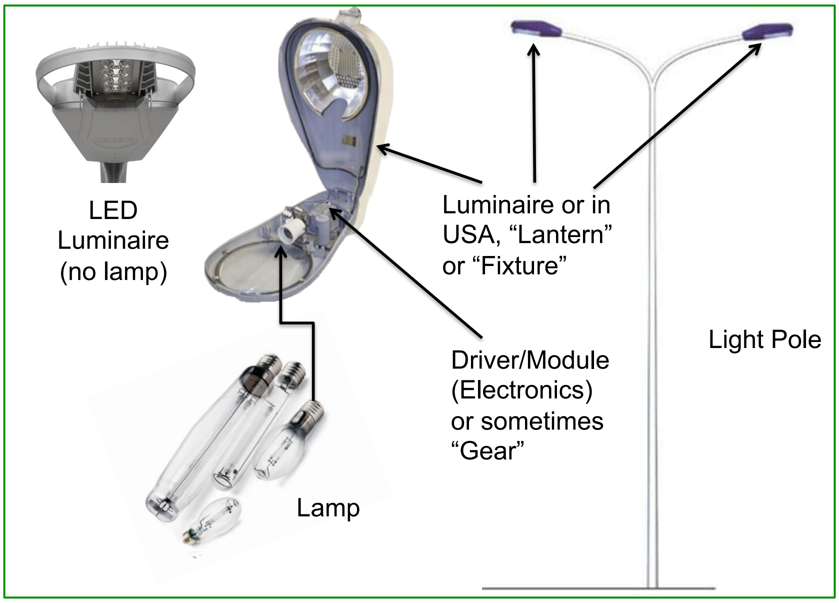

Figure 10 Components and terminology used in Street Lighting (Source: SLP from the Internet**)**

4.2 Summary of benefits of LED Lighting over HPS lighting

The advantages of LED road lighting over current HPS lighting are listed below.

1) Energy savings, with the potential for significantly greater than 50% savings over HPS and metal halide;
2) Long life with high performance luminaires rated at greater than 80,000 hours operation until end-of-life (approximately 20 years), defined as when the LED module reaches a lumen output of less than 70% of the initial lumen output. This is between three and five times longer than HPS lamps;
3) Continuously dimmable down to very low levels with minimal internal efficacy losses;
4) Instant on/off operation, without decreasing system life;
5) Ability to integrate internet based Central Management Systems (CMS) that have been reported to increase systemic energy efficiency by up to an additional 20% and also to provide significant additional amenity values;
6) Directional light emission that, with appropriate optics, can deliver highly efficient lighting schemes and reduce "light spillage";
7) High colour rendition, generally over 70 CRI. This means that coloured road markings, signs, vehicles and people can be seen in contrast to the yellow HPS lights with CRIs of about 20 which makes discerning colours virtually impossible;
8) Enhanced visibility and reduced driver reaction times due to its broader and more visually appropriate spectral distribution (white light);
9) No toxic mercury content compared to High Intensity Discharge (HID) lamps;
10) More resistant to traffic-induced vibration than any of the older technologies.

Conclusion: These substantial advantages explain why many analysts, including the authors, believe that LED lighting will rapidly displace the majority of existing technologies shown in Figure 11.

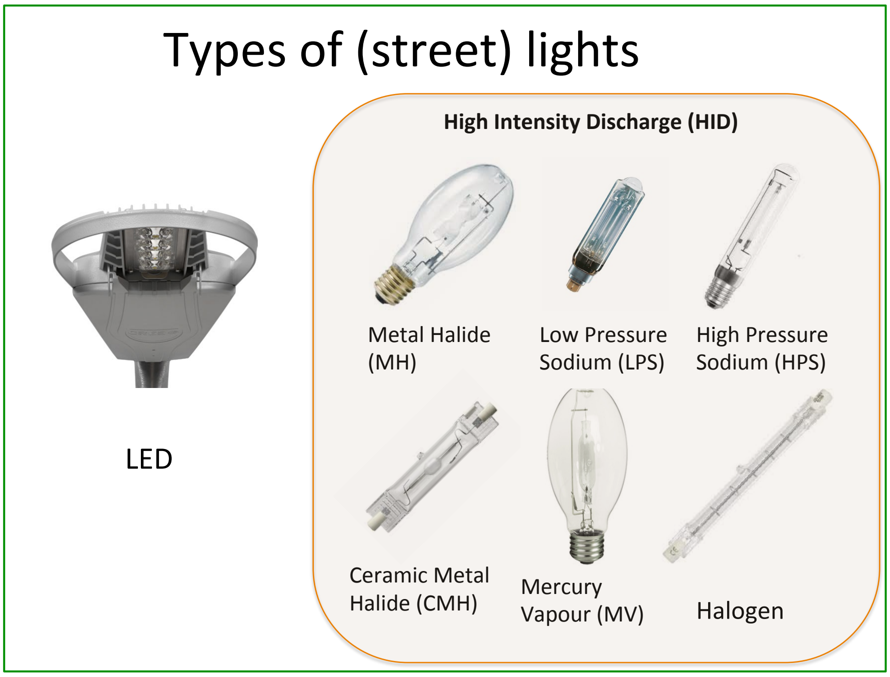

Figure 11 NZ Street Lighting Technologies being superseded by LED (Source: SLP from the Internet**)**

4.3 Energy Savings

An upgrade to an LED lighting and control system could save as much as 75% of energy use versus HPS. In Los Angeles the energy saving was 63% over 140,000 HPS luminaires replaced by LED luminaires – without a control system. This information was presented to a recent conference, Road Lighting 2014, held in Auckland, as shown in Figure 12 below. Los Angeles and most other developed nations have higher lighting levels than New Zealand so the energy saving will not be as great here. However, a 50% electrical energy saving is feasible and this corresponds to what Auckland Transport is predicting from conversion to LED street lighting.

Unfortunately this electrical energy saving will not reduce electricity costs by 50% because Electricity Network Companies (including Wellington Electricity Lines Ltd) charge a combination of fixed and variable prices to recover the capital and operating costs of the assets used to transport electricity. (As a regulated monopoly, Wellington Electricity is unable to charge more or less than the cost plus a modest regulated profit margin.)

For street lighting the approach in other NZ cities and towns is to use a figure of 50% of the total street lighting electricity cost being charged by the distribution company to “transport” the electricity to its point of use. The overall resulting saving in costs is therefore only 25%. In Wellington, total electricity costs are understood to be about $2 million pa, thus a saving of at least $500,000 pa is realistic.

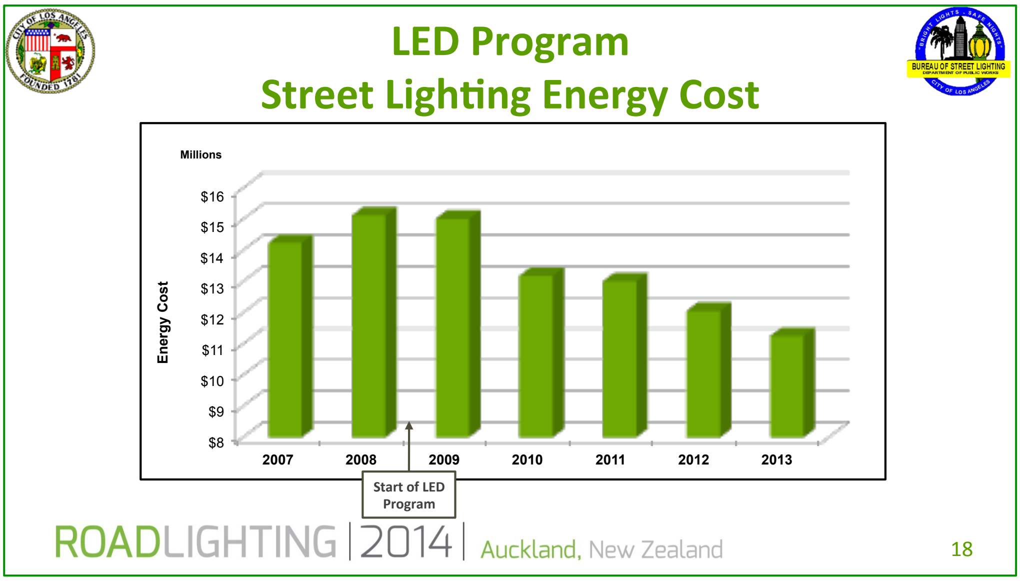

Figure 12 Energy Cost Savings experienced by Los Angeles

4.4 Maintenance Savings

Another fundamental difference of the technology is that it lasts three to five times longer than current lamp technologies (with the exception of rarely-used induction lighting), which leads to a fundamental practical difference between the "packaging" of LED street lighting and that of the older technologies. As shown in Figure 10, a non-LED street light is made up of the "luminaire," which is the physical and electrical container for the light-producing element (the lamp).

Thus when an HPS lamp ages unacceptably or eventually fails, only the lamp is replaced, not the whole luminaire. In contrast, the light-producing element ("LED Module") in LED street lights does not fail before its other elements, and reliably lasts for 15 to 20 years. In the very rare occurrence that the LED module fails, the whole LED luminaire is replaced. This is one of the reasons why, for large quantities, most manufacturers offer warranty periods of 10 years.

LED road lighting luminaires are expected to last four to five times longer (16-20 years) than HPS lamps and can therefore be expected to require 50-80% less maintenance. Unlike energy savings, this **will** generally translate into similar 50-80% cost savings. Experience based on three to four years' operation of street lighting in the field suggests that savings are greater than this[25] but until more track record data is built up SLP recommends a conservative approach be taken until savings have been proven.

Note that astutely negotiated warranty provisions will protect purchasers from the cost of any random luminaire failures for an extended period (10-15 years at least). Accumulating international experience with good quality luminaires is indicating that random occurrences of failure are an order of magnitude lower than with legacy technologies.

US field experience of LED installations is illustrated in Figure 13, which shows the remarkably low levels of lumen *and* dirt depreciation observed over the six years since installation of the first LEDs – which represent early LED technologies, not the latest greatly improved luminaires. Of particular note is that dirt depreciation is virtually zero. This was determined by measuring the lumen output before and after cleaning. The Los Angeles' Bureau of Street Lighting suggests that this is probably because the luminaires operate at significantly cooler temperatures than HPS lamps, so the dirt is not being "baked" on.

[25] Smalley, E., Municipal Solid State Lighting Consortium (MSSLC), "Advantages & Achievements of a Collaborative Municipal LED Street Lighting Program(me) - the US Approach", Road Lighting 2014, 11&12 March, Auckland, New Zealand

Furthermore, Los Angeles are experiencing extremely low levels of LED failures – 0.3% in comparison to the 10% experienced for HPS lamps across all 140,000 street lights.

Nevertheless, in SLP's view it is prudent for WCC to use a 60% saving in its budget forecasts, as Wellington and Los Angeles are very different in a many ways including climate, location and working culture. With WCC maintenance costs understood to be about $1 million pa, another $600,000 pa (60% saving) should be reliably saved after conversion to LED lighting.

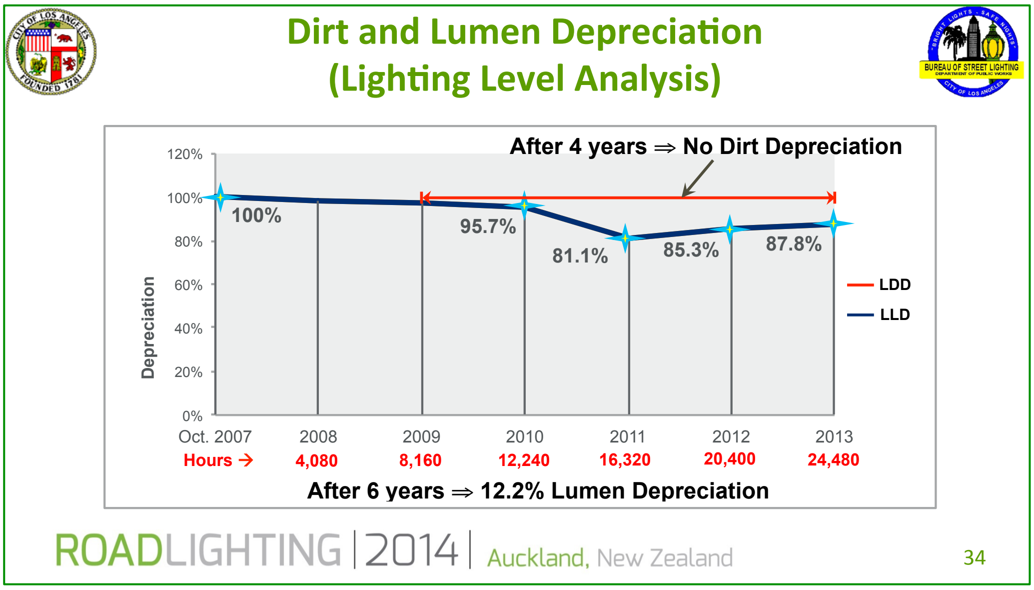

Figure 13 Field experience of LED dirt and lumen depreciation in Los Angeles

4.5 Continuously dimmable and instant switching

The revolutionary nature of LED lighting systems provides benefits which are significantly amplified by the rapid development of Central Management Systems (CMS). Such systems are much more important and interesting than the name suggests. They are important to delivering a convincing street lighting business case as they are they are the "brains" of a modern street lighting system.

Because LED lighting systems are semiconductor based, with no requirement for high voltages to ionise gas (as in HID systems such as HPS lighting) LED luminaires can be controlled by electronic signals driven by IT systems, with greater precision, to much lower lighting levels and without the significant internal energy losses of HID systems. This gives rise to two major strategic consequences described in the next section.

