A STUDY OF VARIOUS PUBLIC LIGHTING MAINTENANCE PRACTICES AND THE DEVELOPMENT OF A LOCALLY APPLICABLE MAINTENANCE MODEL IN LINE WITH INTERNATIONAL TRENDS

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Abstract

Public lighting is seen as a non-core function by many municipalities and therefore does not always receive the necessary management attention. As a result the provision of public lighting maintenance differs substantially between Local Authorities; in some instances public lighting is in a state of disrepair and in other instances the service delivery is excellent.

One of the major problems identified is the lack of information with regard to the number and types of fittings installed and also the number of failures that occur. As a consequence many municipalities cannot provide accurate costs to enable comparison with other Local Authorities. There is also a general lack of consensus as to what constitutes appropriate service delivery in terms of system availability and failure response times. This results in large differences in terms of costs, which range from R11.50 to R26.60 per fitting per month and system availability, which ranges from less than 70% to better than 99%.

To establish appropriate service levels responses were obtained from the general public and two groups more directly involved with streetlight maintenance namely, public officials and street lighting experts. This data together with the evaluation of historical data collected over the last 16 months on the Benoni network allows the formulation of appropriate cycle times in order to achieve the expected service delivery in terms of system availability and response times.

A holistic literature survey is presented covering the major aspects which impact on service delivery such as the restructuring of the electricity distribution industry and local authority transformation. The aspects of energy efficiency and equipment life expectancy are covered in detail and recommendations are made as to the appropriate replacement cycles. The different lamp replacement policies are also discussed and cost comparisons made.

Recommendations made are that a system availability of 98% is both acceptable and achievable with a moderate budget. Response times of less than 24 hours would be ideal but this does not optimise the utilisation of resources, budget constraints may dictate a longer response time. Response times of more than 5 days would generally be unacceptable. Optimal fitting replacement age is between 19 and 23 years. Under normal circumstances the introduction of energy efficient luminaires is the most cost effective when inefficient fittings have reached their optimal replacement age. Changes in energy costs, tax concessions or cost subsidisation will however impact on the appropriate replacement strategy.

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1 Introduction

The provision of public lighting maintenance differs substantially between Local Authorities; in some instances public lighting is in a state of disrepair with as many as 30% of the fittings out of service; in other instances the service delivery is excellent with less than 1% of the fittings being out.

A major reason cited for this is that public lighting has been identified as a non-core function in many Local Authorities. As a result it has suffered under the transformation process in Local Authorities, in that it has received very little management attention. Not only are the Local Authorities (LA's) undergoing change but also the electricity distribution industry is being restructured, this has brought about major uncertainty to the industry and for a long time the 'fate' of street lighting was uncertain. It now appears to be more certain that street lighting will remain with the LA's, while the rest of the Electricity departments will be incorporated into the Regional Electricity Distributors (RED's), this will leave the LA's with no in house means to maintain their lighting networks.

Public lighting is however a social responsibility and globally it is recognised to significantly reduce vehicle accidents and also to play an important role in the reduction of crime and vandalism. Although public lighting is seen as a non-core function by many municipalities with proper management it can be provided for inexpensively and efficiently.

1.1 Problem Statement

There is a basic lack of information with regards to current levels of service, the number and type of different light fittings and material usage. Very few municipalities know how many faults are attended on a daily basis let alone how quickly complaints from the public were handled. Very few LA's have even a basic management system in place for the maintenance of public lighting. Budgeting is problematic in these situations where no facts or figures are available to substantiate staff, equipment and stock levels. No accurate benchmarking can be accomplished without this information with the result that many LA's budgets for streetlight maintenance are inappropriate.

Skills levels of maintenance staff are poor resulting in ineffective work being carried out and many tasks need to be repeated before the problem is resolved.

Public opinion which is important in establishing acceptable levels of service is in most cases not considered when planning streetlight maintenance policies.

In South Africa the majority of fittings installed utilise Mercury Vapour technology, which is not only inefficient but can easily lead to Mercury contamination if incorrectly disposed of. As South Africa is a willing participant in the field of sustainable resource utilisation, Local Authorities will be forced to review their existing policies on the use of inefficient street lighting technology.

1.2 Background information

Due to its non-core status and the moratorium on new employees, public lighting maintenance staff have been drawn into vacant positions in core areas such as network maintenance, leaving most public lighting maintenance divisions operating on a skeleton staff, this results in poor service delivery and long delays are experienced in the rectification of faults. This has further been exacerbated by the failure of most Local Authorities to finalise their organisational structures and officially appoint staff into the new structures. It is now nearly four years since the December 2000 municipal elections, and in some organisations many senior positions are still defined as 'acting'. Failure to finalise staff appointments has had very demoralising effect and has adversely affected service delivery in all sectors.

In Principal, three methods (or a combination thereof) are being utilised by Local Authorities to maintain public lighting.