4.6 Controllability & integration with central management systems (CMS)

Firstly, individual luminaires can be controlled independently. The electricity network supply to each luminaire is always activated, unlike most current NZ systems which switch the electricity supply to large areas. Control and monitoring systems are based on two fundamental communication platforms: Radio Frequency (RF), where the control signal is sent to each luminaire by radio frequency; and Power Line (PL), where the control signal is sent through the electricity supply cables.

The second strategic change provided by CMS is that two-way "conversations" between the luminaires and the network are now possible and system managers can determine in real-time the operating status of a wide variety of parameters including component thermal characteristics, revenue grade[26] energy usage, system energy peak demand, times of operation, and hours logged. Together with typical IT system software they also provide operating history with data-logging and substantial asset

[26] The term "revenue grade metering" is used to describe the electronics that measures electricity use to an accuracy that allows it to provide electricity retail companies with data that can be used to invoice its customers. Such "revenue grade" metering is a necessarily certified by regulatory authorities to reduce the probability of errors or fraud.

management services so that accident and fault diagnostics, maintenance and replacement services can be performed to a high level.

After an initial 50,000 unit deployment (without-dimming), Los Angeles decided to defer further control system deployment to allow a more rapid rollout of the LED lighting. Consequently it has spent more time analysing the systems available. At the Road Lighting Conference in Auckland, the Director of the City of Los Angeles Bureau of Street Lighting, Ed Ebrahimian, who was in charge of the Los Angeles programme, presented the desirable "extras" required above standard market offerings, as shown in Figure 15 below.

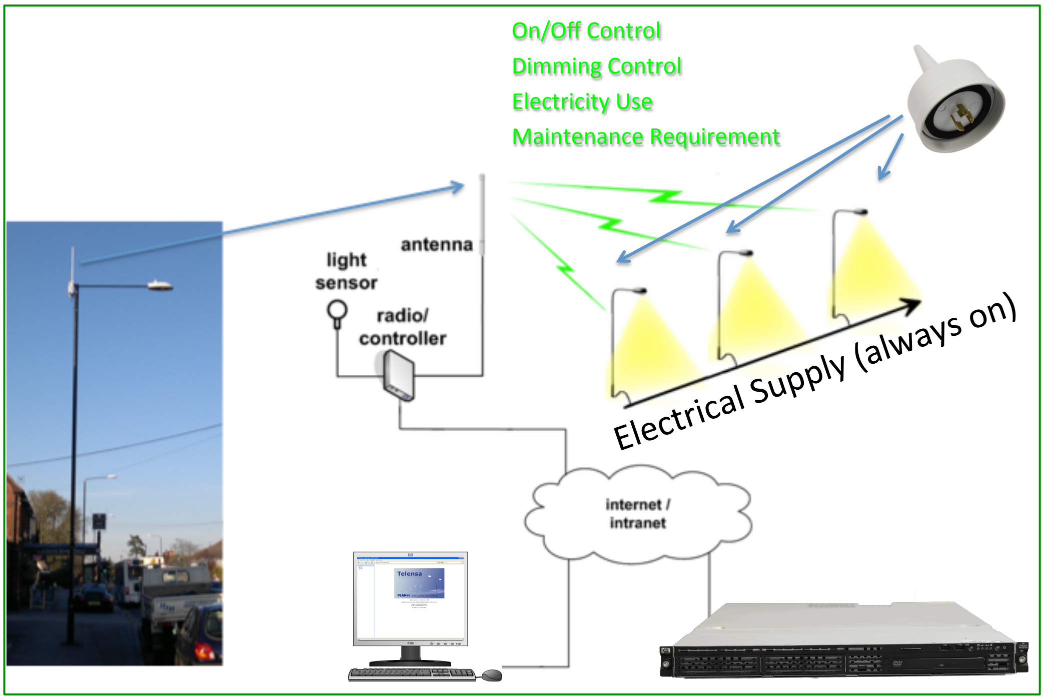

Figure 14 Components of a modern street lighting system (Source: Telensa diagram significantly modified by BBA. NB this shows a radio based system: power line carrier systems also exist)

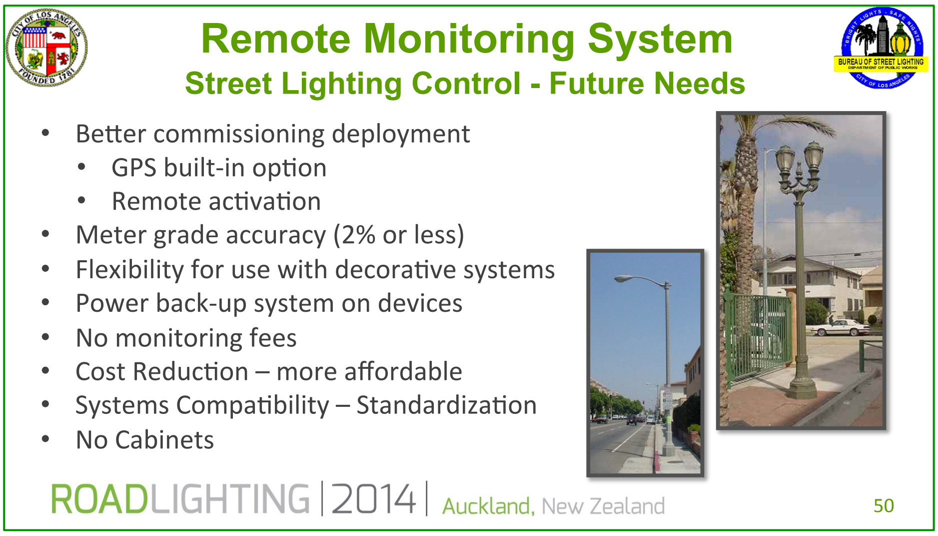

Figure 15 Desirable Specifications of street lighting controls for Los Angeles (Source: LA Bureau of Street Lighting, 2014**)**

4.7 Precise optical projection

One of the significant contributors to LED street lighting efficiency is that its construction allows very precise beams of light to be directed only where they are required. This benefit also allows a wide range of designs to be manufactured for a wide range of different applications. This is a big advantage, but requires a greater design skill capability and thus the risk of poor design or application is increased, especially as it is a relatively new technology.

One of the practical applications of this benefit is that the beams do not "spill" unnecessarily over into home frontages close to the road reserve or "pollute" the sky with upward waste light.

4.8 High colour rendering

This is the light's ability to show or "render" colours. HPS lighting is almost monochromatic yellow, which in practice makes it almost impossible for humans to accurately discern colours. Its colour rendering index (CRI) is about 20 whereas LED lighting has CRIs better than 70. In addition to the safety benefits identified in section 3, the greater colour rendering of LED lighting allows easier identification of people, their clothes and vehicles, thus improving the use of lighting as a security and policing tool.

4.9 Crime impacts

Substantial (and quite dated) research exists that positively correlates the existence of road lighting with reductions (or displacements) in crime, but it does not address the amount or the colour of the light. In the absence of recent research, what is available is experience from cities that have converted to LED lighting, or have instigated dimming or switch-off lighting regimes and have monitored before-and-after crime levels.

City of Los Angeles, USA

The Director of the City of Los Angeles Bureau of Street Lighting[27], Ed Ebrahimian, has reported a decrease in several types of street crime after the replacement of 140,000 yellow HPS lights with white LED lights in Los Angeles. Overall the Los Angeles Police Department recorded an 11.9% reduction in street crime, as shown in Figure 16 below.

Suffolk County Council, UK

In Suffolk, where 60,000 yellow HPS road lights were installed two years ago with a Telensa CMS costing £2.6 million (about £40 per light), the control system was used to turn off 42,000 residential street lights between midnight and 6am[28]. The system is also used to reduce lighting levels ("dim") and the overall saving was more than 60% on electricity costs. What was highly unexpected was an accompanying 18% reduction in crime.

These surprising results do not meet scientific reporting standards, but they point to a strong need for scientifically credible information to inform local body or central government policy and practices in relation to crime.

The objective of any change to existing street lighting is to provide a city with the right amount of light (not too much or too little) at the right place, at the right time – and have a scientifically credible team to verify when this has been established. Once established, it will inform the rest of New Zealand and contribute to the world's understanding of this important subject.

[27] Unlike NZ Council structures this is one of 14 roles that reports directly to the Mayor of Los Angeles.

[28] Webster, R., Suffolk County Council, UK, "Two years of experience with control systems that reduce crime - as well as energy!", Road Lighting 2014, Auckland, New Zealand 11 & 12 March 2014.

Crime Statistics
(Incidents between hours of 7 PM to 7 AM)

CRIME TYPES	YEAR 2009	YEAR 2013	REDUCTION
Theft from Vehicle	15,778	13,772	12.71 %
Burglary-Robbery-Theft	19,967	18,182	8.94 %
Vandalism	11,115	9,321	16.14 %
Total	**46,860**	**41,275**	**11.9 %**

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Figure 16 Los Angeles Street crime improvement after LED street lighting replacement (Source: LA Bureau of Street Lighting, 2014**)**

4.10 Community Comfort

There have been many trials of LED street lighting around the world where public opinion has been canvassed. One of the largest was facilitated by the Climate Group, a not-for profit organisation supported by the commercial and public sectors. In a 10-city worldwide study[29] they stated "The public prefers LED products. Around 90% of survey respondents support a full rollout of LEDs across city street lights." A slide taken from one of the presentations on that study showing the results for London is shown in Figure 17 below.

Conclusion: These perception surveys are made redundant by city-wide roll-outs of LEDs as described in the next section, where cities are reporting strong public support for the more attractive white LED lighting.

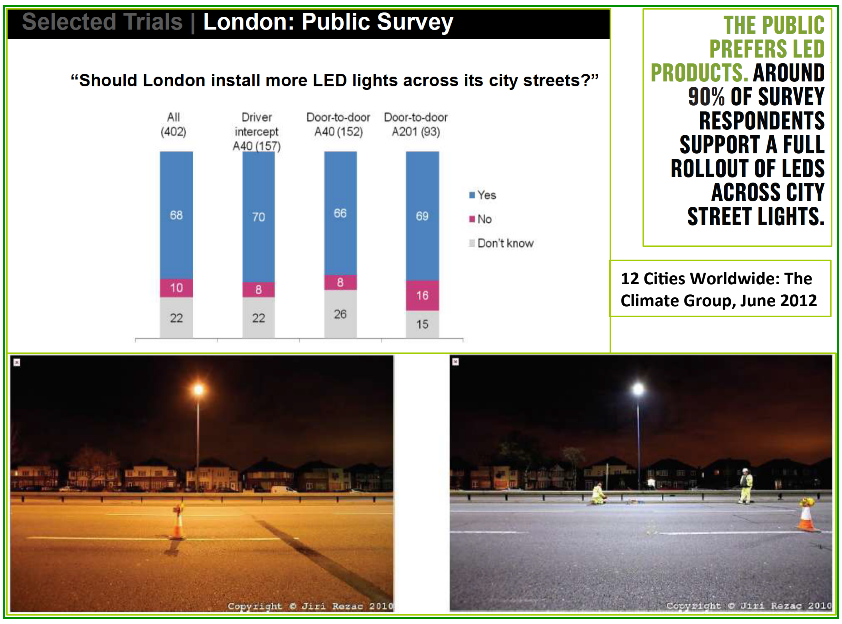

Figure 17 Results from trials across 12 world cities provide strong evidence of public support for white LED lighting (Source: Climate Group, 2012**)**

[29] The ten participating cities were Adelaide Australia, Haldia India, Hong Kong, China, Kolkata India, London United Kingdom, New York United States, Quezon City Philippines, Sydney, Australia, Thane, India, Toronto, Canada

4.11 International Experience

In the past two years many large installations of LED street lights have been made. More than 20 cities world-wide are currently installing or have recently completed installing 20,000 LED luminaires or more (see Table 1 below).

The largest completed installation of LED street lighting in the world has been done by Los Angeles' Bureau of Street Lighting, which finished replacing 140,000 HPS lights with LED lights in June 2013. More recently, the City of New York announced its intention to replace 250,000 of its lights with LED.

A distinctive feature of these and other leading LED street lighting projects is the pivotal role played by key individuals who have provided the visionary leadership necessary to navigate through the obstacles and difficulties to see the projects successfully delivered. The need for political and executive champions is a vital element in the recipe for success.

4.12 Conclusion

The development of LED luminaires and CMS lighting systems together represent a paradigm shift in street lighting. They provide a strategic opportunity to precisely manage and monitor street lighting operation to provide city-wide benefits that have never before existed.

The improvements in safety, potential reduction in crime and material savings in energy and maintenance costs provide an overwhelmingly compelling case to upgrade street lighting to LED and controls. Not doing so is arguably an abdication of local government's duty.

In the words of Ed Ebrahimian, the man responsible for the world's largest upgrade to 140,000 LED street lights in Los Angeles (and direct report to the City's Mayor), "when we began this LED upgrade program 4 years ago we were taking real risks, but for anyone setting out today it's a no-brainer".

	Location	Country	Total Lights Committed	Status
1	New York City	USA	250,000	Funding approved
2	Los Angeles	USA	141,000	Completed June 2013
3	Chennai	India	110,000	Funding approved
4	Birmingham	UK	95,000	20,000+ installed
5	Buenos Aires	Argentina	91,000	10,000+ installed
6	Nova Scotia	Canada	85,000	Awarded
7	New Brunswick	Canada	72,000	20,000+ installed
8	Washington	USA	71,000	Awarded Dec 13
9	Boston	USA	64,000	25,000+ installed
10	Sheffield	UK	58,000	Awarded Sep 12
11	Mississauga	Canada	49,600	21,000+ installed
12	Guangdong	China	48,000	Awarded
13	Las Vegas	USA	42,000	Completed March 2013
14	California (Caltrans)	USA	42,000	Awarded
15	Seattle	USA	41,000	31,000+ installed
16	London	UK	35,000	Funding approved
17	Austin	US	35,000	Awarded
18	Leicester	UK	33,000	1000+ installed
19	Oakland	USA	30,000	RFP issued
20	Salford	UK	26,000	Awarded
21	San Antonio	USA	25,000	Awarded
22	Portland	USA	25,000	Awarded
23	Beibei District, Chongquing	China	20,000	Completed
24	Heredia	Costa Rica	19,000	Awarded
25	North Lincolnshire	UK	16,500	Awarded
26	Anchorage	USA	16,000	Installed
27	Cuernavaca	Mexico	15,000	Completed Aug 2011
28	Yonkers	USA	12,000	RFP Issued
29	Shenzen	China	10,000	Completed Jul 2011
30	CDEEE (owner of electricity network)	Dominican Republic	8,000	Awarded

Table 1 International LED road lighting installations (Source: SLP and Next Energy, from the Internet, April 2014**)**

5 Procurement Practices

5.1 Introduction

Street lighting is a largely a public sector activity, and as previously mentioned it is experiencing profound disruptive change. It is therefore essential that prudent best-practice procurement tools and processes are used by the public sector .

Traditional practices using, Competitive Price (CP) methods (explained below) are now inadequate and Best Value (BV) methods (also explained below) are required to capture the benefits of new technologies and techniques.

The CP approach is the conventional method used in street lighting where a tender is called for the supply of a specified quantity of luminaires of a predetermined technical and physical specification under commercial terms and conditions. The winning tender is usually the bid with the lowest purchase price conforming to the specification. One of the big disadvantages of this approach is that it is not well suited to situations where there is rapid change in practises and/or product sophistication. The conventional CP approach has substantially higher risks for the public sector and is now being superseded by the more sophisticated BV approach which has a greater focus on the asset's (or service's) total life, not just its initial purchase.

The difference between BV and CP is particularly relevant to street lighting where the advantages of LEDs is undervalued by CP processes. BV identifies the best performing product or service from a range of competing options. These products or services are evaluated under a carefully pre-determined set of operational criteria spanning whole-of-life. This approach considers total system performance and cost of ownership. In the case of street lighting, it encompasses luminous, optical, electrical and control system performance.

The assessment and determination of the successful product(s) is based on the rating and ranking of systemic performance indicators such as performance per km of roadway over whole-of-life for "multiple bottom-line" parameters such as economic, environmental and social factors. This allows for and encourages innovation, as it does not pre-suppose or prescribe the micro-detail of the equipment being sourced.

This approach requires greater investment in the planning and formulation of the procurement process, as illustrated in Figure 18 from the Ministry of Business Innovation and Employment (MBIE)[30].

There are a number of references available from the European Union (EU), UK and USA and Canada on practical LED lighting procurement and general Green Public Procurement (GPP) approaches that can be adapted for NZ application.

A concise and informative guide to smart procurement is a European Commission document called "Guide on Dealing with Innovative Solutions in Public Procurement"[31] from which the main recommendations are:

- Consult the market before tendering
- Involve key stakeholders throughout the process
- Let the market propose creative solutions
- Seek value for money, not just the lowest price
- Decide how to manage risks
- Use contractual arrangements to encourage innovation

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30 In April 2013 but does not include Territorial Authorities because they belong to the "Public Sector". However, the MBIE "rules" mandated for the Public Service are "strongly recommended" for the Public Sector and thus local government. See "Government Rules of Sourcing: Rules for planning your procurement, approaching the market and contracting" were published in April 2013 and "in force" on 1 October 2013.

31 SEC 2007 280: European Commission, Brussels, October 2009, ISBN 92-79-03471-5

NZTA's Procurement Manual, published in 2009, contains specific requirements that must be met in order to be eligible for NZTA funding subsidies. These include BV economic approaches, life cycle costing, environmental and social impact assessment and the consideration of innovative methods and technologies. The Manual states in general what these requirements are but provides no specific guidance on exactly what methods will deliver the outcomes desired.

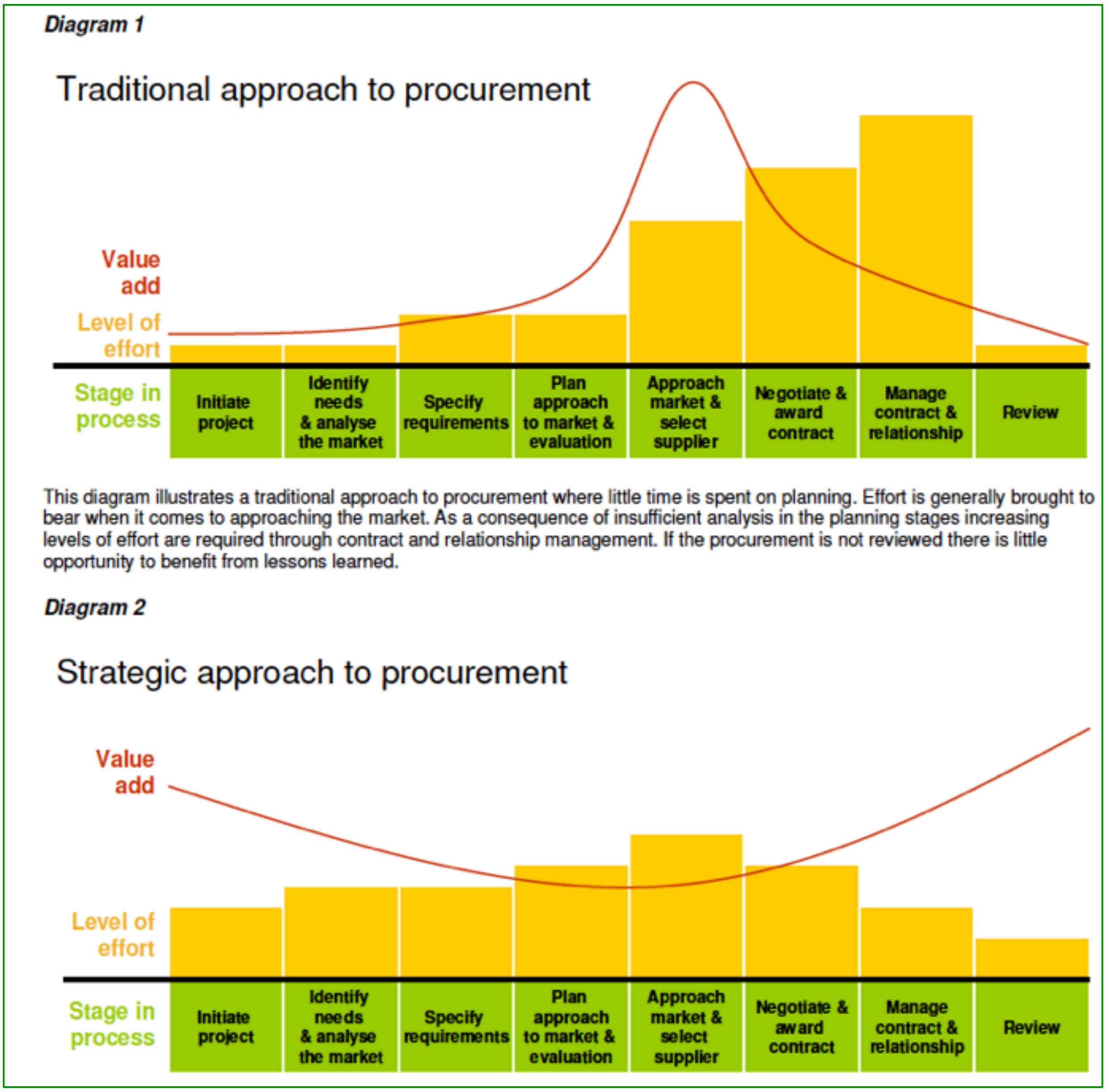

Figure 18 The difference between Traditional and "strategic" procurement Approaches (Source: Ministry of Business Innovation and Employment, 2013[32]**)**

5.2 Items to be Procured - Equipment and Services

Understanding modern LED street lighting and controls requires capabilities in civil, transport, electrical, electronic, optical and computer engineering. Thus greater knowledge and care must be utilised and invested to minimise risk and ensure productive outcomes. This is demonstrated by the range of requirements listed below for LED street lighting:

32 Page 9, "Mastering Procurement: A structured approach to strategic procurement", Ministry of Economic Development, (the predecessor to the Ministry of Business, Innovation and Employment) March 2011

a) LED luminaires including electronic drivers that can be remotely controlled and allow monitoring of luminaire operation and condition. The luminaire must also have NEMA type standard digital connectors to the "outside world" to ensure it is future proofed.
b) Electronic devices that provide communications, monitoring and control system hardware and software via the NEMA connection mentioned above;
c) A service that quickly and efficiently surveys the condition and orientation of the column, pole, luminaire and the luminous output of the existing street lights to ensure that the benefits of new hi-tech lighting aren't undermined by existing problems in the field;
d) A service to remove existing luminaires from lighting columns and poles and replace them with new LED luminaires as necessary;
e) A service to replace or improve lighting columns and poles where necessary;
f) A service to undertake remedial electrical work or adjustments to the network required for economic or safety reasons;
g) A service to test and commission the luminaires and controls in the field;
h) A service to sell replaced luminaires for repurposing and/or recycling;
i) A service to commission the street lighting control system computers and display interfaces, including systems to operate the system and diagnose problems over the internet, from anywhere in the world.

5.3 Equipment and Services Costs

5.3.1 LED Luminaire Costs

The capital cost of luminaires is a major factor in the economic assessment of street lighting systems. Prices for street lighting LED luminaires have fallen dramatically in recent years both internationally and in NZ. The price has dropped by around 50% over the past three to four years and performance levels have improved by around 5-10% per year.

These steep price reductions are not expected to continue indefinitely as LED acceptance and expanding worldwide demand is likely to outstrip the supply capacity of the more popular manufacturers. Prices are then likely to stabilise, or may even rise, if manufacturing capacity becomes constrained. However, at the moment manufacturing capacity is under-utilised and Cree in the USA has reduced the price of its smallest street light luminaire to US$99 each "in quantities". This suggests that LED luminaire pricing will soon be much the same as traditional HPS luminaires.

The NZ LED luminaire price points in Table 2 below, generated from a recent SLP survey of key NZ suppliers for a hypothetical large volume NZ project, are likely to be -

	High Pressure Sodium Power (Watts)	Where Used	Manufacturer's LED Equivalent LED Price NZ$
	70	P Category residential roads	350
	100		410
	150	Midblock	470
	150	Intersections	510
	250	V Category	540
Notes			
1	NZD GST Exclusive		
2	Quantity 10,000+ units		
3	Based on City of Los Angeles HPS to LED retrofit wattage equivalency		
4	Luminaires controls enabled (ie incl. dimming drivers)		

Table 2 Estimated pricing for LED equivalents to HPS luminaires (Source: SLP, 2014)

These estimates are based on requested pricing from the NZ distributors of international LED manufacturers and include allowance for the new NEMA 7-contact controls receptacle. Such requests many not necessarily reflect the true competitive pressures that would exist in a real and eagerly contested tender process. It is possible that a suitably promoted large scale international EOI/RFP may attract a wider scope of international suppliers and prices may be offered at more attractive rates.

Some high profile US projects are stating LED luminaire price points very much lower than this (approx USD$150-170 for 70W HPS equivalent), suggesting that NZ councils should consider international EOI/RFP processes rather than simply engaging with NZ agents. As no large scale NZ EOI/RFP has yet been undertaken it is unknown what actual figures may be achieved.

We consider that that the above luminaire price points should be used as "best estimates" for current financial modelling purposes but that some "optimistic" sensitivity analysis should be applied in order to determine the impacts should an international EOI/RFP yield more attractive luminaire costs.

5.3.2 CMS Control System Costs

Lighting control systems are also reducing in cost and improving in functionality, performance and value. About 9 months ago the price of a CMS including all necessary hardware and software was about NZ$110 per luminaire. This would allow control, monitoring and metering of each light and integration with a modern asset management system with malfunction alerts and predictive maintenance ability.

At that time there was also an annual operating charge to cover the software license and maintenance of the system. This could range from $50,000 to $200,000 depending on the size of the project, the business model selected and the particular communication technology employed.

5.3.3 Luminaire Installation Costs

High volume installation costs per luminaire are estimated in Table 3, based on 18 minutes (0.3 hr) per luminaire with the resources as identified. For reference the retrofit by Los Angeles averaged 15 minutes per luminaire with only two people so the listed figures should be conservative.

Installation	Number	Rate $/hr	Hrs	$
Labour Units	3	90	0.30	81.00
Cherry Picker Truck	1	150	0.30	45.00
Traffic Management Signs	4	20	0.30	24.00
Total				**150.00**

Table 3 Installation cost per luminaire (NZD) (Source: SLP, based on City of LA)

5.4 NZ Procurement Options

This section outlines the options available to WCC for the procurement of road lighting equipment and services.

Whilst it may initially appear unnecessary to analyse the well-established CP approach there are a number of nuances with this model that are not always evident to the purchaser. We thus dissect the features of the CP approach in order to clarify the process and to identify the sometimes unseen supply chain inefficiencies and to provide a firm reference point to evaluate alternative methods.

5.4.1 Traditional Competitive Price (CP) Specification and Tender

This is the traditional benchmark approach to procurement which has served public and private purchasers reasonably well for many years. It may be acceptable where technologies and practices have not changed or have only exhibited evolutionary or incremental change.

This approach only considers the upfront financial cost so the contract is awarded to the tenderer submitting the "lowest cost conforming". Full lifetime cost of ownership and its impact on environmental and social factors are not considered. The fundamental assumption in this approach is that the tender writer is well informed on the wide choices available in the market, and has all the knowledge and capability to narrow the choices in the interests of the Council when compiling the specification.

The advantages of this approach are simplicity and familiarity. The disadvantages of the CP process are its high reliance on the tender writer to interpret requirements and pre-select the best specification, lack of focus on long-term cost of ownership and its substantial constraint on innovation.

The two variations on this model for road and amenity lighting are described below:

5.4.1.A) Product Supply and Install CP Contract

A specialist design consultant, electrical engineer, lighting engineer or lighting designer is commissioned to design lighting to meet the expected standards within a framework of AS/NZS criteria and NZ Territorial Authority (TA) compliance requirements. The design consultant will specify the luminaire type and brand in detail, as well as installation methods.

These design requirements are then expanded into a schedule of quantities and combined with construction contract requirements. This supply and install contract package is then offered to the market for bids by construction works contractors who will themselves seek luminaire pricing from suppliers or importers and will sometimes use electrical wholesalers as intermediaries in the lighting supply chain.

An example of such a NZ tender contract was for Tauranga City Council - Contract TC 72/10 - Capital Streetlight Upgrading 2010/2011.

Advantages

- A well understood traditional model which has worked adequately during times of little change.
- The process is simple and selects a singular "lowest cost conforming" bid.
- Procurement costs are low.

Disadvantages

- Focus is on the detailed technical inputs rather than on the outcomes actually required.
- May stifle innovation and/or competition.
- The "consultant as gatekeeper" approach to product selection can lead to a restriction of options.
- The selection of one brand of luminaire with the "or equivalent" option can dilute or destroy value.
- Conservatism is incentivised in a process where risk aversion is paramount.
- There is a fundamental disconnect between capex decisions and opex outcomes.
- The use of electrical wholesalers in the supply chain adds undisclosed margins.
- Supply chain brand loyalty bonuses add undisclosed margins.
- Usually there are very short (1-3 year) product warranty periods.

5.4.1.B) Product Supply Only CP Contract

As an alternative to the above, a lighting consultant could develop a luminaire product specification and this will be combined with supply-only contractual conditions by a project manager and be offered to the market for tender bids from luminaire suppliers/importers. After procurement by the council, the luminaires will then be issued to a selected construction works contractor for installation.

A recent NZ example of a Product Supply Only Contract is: Napier City Council - Contract 741 - Supply of Street Lighting Luminaires - April 2012

Advantages

- As above - 5.4.1A

Disadvantages

- A contractor supplying "labour only" installation services may not have an adequate incentive for appropriate pre-installation care and handling of client-supplied goods. Installation contractors usually have a strong preference for being part of the supply chain for the supply of goods as this is often more profitable for them. Contractor friction can occur if this opportunity is precluded.
- Also all other disadvantages, as above 5.4.1A

5.4.2 Performance Contracts

Contracting externally for a street lighting service is a new concept for New Zealand but is extensively used in Europe/UK and has had recent uptake in Australia (such as Sunshine Coast Regional Council and Moreland City Council). It offers potential performance gains and cost savings from advanced lighting technologies without the need for a council to have the finance, resources or expertise in-house. A variety of contracting approaches exist, the most common being Energy Performance Contracts (EPC) or Public Private Partnerships (PPP).

Street lighting infrastructure is a long-lived asset and therefore lends itself to long-term outsourcing arrangements, typically over 15-25 years. These types of outsourced contracts generally involve designing, building, financing, operating and maintaining a large street lighting project of many thousands of lights. The initial stage (1-5 years) of such contracts is called the Core Investment Period (CIP) during which the legacy lights of an existing network are removed on an accelerated basis and replaced with advanced lighting technology. The advantages for a council are the fully encompassing nature of the arrangement with a financed and risk-managed contract, usually with guaranteed savings and/or continuous improvement provisions.

5.4.2.A) Performance Contract - Non-Financed

This model is an output-based turnkey performance contract that stipulates the required outcomes to be delivered but does not specify the required product engineering attributes at the micro level. This is a systems-based contract specification for the procurement and maintenance of an installed road lighting network that states a wide range of quantitative and qualitative attributes required and the KPIs that measure and verify those attributes.

The KPIs are usually focused on the main areas of economics, energy savings and the resultant carbon emissions savings, lighting quality and service levels, lighting failure response and waste and environmental practices.

The turnkey project approach requires the formation of an alliance group contracting company (called an SPV, Special Purpose Vehicle) to "Design, Supply, Install, Commission, Operate and Maintain" the road lighting system for a stipulated contractual term. Financing is not part of this model and asset ownership resides with the Council.

The design risks, product performance risks and operational risks are all assigned to the private contractor who indemnifies the client council against untoward occurrences. There are usually penalties levied upon the contractor should they fail to deliver the required quantitative performance.

The City of Sydney provides an example of a Non-Financed Performance Contract - Tender No. 1121 - Energy Efficient LED Lighting Retrofit of the City's Public Domain Lighting Luminaires - April 2011

Advantages

- The complete turnkey project responsibility is with the contractor.
- Outcome-focused KPIs determine contractor rewards or penalties.
- Whole-of-life cost is the focus, not just first cost.
- Technology neutral performance is paramount, not favourite technologies.
- Brand neutral performance is paramount, not favourite brands.
- Open RFP requirements encourage and incentivise innovation and do not restrict options.
- Performance comparisons are quantitative, allowing objective ranking of offers.
- Supplier underwrites technology and operational risk.
- Extended and long-term warranties are the norm.

Disadvantages

- The procurement process is less well understood.
- Procurement contracts are more complex and require more time initially to develop
- More time is required to evaluate responses.
- The transaction costs are higher, for both purchaser contractor.

5.4.2.B) Performance Contract - Financed

There is a range of descriptors for financed performance contracting models, including Public Private Partnerships, Private Finance Initiatives, Shared Savings Schemes, and Energy Performance Contracts. These are all variations on a common theme and will be referred to in this report as Public Private Partnerships (PPPs).

The PPP model is an outcome-based turnkey performance contract that stipulates the required outcomes to be delivered but does not specify the required product engineering attributes to the micro level. A PPP is a systems-based contract for the procurement, financing, operation and maintenance of an installed road lighting network over the longer term (typically 15 to 25 years). The contract documents state a wide range of quantitative and qualitative attributes required and state the metrics that measure and verify those attributes.

The structure of KPIs and turnkey approach are virtually the same as for the non-financed Performance Contract described above in section 5.4.2.A).

Payments to the contractor are made on a regular (monthly) basis with contractual provisions for various inflationary adjustments to cater for longer term contract viability.

At the end of the contractual term the network asset is usually vested to the client council at zero cost.

The design risks, product performance risks, financial and operational risks are all assigned to the private contractor who indemnifies the client council against such exposure. There are usually penalties levied upon the contractor for failing to deliver the required quantitative performance results.

There are usually required provisions upon the contractor to drive further gains through innovation and to update and improve the system performance at stipulated regular intervals over the life of the contract; the savings generated being shared by the client and contractor on a pre-agreed proportional basis.

Advantages and Disadvantages

The same advantages and disadvantages exist as with non-financed performance contracts but the financing element is introduced. This makes the procurement process and management process more involved, but acts as a project enabler when internal council finances cannot deliver the required capital funding.

This type of contract requires quite a complex contractual and management model. There are however, many model templates available for road lighting application (eg UK Treasury 4Ps model).

5.5 RFP/RFQ Structure Documentation[33][34]

In order to avoid project delays and project risk a very structured process is required for both RFI and RFP/Q supplier contact phases that request "fill the box" or "tick the box" answers, with yes/no responses where applicable. The response documentation should require explicit "signoff" by an authorised company officer as a clear statement of factual and binding product and performance criteria.

Also, a NZ-centric glossary of terms (and requested usage) would be useful to avoid the confusion that often exists among international cultural blocs (eg NZ/AU/US/EU/CN) for product, lighting design and energy performance terminology.

Lighting company sales staff sometimes have a minimal grasp of the design, construction and performance of the products they represent (particularly with newer LED products) and some have

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[33] "PRO INNO Europe paper No.1– Guide on Dealing with Innovative Solutions in Public Procurement". European Commission. ***http://www.proinno-europe.eu/publications***

[34] NZTA "Procurement Manual – For Activities Funded through the National Land Transport Programme" – July 2009. ISBN-978-0-478-34658-9. http://www.nzta.govt.nz/resources/procurement-manual/

never seen their products in actual use. Very knowledgeable sales engineers do exist but this should a specified requirement and not be assumed.

Much time can be wasted trying to decipher vague, ambiguous, inept, or generalist information, where suppliers may:

- answer questions generally, supply a catalogue and expect the client's consultant to sift, identify and extract the data.
- provide photometric lab reports of low credibility or dubious provenance.
- provide technical data different to the requested format (ie IESNA LM-79 L70 lumen depreciation) and expect the consultant to correlate performance.
- provide computer-generated lighting design reports that are unintelligible and expect the client's consultant to extract, interpret and validate the relevant parts (at significant extra cost).
- supply lighting designs that use photometric files from products different to the product submitted (in terms of colour, temp, chip generation, module size, drive current etc)
- extrapolate photometric performance from a lab report only vaguely similar to the proffered product.
- have technical data and lab reports only in foreign languages.
- not disclose the real facts.

This is a minefield for the RFI/RFP-Q requesting party. Even inept responses take time to interpret and digest, so that rejections can be made for valid reasons. On large public sector projects, rejected parties often require a detailed explanation regarding rejection.

In summary, project-specific RFI/RFP-Q response forms that make respondents responsible for their submissions are a very necessary part of the process.

5.6 Standards and Specification Compliance

5.6.1 Revisions to AS/NZS Road Lighting Standards

AS/NZS 1158: Lighting for Roads and Public Spaces is the series of standards applicable for public lighting in New Zealand. Using AS/NZS 1158 has historically been the only realistic way to demonstrate that parties are exercising an appropriate duty of care in the specification, management and maintenance of street lighting.

5.6.2 Current Revision of Luminaire Standard - AS/NZS 1158.6

AS/NZS 1158 Part 6 covers the design and construction of road lighting luminaires. This is the first part of the standard to be reviewed and updated by Standards Australia to accommodate LED light sources. Currently LED light sources are "not permitted" as this standard only permits technical features by specific inclusion and LED sources are not yet incorporated. This is an untenable situation and there is strong public and private sector pressure on Standards Australia to remove this omission.

An update of Part 6 is intended for publication later in 2014 with basic changes included to permit the use of LED lighting. A second phase of the review should result in alignment with the international street lighting luminaire standard *IEC 60598-2-3 Particular requirements - Luminaires for road and street lighting*. This will probably emerge as an AS/NZS standard, based on the IEC standard but with some additions relevant to Australia and NZ.

There is, however, an impediment to the publication of the first stage of this process as there have been many stakeholder assertions that some of the very specific technical requirements proposed are in breach of the World Trade Organisation (WTO) Technical Barriers to Trade (TBT) treaties. The current embargo on publication and search for a solution to these issues means that the work on the first stage revision may delayed or may be shelved and the process moved directly to stage two.

5.6.3 Revision of Design Aspects of AS/NZS 1158

A broader review of the design aspects of AS/NZS 1158 is also underway. Recent international research on the energy and road safety impacts of white light is fuelling a fundamental reappraisal of lighting for roads and public spaces. Some international design standards (eg British Standard BS-5489-1 2013) are already incorporating new approaches such as the application of Scotopic/Photopic (S/P) ratios. These approaches support and incentivise the use of white light sources, such as LED lighting, to deliver standards compliance and superior user perceptions at significantly lower energy consumption than traditional systems such as HPS. There will also be a revision of luminaire maintenance factors to allow for lumen depreciation and atmospheric dirt accumulation with LED luminaires: these parameters are very different to (and better than) those encountered with HPS technology. It is very likely that the parts of AS/NZS 1158 dealing with lighting design will also incorporate guidance on S/P application.

5.6.4 NZTA M30 Specification and Guidelines for Road Lighting Design

The recently initiated NZTA *M30 Specification and Guidelines for Road Lighting Design* will cover NZTA's technical and application requirements for street lighting funding assistance to RCAs under the National Land Transport Fund (NLTF) programme. The specification is still in development and is due to be released for public consultation in August 2014, with final publication due in October 2014. SLP believes that this document will provide a strong signal of confidence and endorsement for LED and CMS technologies to RCAs in NZ and is likely to fill the void caused by the long and continuing delays in the review of AS/NZS1158 Part 6.

NZTA's M30 document covers luminaires, lighting columns, electrical installation and reticulation and provides an introduction to CMS controls systems.

LED luminaires are likely to be mandatory for Category P residential road lighting and mandatory in most cases for Category V arterial road and highways lighting. HPS lighting may still be allowable for some Category V applications if the Net Present Value (NPV) is shown to be better than that for LED and if the particular HPS luminaire is on the forthcoming NZTA M30 "Approved List". In addition, all luminaires are required to be "controls enabled" and incorporate variable lighting (dimming and brightening) capability to work with a CMS and accommodate an interoperable "open source" software platform (eg TALQ). There will also be a preference for luminaires that incorporate a NEMA type (ANSI C136.41) seven contact receptacle for the use of third-party external plug-in control/communication devices.

The draft specification includes a requirement for a 15 year full-replacement "Return to Base" (RTB) product warranty with a "No Questions Asked" (NQA), purchaser-defined stipulation of product failure modes. This means that any site replacement costs (labour etc) for faulty luminaires and product freight to supplier company premises will need to be covered by the purchaser. The legal and commercial implications of an NQA policy are being explored and are subject to ratification.

The NZTA M30 specification will be released for a six week public comment period and details will be fine-tuned as part of this process.

5.6.5 The City of Los Angeles "Better Than Before" (BTB) Approach

The rapidity of technology development and slow response of worldwide standards organisations has significantly delayed large scale LED deployments almost everywhere.

What should be done in the absence of guidance from standards?

An early example of leadership was the City of Los Angeles, currently the site of the world's largest LED deployment of almost 150,000 lights. The Mayor and his direct report Mr Ed Ebrahimian, the Director of the Los Angeles Bureau of Street Lighting, forged ahead with a pragmatic approach based on providing a lighting service that was "Better Than Before" (BTB) to minimise the probability of litigation in a very litigious country. As a result Los Angeles has reduced energy consumption for street lighting by 63% and saves USD$10 million per year in energy and maintenance costs – without the benefit of controls. Other US/EU/UK cities have taken this lead and adopted similar principles to help overcome the paralysis.

The Los Angeles BTB approach by-passes the details of "Light Technical Parameters" and complex design compliance and instead focuses on the outcomes of the retrofit. Los Angeles simply ensured that all LED luminaires produced better lighting than was currently in place by working with the manufacturers to do representative sample testing on roads with replacement LEDs.

An important feature of this approach is that it overcomes one of the drawbacks of road lighting everywhere – that of lack of continuous monitoring over the life of the infrastructure. As mentioned in section 3.6.4, compliance of continuous stretches of roading is not regularly monitored, so most cities – including Los Angeles - do not really know to what extent they are compliant. By using the BTB approach Los Angeles avoids debate over detailed design issues. SLP strongly recommends that WCC take the same approach.

5.7 Product Warranties, Performance Insurance, Government Guarantees

Wherever a new technology is developed, especially in the safety infrastructure sector, the risks of deployment need to be carefully evaluated and managed. Fortunately, new lighting technology developers and suppliers acknowledge these risks and generally now offer stronger warranties to encourage purchases.

Manufacturers of new LED and CMS systems are in the best position to assess the risks of their own technology, so prospective purchasers need to examine this aspect closely.

Some of the key issues to consider are:

- Will the technology and products and systems be sufficiently reliable?
- Will the project outcomes deliver the performance and savings expected and required?
- Will the supplier be operational in 5-10-20 years' time?

A number of mechanisms have emerged to underwrite and indemnify the inherent risks of new road lighting technology. The objective is to ensure that the purchaser is not exposed to the risk of technology malfunction and/or corporate non-performance by suppliers. A balance is required to assess the level of risk and amount of cover required as all insurance schemes have a cost, whether explicit or implicit. Non-essential protection will raise costs without providing commensurate value.

Three examples of risk mitigation are discussed below:

5.7.1 Long Term Product Warranties

Most of the reputable and committed LED suppliers can now offer extended product warranties of up to 20 years. Warranties of up to 10 years are usually included implicitly in the quoted cost of the product, but are often transparently separated out where longer (10-20 year) protection is requested. Such warranties are not always offered upfront and some suppliers may react with a degree of reluctance, but should the purchaser require such cover there are suppliers willing to meet this need.

Some longer duration warranties may include a planned replacement of LED drivers and/or modules at an agreed predetermined point.

It is very important to ensure that procurement processes specifically include methods of warranty activation. One method is to stipulate detailed explanations of failure modes and definitions of component failure or performance degradation. Alternatively, the "No Questions Asked" approach can be taken where the contract states that the purchaser will reasonably define which failure modes constitute warranty activation. An underlying tenet of such an approach is that ongoing business prospects for a supplier are linked to a supplier's acceptance of purchaser judgements.

Longer term warranties sometimes have pro-rata clauses included to apportion the value of "already enjoyed life" up to the point of failure. These should be viewed with much caution. A luminaire that has been replaced under warranty may cost the purchaser a pre-determined proportion according to the point in time when the failure occurred. Thus if the failure occurs early, then nothing might be charged, but if the failure occurs in the year before the warranty expires, a significant proportion of a new luminaire (or component) price might be charged.

5.7.2 Supplier Performance Guarantee Insurance Policies

Some LED luminaire suppliers offer long term Performance Guarantee Insurance policies to purchasers for their company and product performance, to cover technology risk, performance risk and longevity risk[35]. Large international reinsurance companies (eg Hannover Re[36], Munich Re[37]) now offer performance indemnity cover for LED suppliers to the municipal market which can span periods of up to 25 years. Such policies may be useful to build the perceived "bankability" of projects centred on newer technologies. There are also complementary insurance policies available to purchasers to provide guarantees to cover the risk of post-project supplier company closure and/or insolvency risk.

5.7.3 Government Guarantees

Some government agencies from the home country of the exporting supplier (eg Canada) offer government backed indemnities for the supplier company and the performance of their products to encourage international customers to purchase the equipment.

Such measures can be attractive to buyers as they transfer risk away from the purchaser and onto the vendor and associated parties. However, the attractiveness is dependent on the incremental cost of the service and the outcome of a BCR analysis.

5.8 Conclusion and Recommendation

SLP recommends that WCC use the Financed Performance Contract procurement model.

This approach requires contractual and management models that focus on well-defined output-based performance criteria. There are internationally available precedents, guidance information and model templates available for road lighting application.

Key attributes of such contracts are that they are:

- Turnkey based;
- Output focused;
- Life cycle based;
- Brand neutral;
- Technology neutral;
- Innovation Incentivised;
- Systemically monitored;
- Supplier risk indemnified;
- Extended warranty protected;

The conclusion to recommend a Financed Performance Contract are based on balancing the opportunity for harvesting the gains from innovative design, technology and management approaches whilst identifying and externalising the potential risks to WCC of non-performance and the resultant operational and financial exposure.

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35 *http://www.hsbeil.com/EIL/uploadedFiles/Content/Knowledge_Centre/HSBEI-1225-1113%20Energy%20efficiency%20Insurance%20-%20Product%20overview.pdf*

36 *http://www.hannover-re.com/media/press/archive/pr130516/index.html*

37 *http://www.munichre.com/en/group/focus/climate-change/insurance-and-financial-solutions/performance-guarantee-insurance-for-LED-modules/index.html*

6 Risks and Mitigation

Table 3 and Table 4 in this section provide an outline of the risks, probability of occurrence, their impact and processes required to mitigate the risks – listed in order of SLP's assessment of the magnitude in each case.

Item #	Risk	Description	Probability of Occurrence	Probability Explanation	Impact Size	Impact Consequences	Difficulty to Mitigate	Mitigation
1	Missed Opportunity	Missing the investment opportunity to gain strategic lighting benefits	High	The universal focus on LEDs for improved energy efficiency and reduced maintenance overlook the other strategic benefits available	High	Streetlighting does not receive strategic investment. Once this opportunity to do so is missed, all further investment will be tactical with little or no ability to make strategic improvements	Low	Invest in fully appreciating the extent of the opportunity and identify the parts which need to be treated strategically and which can be incrementally improved over time
2	Electricity Regulatory Barriers	Electricity Authority (EA) delays approval of streetlight monitoring to be the basis of payment for electricity	High	Street lighting does not have the priority it deserves by the Electricity Authority and they have not caught up with the technology that allows metering of every individual street light	Medium	Until this approval occurrs some of the energy efficiency benefits of LED and controls enabled streetlights are delayed	Medium	Early engagement at senior levels of EA, together with Local Government NZ and Minister of Local Government and staff to advocate for quick resolution by EA (especially as currently all electricity usage is estimated not measured). The accuracy required for revenue quality metering is greater than required for a street light.
3	Technical Specification	Technical specifications used don't match the requirements	Medium	LED and controls are new technologies with few experienced practitioners available in NZ. However, the reputable manufacturers and international consulting engineers have had significant experience on which to draw.	High	As is the case for most engineering infrastructure, getting the specifications wrong has major negative consequences for the community.	Low	Obtaining experienced international procurement advice is not difficult, it will just cost a bit more than usual. Use high quality pre-installation asset condition monitoring.
4	Sub-optimal Procurement	Procurement process is not structured correctly	Medium	Procuring LED and controls are more complex than traditional street lighting. People experienced in traditional lighting procurement are likely to not appreciate this and be over-confident	High	All infrastructure procurement processes have potentially large and long lasting impacts. Street lighting is no different except that it has under-appreciated safety characteristics	Low	Obtaining experienced international procurement advice is not difficult, it will just cost a bit more than usual. Use high quality pre-installation asset condition monitoring.
5	Electricity Line Charges	Network line charges from Electricity Distribution/Network Business could result in no saving despite 50% reduction in energy	Medium	The 28 network companies have no standard way of charging - ranging from 100% fixed to 100% variable dependent on the energy used. Each extreme is incorrect and comes with potential for overcharging local authorities. Street lighting has not received the priority it deserves.	Medium	Significant financial savings on network line charges lost despite savings of 50% experienced in electrical energy.	Medium	The Commerce Commission needs to be engaged as they are responsible for ensuring network companies are charging for their services fairly and in a way that benefits society.
6	Controls Pricing	The prices quoted by suppliers are greater than expected	Medium	Controls for street lighting are less mature than LEDs and there are more suppliers for them than LEDs.	Medium	Controls are approximately 15% of the cost of a luminaire but they represent a significant level of complexity and unappreciated added value	Medium	The greater the quantity of controls purchased, the greater the ability to tender internationally and receive globally competitive prices, but sales of wholesale quantities of controls are newer in the marketplace than LEDs

Table 3 SLP Assessment of Risks, Probability, Impact and Mitigation – Items 1-6

Item #	Risk	Description	Probability of Occurrence	Probability Explanation	Impact Size	Impact Consequences	Difficulty to Mitigate	Mitigation
7	Pre & Post Condition Survey	Survey does not properly identify the condition of the assets	Medium	Traditional street lighting condition monitoring is simple to do and usually done visually. LED and controls are a high performance technology that can be relatively easily degraded by lack of physical and electrical attention to conditions in the field	Medium	Similar to all safety infrastructure, the impact of not establishing pre-retrofit conditions properly could have significant financial consequences from lack of supplier accountability, similarly for post-retrofit surveys.	Low	Ensure that the survey process is correctly specified in the procurement process.
8	Procurement Delay	Unexpected delays caused by procurement process	Medium	The technology is new to NZ and requires some innovation within the procurement process to obtain maximum benefits	Medium	Delay postpones benefits, but also has consequences if linked contracts have not been drafted to allow for this	Low	Ensure procurement process is well planned and executed
9	Procurement Cost	Costs of procurement process higher than expected	Medium	The technology is new to NZ and requires some procurement innovation to obtain maximum benefits	Low	The procurement process cost is relatively small compared to the whole retrofit investment	Low	Ensure procurement process is well planned and executed
10	NZTA Funding	NZTA refuses to fund its usual approximately 50% proportion of street lighting	Low	Probability has recently changed from "medium" to "low" as a result of NZTA's new M30 Guidelines for street lighting to be published for consultation in July or August 2014, effectively making LEDs the only lighting that will receive funding	High	NZTA is expected to contribute about 50% of the funds	Low	NZTA appear to now recognise the substantial benefits available to them
11	LED Pricing	The prices quoted by suppliers are greater than those identified	Low	Procurement process identifies pricing which is significantly higher than expected	High	Because there are so many luminaires to replace, the financial consequences of higher than expected prices is high	Low	Although LEDs are relatively new compared to HPS, they have now been in the market for several years and several millions installed so the market has a lot of pricing information available to it especially as this is for the relatively transparent public service. The greater the quantity of luminaires purchased, the greater the ability to tender internationally and receive globally competitive prices
12	Maintenance Benefits Overstated	Achievement of 50% reduction of maintenance savings does not eventuate	Low	International evidence suggests that maintenance costs will be reduced by as much as 80% so a 50% claim is conservative, but prudent especially as maintenance costs are less transparently tracked	Medium	Non-achievement of 50% maintenance saving will have a medium level financial impact on the business case	Medium	Mitigation is primarily through not raising expectations unrealistically. Other possibilities include sharing the risk with suppliers, or transferring the risk completely to the private sector through a performance contract/lease or a PPP.
13	Energy Benefits Overstated	Estimation of the energy savings provided by investment in controlled white LED streetlighting is less than expected	Low	International experience suggests 60% energy savings without controls, and 75% with controls. So despite higher lighting levels overseas, a 50% energy saving is conservative.	Medium	Energy savings are expected to be about 40-50% of the total financial savings achieved	Low	Energy use is closely monitored by electricity suppliers and manufacturers specify the power usage of luminaires very closely so the only risk to mitigate is that the luminaires provide the illumination specified. Consumer guarantees act and Supplier warranties mitigate the rest of the risk
14	Safety Benefits Overstated	Estimation of the safety benefits provided by investment in controlled white LED streetlighting	Low	Safety benefits have been conservatively estimated and are not used to justify the investment	Low	The financial impact for local government is virtually zero as these safety benefits are not currently valued by local government	Medium	It takes significant effort to relate safety outcomes to street lighting, but with controls and off-the-shelf databases of crashes, injuries and crime this isn't very difficult.

Table 4 SLP Assessment of Risks, Probability, Impact and Mitigation – Items 7-14

7 Life Cycle Cost Management and Total Cost of Ownership

7.1 LCC Systemic Structure and ISO Standardised Methods

7.1.1 Overview - Life Cycle Assessment - The Systems Approach

Life Cycle Assessment (LCA) is a well-established ISO standardised methodology that addresses the energy and environmental aspects and consequent impacts throughout a product's life cycle, from raw material acquisition through production, installation, use, end-of-life treatment, recycling and final disposal.

The identification and structuring of such elements allows a variety of competing product choices and operational scenarios to be objectively and quantitatively evaluated and the resulting positive and negative financial consequences to be compared on a comprehensive and transparent basis.

The standard ISO 14040 Environmental Management - Life Cycle Assessment - Principles and Framework provides the conceptual model to identify the scope and boundaries of the assessment and the items that need to be quantified in order to ensure that a true fully costed "user pays" evaluation occurs.

Figure 19 below shows a holistic product system with energy supply at the raw material, production, use, recycling and waste treatment phases.

For street lighting the energy supplied may be direct, as in diesel fuels used for maintenance vehicles, or indirect, as in grid electricity purchased from electricity retailers. The LCA process defines the inclusions required and the cost impacts of resource acquisition and waste materials treatment and disposal.

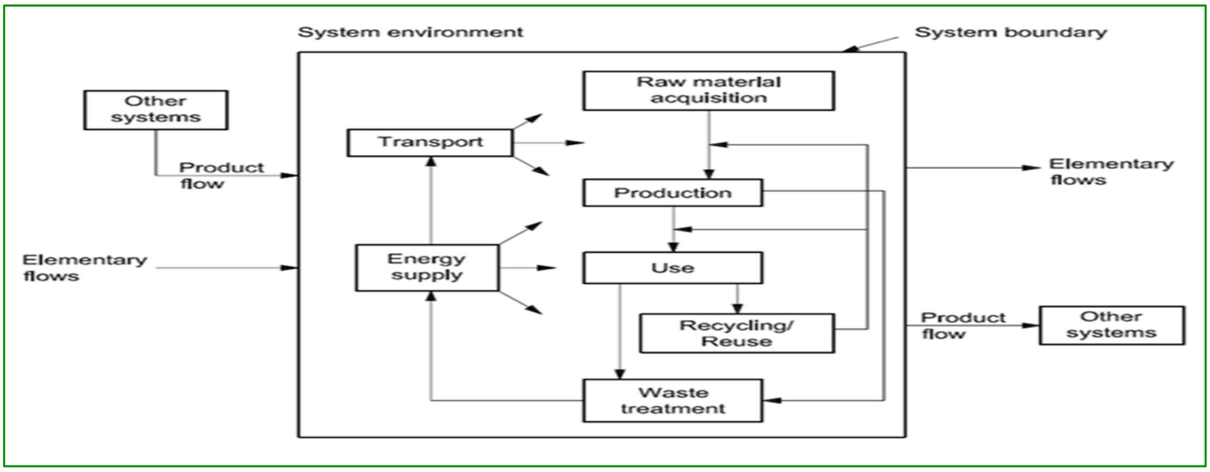

Figure 19 Example of a product system for Life Cycle Assessment (Source: ISO14040)

For street lighting, this approach provides a framework for assessing the total impacts of extended luminaire maintenance intervals, as it encompasses diesel fuel energy and any self-generated energy, rather than simply purchased electricity. It can thus accommodate "next generation" local council energy approaches such as solar PV microgeneration (if applicable).

7.1.2 ISO Standards - Life Cycle Costing

Extending from the overarching ISO LCA framework above, the Life Cycle Cost (LCC) process is defined in *ISO 15686:5 Buildings and Constructed Assets - Service Life Planning- Life Cycle Costing*

This standard provides guidance on building and infrastructure asset costings. These general guidelines are readily adapted to street lighting applications and cover:

- Asset management and financial definitions and nomenclature
- Principles and concepts (ie differences between whole life cost (WLC) and life cycle cost (LCC)

- Scope and Boundaries
- Environmental and social costs
- Operation, maintenance, and of life costs
- Externalities and wider cost impacts
- Financial calculation formulae
- Sensitivity analysis

Reporting

It is understood that the forthcoming *NZTA M30 Specification for Road Lighting Design* will recommend that ISO based LCC techniques be used as a basis for NZTA NLTF funding.

The following problems have been historically encountered in assessing cost and performance:

- Confusion over scoping and terminology – i.e. WLC vs LCC
- Lack of a common methodology and cost data structure
- Lack of ability to present information to enable stakeholders to understand the interrelationship between costs, quality and environmental, energy and social aspects
- Lack of tangible know-how to make it happen

The confusion over terminology has involved the differences between WLC and LCC. WLC is a wider concept than LCC.

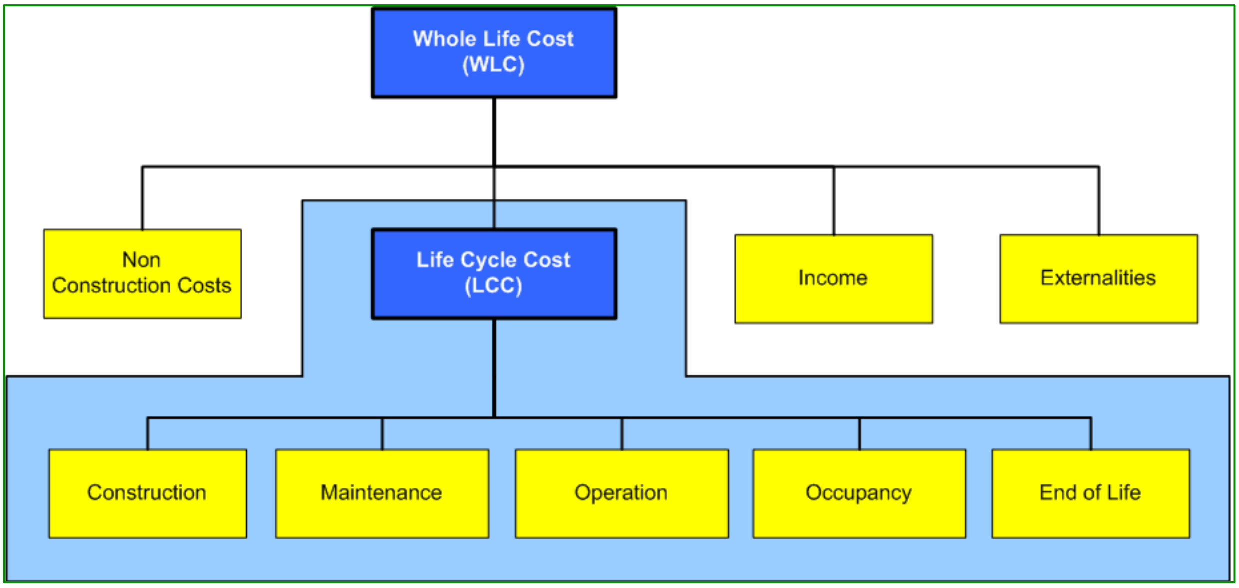

Figure 20 Costing Structures Defined (Source: BS ISO 15686-5)

For NZ street lighting application the use of LCC addresses the tighter concept of construction and operation costs. The WLC cost externalities such as financial incentives, rebates, levies, administrative costs, penalties etc may be considered later if applicable.

LCC may form part of a wider WLC process for costing a sustainable development assessment (multiple bottom line). A common issue and area of conflict is the balance between affordability and sustainable development.

Scoping - the exact menu of inclusions and exclusions for NZ street lighting

The following are typical NZ LCC inputs and cost impacts-

Design, Construction, Operation, Maintenance, EOL.

Lighting design -The primary performance input to LCC

Energy Cost - Purchased energy

Lines Charge Cost - Fixed and/or variable

Environmental impact cost - Mercury disposal costs

Maintenance Cost - Routine cleaning

Maintenance Cost - Fault rectification (non-warranty)

End-of-life - Waste management - Removal costs.

Repurposing and recycling old luminaires

Use of recycled materials (sometimes at higher cost)

Disposed Waste Materials - Negative Cash Flow

Hazardous waste disposed - Cost of HPS lamp mercury hazwaste treatment

Non-hazardous waste disposed - Cost of waste processing and/or landfill

Exported Materials - Positive Cash Flow

Components for re-use - Income from luminaires sold for reuse or repurposing

Materials for recycling - Income from scrap aluminium, steel, copper, glass

Materials for energy recovery - Income from scrap plastics (waste to heat)

7.1.3 Calculation tools

The EECA RightLight Road Lighting website has a Road Lighting Calculator for the holistic calculation of economic, energy and environmental impacts over whole of life. This was developed by Bryan King in 2009 under contract to the NZ Electricity Commission. Methodology is as per ISO 15686-5 and compares various user-defined scenarios using Net Present Value (NPV) financial evaluation.

The assessment modes are-

- Economic analysis - NPV financial evaluation
- Energy analysis - Electricity and Diesel (maintenance vehicle) energy (inc self-generated electricity)
- Carbon analysis - Based on electricity use and the power generation mix.
- Mercury analysis - Based on lifetime usage of mercury containing HID lamps (if applicable)

This tool is now somewhat dated but is still very useful as a calculation tool where the user is familiar with appropriate cost input figures, and is very suitable for rapidly working through a high number of different scenarios to reach a “sweet spot” that then requires spreadsheet analysis in micro-detail.

When this broad-brush method has identified a shortlist of a few likely solutions it is appropriate to then build a dedicated Excel-based calculation model that focuses directly on the exact project nuances and council requirements. The planning horizon is dependent on the needs of the client council, but a period of 20 years is the typical expected life under AS/NZS1158 series standards.

7.2 Practical Application - Decision Support Tools

7.2.1 Environmental Product Declarations (EPD) as a decision support tool

There are recently developed international evaluation methods available for construction product suppliers to communicate the energy efficiency and/or environmental performance of their products in a “greenwash-free” way. These are called Environmental Product Declarations (EPDs).

Figure 21 Environmental Product Declaration Process (Source - InterfaceFLOR)

EPDs are based on the calculated outcomes of an LCA assessment and use a set of accepted rules specific for that industry. These Product Category Rules (PCRs) evaluate the life cycle performance of the product. PCRs are developed by construction research organisations (eg BRANZ) within ISO and EN standards frameworks. The results are released as an Environmental Product Declaration (EPD) which is an independent third party verified attestation of product or system performance. When determined under ISO Standards processes (an ISO 14025 Type III declaration), this is a highly robust and trustworthy communication model.

An EPD allows a product marketer to credibly claim product energy and environmental performance, so purchasers can make reliable comparisons of product performance. This provides full product transparency in construction products and projects with:

- Internationally harmonised metrics and methods.
- Standardised, quantified and transparent user information
- Greenwash-free product performance data
- Internationally harmonised base for project financial modelling

EPDs have been pioneered in Germany and Northern Europe and fully embedded in those regions as a powerful tool for purchaser decision support in construction and infrastructure procurement. In the lighting industry a growing number of European and US aligned manufacturers are undertaking EPDs for their product ranges. Increasingly, international Green Building Councils are embedding such processes into their rating systems eg BREEAM UK, LEED USA, Green Star Australia.

As such approaches become more popular with international suppliers to the street lighting market this will allow public sector purchasers to mandate such documentation as part of their RFP/RFQ procurement methods. For councils this should greatly simplify the task of eliciting trustworthy product data and identifying the best-performing contenders and thus obtaining the best value for money.

7.2.2 Lighting EPD in New Zealand Practice

7.2.2.A) The Australasian EPD Programme Ltd

The emergent "Australasian EPD Programme Ltd" is an assessment validation programme for the Trans-Tasman construction industry. The Life Cycle Association of NZ (LCANZ) and the Australian Life Cycle Assessment Society (ALCAS) are working towards the establishment of an EPD scheme in NZ and AUS. A Memorandum of Understanding between LCANZ, ALCAS and the International EPD scheme has been signed and a not-for-profit company has been started.

•The Australasian EPD Scheme will:

a) be based on an international scheme to ensure international recognition, compatibility and a cost effective way of leveraging off existing experience

b) provide a "local" point of reference and a mechanism by which New Zealand and Australian companies, or companies importing products into these countries, can obtain third party verified EPDs.

•The Australasian specific scheme will enable New Zealand and Australian industries to clearly and transparently communicate to their consumers, thus reducing the problem of 'greenwash'.

•New Zealand and Australian specific EPDs will arrive in the marketplace in late 2014.

The Australasian EPD Programme Ltd is operated by Enviromark Solutions Ltd, an associated company of Landcare Research Ltd.

Figure 22 Australasian Environmental Product Description Programme Logo

(Disclosure of interest - Bryan King is an unpaid independent director of The Australasian EPD Programme Ltd, an NZ-registered not-for-profit company.)

7.2.2.B) Building Research Association of NZ (BRANZ)

BRANZ is a leading NZ organisation promoting LCA and EPD in NZ. As well as undertaking fundamental systemic research they offer product LCA and EPD evaluation and consultancy services. This service is likely to be of some value (as part of the shortlisting process) when NZ councils are considering the mass deployment of LED luminaires.

7.2.2.C) NZ Luminaire Examples

The current NZ local suppliers of luminaires and related components that offer EPD reports are Tridonic, Zumtobel, Thorn, WE-EF, and Schreder. This list is likely to expand as the street lighting business opportunities in NZ expand with the unlocking of large scale LED deployments.

7.2.2.D) CAD Design Software

Basic LCA reporting of constituent components can be produced from commonly used product design CAD software. CAD engineering design software systems such as "Solidworks" have modules called Sustainability and Sustainability Xpress[38] that can readily calculate holistic energy and environmental impacts (with limited, but comaprable parameters.

Thus the requesting of such data by NZ purchasers for large scale projects is by no means unrealistic and is likely to become common part of green building and sustainable infrastructure projects in the near future

38 http://www.solidworks.com/sustainability/sustainability-software.htm

8 LED/CMS Case Studies - Trials and Rollouts

There have been about 15-25 small trials, tests and evaluations on LED installations in NZ over the last few years (some including CMS or other controls). Most of these have not been well conceived, analysed or documented so the knowledge from many of these efforts are not readily accessible or transferable. Good lighting trials are time consuming to plan, execute and report on and require specialist expertise to apply appropriate benchmarking and validation processes.

The necessary elements for meaningful lighting trial include:

a) A coherent plan that specifies the objectives of the trial, the identification of performance parameters, metrics and required hurdles;
b) Robust and transparent technical methodology that benchmarks against relevant existing lighting schemes;
c) Structured before and after trial site light level surveys;
d) Rational and comparable standards based Life Cycle Costing methods;
e) Standards based NPV financial analysis;
f) Good before and after trial site photography;
g) Good before and after trial site resident opinion surveys;
h) A "next steps" action plan that states what will happen if/when the performance goals (energy saving, financial saving) are attained.

The consequent significant expense of conducting fully documented LED street lighting trials has been a barrier to more of these being undertaken in NZ.

NZ Trial Project	Orewa	Eden Park Surrounds	New Plymoutl
Project	Road Lighting Technology Trial - West Hoe Rd	Eden Park surround streets - Sandringham	NPDC Road Lighting Technolog
Location	Orewa, North Auckland	Mt Eden, Auckland	New Plymouth, Suburban Cat I
Council	Auckland Council	Auckland Transport	New Plymouth District Council
Trial Size	6 Luminaires	approx 60 luminaires	Approx 80 luminaires over twc
Trial Date	2011	2011	2013
Trial Objectives	To practically determine the acceptability of LED lighting and adaptive controls in a highly variable traffic flow suurban site	To determine the accepability and performance of a LED/CMS brightening and dimming scenario in high traffic but short duration application.	Performance assessment of LE to evaluate the suitability of ac lighting techniques for NZ conc
AS/NZS1158 Road Category	Category P2 Normal use	Category P3 Normal use	Heta Rd - Category P4 Normal St - Cat P2 Normal Use
Replaced Technology	HPS Bowl Optic Luminaire - 150W	HPS Bowl Optic Luminaire	Heta Rd - 70WHPS, Tukapa St 100WHPS
LED Luminaire	Philips SpeedStar LED	BetaLED LEDway LED	Philips Green Vison Flexi LED
Colour Temperature	5600K	4000K	4300K
Controls Type	Philips Dynadimmer Standalone	Owlet Nightshift CMS Radio Frequency	Philips CityTouch CMS Radio Fı
Controls - Dimming Profiles	P2 Peak, P3 Shoulder, P4 Off-Peak	P1 Sport Events, P3 Normal Peak, P4 Off Peak,	Heta Rd - Adapted 100/50/25% 100/50/25%
Controls Functionality	Pre-set dimming profiles based on pre-measured hourly flow rates traffic flows	internet based CMS RF controls able to be real-time adapted according to event and pedestrian safety needs	internet based CMS RF control real-time adapted according tc and driver safety needs
Resident Survey Done	Yes, RightLight format - Very positive general feedback with some negative on reduced lighting of private property frontages.	Not known	Yes, Full before/after survey ba Rightlight format
Energy Outcomes	54% Energy Saving vs encumbent bowl optic HPS . When theoretically compared on like-for-like glare controlled basis with a flat glass aeroscreen the energy saving would be 73%.	Energy Savings achieved were 17% undimmed and 22% dimmed	Energy savings - Heta Rd - Ada Tukapa St 69% vs LPS and 72%
Safety Outcomes	Residents surveyed reported a very strong sense of improved safety perception. Even with a deep off-peak dimming . A dominant preference for white light over HPS	A feature of this application is the need to maximise personal saftey and policing need for major sports events to moderate neighborhood light intrusion during normal use times.	Heta Rd - Adapted 100/50/25% for drivers and peds, Tukapa St acceptable but 25% level not a
General Comment	A very succesful project that delivered vissual comfort and significant energy reductions. Balancing resident street frontage spill light was an issue with conflicting resident desires, but a good balanace has been achieved.	An excellent demonstration project of urban dimming/brightening scenario for high context pedestrian crowd control comfort and safety.	Trial was not entirely suceesfu optimised lighting design view trial fine tuning to luminaire m still required to balance the im issue of cross site footpath ligh

Table 5 below depicts the main points of four best conceived trials that have been completed in recent years. There are significant localised learnings that can occur from assessing these trials. These local trials, can yield very good input for new applications and deployments under consideration. Such desktop analysis and learning should be a precursor to the undertaking of any new NZ site trials.

In 2014 and onwards, any field trials undertaken should not be about questions of general suitability of LED or the reliability of LED technology, or "what does LED lighting look like". Such questions have been answered many times over by other evaluation teams in NZ and worldwide. These questions should be answered by direct discussion with established triallists or users, or by travel to established sites to view the installed schemes. Lighting evaluation trials are however a necessary and fundamental late stage step in the procurement process to ensure that the LED luminaires shortlisted do actually perform as designed (with actual measured performance tests) and the "human factors" of glare, beam cutoff, light colour preferences and product aesthetics are appropriate.

Finally, any site trial that is undertaken without well-defined "next steps" is likely to be a wasteful exercise. The trial stage should be the tangible confirmation that all designed and calculated criteria are bona fide and that "project approval" should be the likely next step.

NZ Trial Project	Orewa	Eden Park Surrounds	New Plymouth	Project Twin Streams
Project	Road Lighting Technology Trial - West Hoe Rd	Eden Park surround streets - Sandringham	NPDC Road Lighting Technology Trial	
Location	Orewa, North Auckland	Mt Eden, Auckland	New Plymouth, Suburban Cat P roads	Henderson, West Auckland
Council	Auckland Council	Auckland Transport	New Plymouth District Council	Auckland Council
Trial Size	6 Luminaires	approx 60 luminaires	Approx 80 luminaires over two sites	6.6km long walkway cycleway
Trial Date	2011	2011	2013	2010
Trial Objectives	To practically determine the acceptability of LED lighting and adaptive controls in a highly variable traffic flow suurban site	To determine the accepability and performance of a LED/CMS brightening and dimming scenario in high traffic but short duration application.	Performance assessment of LED and CMS to evaluate the suitability of adaptive road lighting techniques for NZ conditions.	To implement a sustainable lighting approach that included energy efficiency and light pollution requirements
AS/NZS1158 Road Category	Category P2 Normal use	Category P3 Normal use	Heta Rd - Category P4 Normal Use, Tukapa St - Cat P2 Normal Use	Category P4 required, but P2 achieved in places
Replaced Technology	HPS Bowl Optic Luminaire - 150W	HPS Bowl Optic Luminaire	Heta Rd - 70WHPS, Tukapa St 90WLPS and 100WHPS	New site
LED Luminaire	Philips SpeedStar LED	BetaLED LEDway LED	Philips Green Vison Flexi LED	BetaLED LEDway LED
Colour Temperature	5600K	4000K	4300K	4000K
Controls Type	Philips Dynadimmer Standalone	Owlet Nightshift CMS Radio Frequency	Philips CityTouch CMS Radio Frequency	Photocell -individual
Controls - Dimming Profiles	P2 Peak, P3 Shoulder, P4 Off-Peak	P1 Sport Events, P3 Normal Peak, P4 Off Peak,	Heta Rd - Adapted 100/50/25% , Tukapa St 100/50/25%	None
Controls Functionality	Pre-set dimming profiles based on pre-measured hourly flow rates traffic flows	internet based CMS RF controls able to be real-time adapted according to event and pedestrian safety needs	internet based CMS RF controls able to be real-time adapted according to pedestrian and driver safety needs	Photocell switching during cycling/walking hours
Resident Survey Done	Yes, RightLight format - Very positive general feedback with some negative on reduced lighting of private property frontages.	Not known	Yes, Full before/after survey based on Rightlight format	Not known
Energy Outcomes	54% Energy Saving vs encumbent bowl optic HPS . When theoretically compared on like-for-like glare controlled basis with a flat glass aeroscreen the energy saving would be 73%.	Energy Savings achieved were 17% undimmed and 22% dimmed	Energy savings - Heta Rd - Adapted 71% , Tukapa St 69% vs LPS and 72% vs HPS	New sheme. Not benchmarked. Low wattage 20 LED luminaire used.
Safety Outcomes	Residents surveyed reported a very strong sense of improved safety perception. Even with a deep off-peak dimming . A dominant preference for white light over HPS	A feature of this application is the need to maximise personal saftey and policing need for major sports events to moderate neighborhood light intrusion during normal use times.	Heta Rd - Adapted 100/50/25% acceptable for drivers and peds, Tukapa St 100/50% acceptable but 25% level not acceptable	Visual comfort and Safety for pedestrians and cyclists
General Comment	A very succesful project that delivered visual comfort and significant energy reductions. Balancing resident street frontage spill light was an issue with conflicting resident desires, but a good balanace has been achieved.	An excellent demonstration project of urban dimming/brightening scenario for high context pedestrian crowd control comfort and safety.	Trial was not entirely suceesful from an optimised lighting design viewpoint. Post trial fine tuning to luminaire mount angle still required to balance the important issue of cross site footpath light levels.	Very successful project with several industry journal articles. IESANZ Dark Skys Award. Excellent spill light mitigation on adjacent propety boundaries. Excellent four year realiability record

Table 5 The best New Zealand LED Street Lighting Trials (Source: SLP 2014)

9 Conclusions and Recommendations

This report leads Strategic Lighting Partners Ltd to draw the following conclusions for Wellington City Council.

9.1 Move quickly

Although SLP have not been commissioned to quantify the cost of delay, the evidence presented in this report suggests that the cost of such delay is likely to be much greater than the relatively minor benefits available from delaying (including reducing equipment costs).

In marked contrast to usual prudent practice, neither WCC nor any local government body in charge of street lighting should rely on the relevant Standard - AS/NZS 1158 - for determining lighting technical parameters as it does not represent best practice and it will take a long time before it does. Instead it should use the "Better than Before" practice that Los Angeles applied, where litigation risk caused by any departure from standards is a much greater than it is in New Zealand.

The main advantages of LED street lighting over WCC's current lighting are:

i. Energy savings, with the potential for greater than 50% savings over HPS and metal halide;
ii. Long life, with high performance luminaires rated at greater than 80,000 hours operation until end-of-life (approximately 20 years). This is between three and five times longer than HPS lamps;
iii. Continuously dimmable down to very low levels with minimal internal efficacy losses;
iv. Instant on/off operation, without decreasing system life and in contrast to HPS that usually take a few minutes to ignite and ramp up to full output.;
v. Ability to integrate internet based Central Management Systems (CMS) that have been reported to increase systemic energy efficiency by up to an additional 20%;
vi. Directional light emission that, with appropriate optics, can deliver highly efficient lighting schemes and reduce "light spillage" and "light pollution";
vii. High colour rendition, generally over 70 CRI. This means that coloured road markings, signs, vehicles and people can be seen in contrast to the yellow HPS lights with CRIs of about 20 which makes discerning colours virtually impossible;
viii. Enhanced visibility and reduced driver reaction times due to its broader and more visually appropriate spectral distribution (white light);
ix. No toxic mercury content compared to current lamps;

The improvements in safety, potential reduction in crime and material savings in energy and maintenance costs alone provide an overwhelmingly compelling case to upgrade street lighting to LED and controls. SLP's view is that not doing so is arguably an abdication of local government's duty of care to its citizens.

9.2 Obtain all strategic benefits available

An upgrade to street lighting as contemplated in this report is a "strategic" investment in that it requires a "strategically" large investment. Because the energy and maintenance cost benefits from this investment are substantial, SLP suggests that other arguably more significant safety and security benefits will be overlooked and thus risk not being captured. SLP suggests that the probability of this risk and its impact are both high, although available mitigation is relatively easily accomplished.

Such risk mitigation actions includes:

i. monitoring lighting performance before, and then at regular intervals after, the upgrade on significant proportions of street-lit roads, and in all "hotspots" where crashes, crime and trouble occur to ensure that lighting: location, intensity, quality (including colour), and maintenance matches expectations over the life of this safety infrastructure. ;

ii. Gather, analyse and regularly update traffic, crash and crime statistics to correlate with lighting performance as measured above, **to actively manage** the reduction of nigh time crashes, fatalities, injuries, and crime;
iii. Utilise modern asset management practices, software and integrate them with CMS controls to maintain and replace assets when necessary;
iv. Collaborate with a world class research organisation experienced in this field (such as Virginia Tech Transportation Institute) to co-ordinate all the issues above.

In the words of Ed Ebrahimian, the director in charge of Los Angeles street lighting, direct report to the Los Angeles Mayor, and individual responsible for the world's largest LED upgrade, "when we began this 140,000 LED street light upgrade program four years ago we were taking real risks, but for anyone setting out today it's a no-brainer".

9.3 Use best-practice procurement

The development of LED luminaires and CMS lighting systems together represent a paradigm shift in street lighting. Although it provides a strategic opportunity to provide communities with benefits that have never before existed, there are significant risks facing any Council that upgrades to the latest technology. SLP strongly recommends that best practice procurement techniques be used including:

i. Best Value (BV) calculation using Life Cycle Costing (LCC);
ii. Strategic Tendering where greater planning effort is invested long before the tender is called;
iii. Aggressive use of long term product and service performance guarantees and warranties and acceptance of any extra up-front cost of these practices;
iv. Consultation with NZTA and close attention to its M30 guidance document when it is published;
v. Utilise international best practice procurement practices especially where they are applied to LED lighting;
vi. Utilise Financed Performance Contract methods;

9.4 Manage Risks

SLP strongly recommends that all the additional risks, where their probability and impact are significant as identified in Section 6 are fully appreciated by senior management and governance parts of Council. SLP's analysis suggests that the following eight risks have "high" or "medium" probabilities of occurring and "high or medium" impacts:

i. Missed strategic opportunity as identified above;
ii. Electricity Regulatory Barriers delay control system implementation;
iii. Technical specifications used for procurement that don't match the needs;
iv. Procurement process is not structured appropriately ;
v. Network line charges from Electricity Distribution Business could result in no financial saving despite 50% reduction in energy
vi. The equipment prices quoted by suppliers of controls are greater than expected;
vii. Pre & Post Condition Survey does not properly identify the condition of the assets;
viii. Unexpected delays are experienced caused by the procurement process.

10 Appendix 1 – Terms of Reference

10.1 Introduction (Changed from previous proposal)

This proposal has been requested by Deven Singh, Wellington City Council's Manager of Transport Assets, Roading Traffic and Transportation at a meeting called by Gareth Mappledoram General Manager of Downer ITS on 17th October 2013. Downer have recently regained the contract for Wellington City Council (WCC) maintenance of road and street lighting assets.

Changed from previous proposal:

A previous version of this proposal dated 5 November was submitted 7 November. A response from Deven Singh dated 22 November requested that SLP resubmit a revised proposal based on a reduced scope of consultancy project. The structure of this document reflects that request from WCC, with some recommended adaptations.

WCC have requested a reduced scope as identified below (referencing section numbers from the original SLP proposal):

1) LED Lighting technology (Section 6)
2) Procurement (Sections 8.2,8.3,8.4)
3) Risk (Section 10)
4) Life Cycle Cost Management and Total Cost of Ownership
5) Empirical evidence from case studies (inc controls and SMS systems)

Section 2.1 below suggests modifications to this above scope.

10.2 Business Case for WCC (No change to previous proposal)

SLP expects that a business case that analyses the conversion of existing WCC street lighting to LED lights would save more than $400,000 per year on electricity and about $250,000 per year on maintenance (at today's costs). These savings come with significant other benefits of increased safety, amenity, reduced pollution and carbon footprint. Naturally these figures are based on substantial assumptions including a 50:50 split in the electricity charges between the energy and the network charge. (In fact we understand that the split between network and energy is significantly different from this.)

The investment by WCC and NZTA to make this return will be significant – of the order of $17 million so that a comprehensive business case is required. SLP recommends that a report with the issues in the next section are addressed, showing indicative page lengths, diagrams and tables.

10.3 Modified Report Content (New)

The SLP project report would cover the following areas -

1) **Contents**
2) **Introduction**
3) **Executive Summary**
4) **LED Street Lighting Technology**
    - 4.1) Introduction
    - 4.2) Benefits - Disruptive technology
    - 4.3) Energy
    - 4.4) Maintenance
    - 4.5) Safety
    - 4.6) Control
    - 4.7) Community comfort
    - 4.8) International experience
    - 4.9) Conclusion
5) **Procurement Practices**
    - 5.1) Introduction

5.2) Items to be procured
5.3) International precedents
5.4) Equipment pricing
5.5) Standards compliance
5.6) NZ practice and guidelines
5.7) Warranties, performance guarantees, performance insurance
5.8) Conclusion

Items above in italics were the only items in this section requested by WCC. SLP believes that items 5.5, Standards Compliance, 5.6, NZ practice and guidelines, 5.7, Warranties, performance guarantees, performance insurance, are also essential to the coherent use of smart procurement tools and processes and the prudent management of public procurement in an application sector experiencing disruptive change.

There are some excellent references from EU and USA on practical LED lighting GPP (Green Public Procurement) tools that can be adapted for NZ use.

Additionally, item 5.6 NZ practice and guidelines, would cover the NZTA Procurement Manual 2009 requirements for Life Cycle Costing, environmental assessment and the incorporation of innovative methods.

We have included these items in the lump sum fee proposal at no additional cost, but are happy to remove them if they are not required.

5) **Risks**
   5.1) Introduction
   5.2) Capabilities
   5.3) Financial
   5.4) Procurement
   5.5) Stakeholder
   5.6) Implementation and indemnification
   5.7) Conclusion
6) **Life Cycle Cost Management and Total Cost of Ownership**
   6.1) LCC/TCO systemic process structure and ISO standardised methods
   6.2) LED/CMS systemic cost inclusions and externalities
   6.3) LED/CMS internationally available equipment pricing
   6.4) Holistic cost calculation methodologies and relevant NZ approaches
   6.5) Road lighting investment analysis metrics and methods
   6.6) Using LCC/TCO for standardised, quantitative and transparent decisionmaking
7) **Empirical Evidence from LED/CMS Case Studies**
   7.1) Overview of NZ LED/CMS trials Case Study experience and outcomes
   7.2) Overview of International LED/CMS rollout Case Study experience and outcomes
   7.3) Review of energy outcomes
   7.4) Review of maintenance outcomes
   7.5) Review of pedestrian and road safety
   7.6) Review of financial outcomes
8) **Conclusion**
9) **Appendix 1 - Terms of Reference**
10) **Appendices XX - As required**

Naturally the format of the above report will require change to accommodate the special requirements of WCC which are not yet known.

11 Appendix 2 – AS/NZS 1158 references

The references below are identified in Part 2 of the Standard:

A2 RELATED DOCUMENTS

Attention is drawn to the following related documents:

1 BARTON, E.V. and FREEMAN, K.D. (1988), Frangible lighting poles: design, testing and use in Victoria, Proceedings of 14th ARRB Conference, Vol. 14 No. 5, Australian Road Research Board.

2 BURRAGE, S. (1993), Managing street lighting maintenance, Lighting, Vol. 13, No. 3, pp.85-87.

3 CIE Publication No. 66 (1984), Road surfaces and lighting, International Commission on Illumination.

4 CIE Publication No. 93 (1992), Road lighting as an accident countermeasure, International Commission on Illumination.

5 CIE Publication No. 115 (2009), Recommendations for the lighting of roads for motor traffic and pedestrian traffic, International Commission on Illumination.

6 DE BOER, J.B. (ed) (1976), Public lighting, Phillips Technical Library, N.V. Phillips, Gloielampenfabrieken, Eindhoven, The Netherlands.

7 FGL Publication 3, Good lighting for safety on roads, paths and squares, Fordergemeinschaft Glutes Licht.

8 FISHER, A.J. (1968), Visibility of objects against dark backgrounds with road lighting Proceedings of 4th ARRB Conference, Australian Road Research Board.

9 FISHER, A.J. (1989), Road lighting as an Accident Counter-Measure, Proc. 35 IES ANZ National Convention Auckland 1989.

10 FOX, J.C., GOOD M.C. and JOUBERT, P.N., (1979) Report No. CRI Collisions with utility poles, Office of Road Safety, Australian Department of Transport.

11 HALL, R.R. (ed) (1980), The design and implementation of fixed lighting for arterial roads and freeways, Australian Road Research Board.

12 JACKETT, M.J. (1996), Accident savings from road lighting in New Zealand, Proceedings of Roads '96 Conference, Christchurch, New Zealand.

13 LAY, M.G. (1986), Handbook on road technology, Volume 2 Traffic Transport, Gordon and Breach.

14 NCHRP (1969), Report 77, Development of design criteria for safer luminaire supports, Highway Research Board.

15 OGDEN, K.W. and BENNETT, D.W. (eds) (1984), Traffic engineering practice (Third Edition), Department of Civil Engineering, Monash University. 202.14.373.0179831

16 PEARCE, R.A. and ARNDT, O.K. (1992), Location of street lighting equipment at roundabouts, Lighting in Australia. Vol. 12, No. 4, pp.114-118.

17 NAASRA, Guide to traffic engineering practice (1988), National Association of Australian State Road Authorities.

18 TRB Report 152 (1974), Warrants for roadway lighting, Transportation Research Board, U.S.A.

19 SCOTT, P.P. (1980), The relationship between lighting quality and accident frequency, TRRL Report 929, Transport and Road Research Laboratory, U.K.

20 TURNER, H. (1962), The influence of road lighting on traffic safety and service, Proc. ARRB Conf., 1 (1), p. 596.

21 TURNER, H. (1972), The effectiveness of the New South Wales lighting subsidy scheme, National Road Safety Symposium, Department of Transport, Canberra.

22 VAN BOMMEL, W.J.M. and DE BOER, J.B. (1980), Road lighting, Macmillan Press Ltd, London.

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TABLE 2.1

LIGHTING CATEGORIES FOR ROAD RESERVES IN LOCAL AREAS

1	2	3	4	5	6
Type of road or pathway		**Selection criteria[a,b)]**			**Applicable lighting subcategory[c,d)]**
General description	**Basic operating characteristics**	**Pedestrian/ cycle activity**	**Risk[f)] of crime**	**Need to enhance prestige**	
Collector roads or non-arterial roads which collect and distribute traffic in an area, as well as serving abutting properties	Mixed vehicle and pedestrian traffic	N/A	High	N/A	P1
		High	Medium	High	P2
		Medium	Low	Medium	P3
		Low	Low	N/A	P4
Local roads or streets used primarily for access to abutting properties, including residential properties	Mixed vehicle and pedestrian traffic	N/A	High	N/A	P1
		High	Medium	High	P2
		Medium	Medium	Medium	P3
		Low	Low	N/A	P4
		Low	Low	N/A	P5[e)]
Common area, forecourts of cluster housing	Mixed vehicle and pedestrian traffic	N/A	High	N/A	P1
		High	Medium	High	P2
		Medium	Low	Medium	P3
		Low	Low	N/A	P4

Table 6 Lighting categories taken from Part 3 of AS/NZS 1158

12 Appendix 3 – Consultant’s credentials

Strategic Lighting Partners Ltd is a specialised management consultancy focused on the effective application and performance of new generation road lighting.

Our span of competence embraces the fields of technology, economics, energy, environment, safety, marketing and communications. We act as strategic advisors integrating these wide ranging activity streams into coherent and investable business cases for lighting infrastructure asset owners and operators.

12.1 Capabilities

Our expertise in road lighting covers the following areas -

- Infrastructure governance for the public and private sectors
- Economic analysis and investment return
- Risk analysis and management
- Lighting infrastructure asset management
- LED lighting technology benefits and costs
- Adaptive lighting and Central Management Systems (CMS)
- Energy efficiency and holistic energy performance
- Environmental impact assessment and quantification
- Performance based procurement contracts
- Lighting Standards - AS/NZS and International
- LED performance warranties
- Economic analysis and financial modelling
- Lighting product life cycle assessment and waste management
- Stakeholder research, analysis, and management
- Social research and human impact studies
- Marketing, Public Relations, communications, technical journalism and media relations.

12.2 Godfrey Bridger MIEEE, ME(Elect), MBA(Exec) – Managing Director

Godfrey is an experienced CEO and senior manager with over ten years management consultancy experience. His LinkedIn profile is available at ***http://www.linkedin.com/in/godfreybridger***.

Godfrey was commissioned by the NZ Transport Agency to write a report in 2012 called “Strategic Road Lighting Opportunities for New Zealand” with Bryan’s assistance. Subsequently he and Bryan formed Strategic Lighting Partners Ltd which has completed several business cases for Local Authority street lighting upgrades. Together with his fellow SLP principals Godfrey established Australasia’s inaugural Road Lighting 2014 conference in March 2014.

Godfrey is a former CEO of the Energy Efficiency and Conservation Authority (EECA), and was a board member of Mercury Energy when it was the largest electricity distribution company (DNSP) in NZ. He has management and business development experience in both the electricity and Crown Research sectors. Godfrey also spent more than seven years running a marketing and PR consultancy Bridger Beavis & Associates Ltd working for clients in the local government, utilities and energy sectors.

12.3 Bryan King MIES, DipBIA, NZCE, MBA - Director

Bryan King is a highly experienced practitioner and recognised authority on road lighting practices worldwide. His LinkedIn profile is available at ***http://www.linkedin.com/pub/bryan-king/13/278/250.*** Bryan has a 30 year history of leadership and governance positions in lighting manufacture and consultancy businesses for the professional and local government lighting sectors.

He is a member of the LG-002 AS/NZS1158 Road Lighting committee, Convener of the AS/NZS1158 Lighting Controls Working Group and member of EL-41 (AS/NZS 60598) Lamps and Luminaires committee.

Bryan was the founding Chair and is now the Executive Director of Lighting Council NZ. He is a former board member of the Illuminating Engineering Society of Australia and NZ (IESANZ) and board member of the Energy Management Association of NZ. He is also Board Chair of the Australasian Environmental Product Declaration Programme Ltd and the NZ Convener of the International Electrotechnical Commission (IEC) Standards NZ National Committee "TC34-Lamps and Luminaires".

Bryan was a co-author of the EECA "Rightlight" Road Lighting webtool and a presenter of the EECA NZ RightLight national workshops on Road Lighting.

Bryan has presented many conference papers in NZ and internationally including the PLDA Professional Lighting Design Convention in Madrid Spain, the IFC World Bank Off-Grid LED Lighting Conference in Dakar Senegal and the Road Lighting 2014 Conference Auckland NZ. Bryan is currently completing a Master of Technology degree (Energy Management) at Massey University with research program on road lighting energy performance.

12.4 Crystal Beavis MA Hons, APR, PGCert Mgt – Director

Crystal is an award winning public relations consultant with more than 25 years' experience in strategic communications, advertising and journalism in New Zealand and the UK. Crystal has worked or consulted for organisations operating across a range of technical and industrial sectors including education and research, health, electrical utilities and financial services, and is a board member of the Waikato District Health Board. She won a Public Relations Institute of NZ award for the inaugural Australasian conference "Road Lighting 2014: Innovation, Efficiency, Safety" organised by SLP.

12.5 Contact details

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