- Internal resources are used
- The maintenance is outsourced to contractors, but management and quality control is still performed by the Local Authority
- The maintenance is outsourced to contractors with an independent external management structure controlling the maintenance programme

These different methods have various levels of efficiency with vastly different cost structures.

A major problem facing many authorities is the lack of information regarding the number and type of luminaires installed, without this crucial information it is very difficult to find a suitable basis on which to compare the costs of the different methods employed. This also impacts on maintenance planning and the provision of optimum levels of stock.

Added to this, Government is committed to the restructuring of the electricity distribution industry. This will be accomplished by the formation of six Regional Electricity Distributors (Red's). To achieve this Eskom's distribution division is to be divided into six regions and combined with the Electricity Departments of all the Local Authorities (municipalities) within these regions. This effectively means that all the electrical staff and infrastructure would no longer be part of the Local Authorities, and LA's will be left with no in-house means of maintaining the public lighting network.

A number of publications are available on the establishment of the Regional Electricity Distributors, which has received a fair amount of public exposure. The available literature includes the Price Waterhouse Coopers investigation on the restructuring of the electricity supply industry. This study was conducted in response to a call for proposals by the Department of Mines and Energy (DME) in 1998. This study has resulted in the issue of a white paper by the Government and the putting into place the interim structures to oversee the transformation.

A number of setbacks have delayed the implementation of the white paper. The majority of these obstacles have now been overcome and real progress is now being made towards the establishment of the RED's. The original programme to have the RED's in place in 2001/2002 has however been significantly revised to 2009. The amalgamation of over 300 electricity departments and Eskom's distribution division into the proposed six Regional Distributors is however a huge task and requires the commitment of several resources from already understaffed electricity departments.

Various other articles on the Red's have been published in journals such as the, Elektron (the official magazine of the SA institute of Electrical Engineers, SAIEE) and the AMEU news (the quarterly newsletter of the Association of Municipal Electrical Undertakings), Very little literature is available however on the issue of Public Lighting in the framework of the RED's.

There are few local publications on public lighting maintenance these are however mostly by individuals or companies operating in the facilities management environment and can be seen as 'sales pitches' by these companies and are often intentionally misleading or inappropriate. Typically cost savings benefits are overstated, particularly when it comes to energy savings and bulk replacement of lamps.

There are numerous National (SABS or NRS) and International (CIE and ISO) specifications with regard to public lighting, these revolve mostly around lighting design, equipment and material standards and recommended lighting levels.

It is widely accepted that as the output of many lamps diminish drastically with time (by more than 30%), maintenance should not merely focus on defective fittings but also on keeping acceptable lighting levels. The International Commission on Illumination (CIE) publication no 33-1977, titled, "Depreciation of Installations and their Maintenance" deals with this topic but does not focus on effective maintenance practices.

There are also a number of companies and institutes such as the IIEC (International Institute for Energy Conservation), the EELA (Energy Efficient Lighting Association) and in South Africa, BONESA (an Eskom initiative) which have been established to promote the use of efficient lighting sources to reduce greenhouse and other harmful gas emissions which are by-products of electricity generation. These however focus mainly on residential, industrial and office lighting, with no guidelines for cash-strapped Local Authorities on how to move towards energy efficient public lighting installations in a sustainable and financially viable manner.

In a number of countries such as the United Kingdom tax incentives are provided to companies to promote the transition to more efficient light sources. In SA Eskom is making some funding available for implementation of energy saving installations through its demand side management programme, however the focus is on projects that can shift load from peak consumption periods. Public lighting although not insignificant, accounts for less than 2% of the countries power consumption and therefore has not been regarded as a priority target by Eskom's DSM division.

Extensive disagreement around the financial viability of replacing Mercury Vapour (MV) fittings with more efficient High Pressure Sodium (HPS) fittings exists in the industry, this issue will be explored in detail in the study.

Further research into secondary sources conducted as part of this study is targeted at the host of available information on the expected operating life of lamps and fittings, this will aid in the analysis of the cost effectiveness of planned maintenance (bulk replacement policy) versus fault repair (breakdown or Burn-to-Extinction policy). Evaluation of secondary data will also establish whether a capital replacement strategy will be more cost effective in the long run than maintaining older and obsolete technology.

1.3 Research Objectives

The objectives of this study are:

a) To evaluate the current levels of service in the major metropolitan areas in Gauteng.
b) To determine what levels of service will be acceptable to the public, and whether these levels can be practically achieved at reasonable cost.
c) To determine what different methods are currently being utilised by the Local Authorities to maintain public lighting and to evaluate the different methods in terms of service delivery and cost efficiency.
d) To evaluate current international trends in streetlight maintenance and to discuss the applicability of issues such as energy efficiency, global warming and hazardous materials in the South African context.

e) Provide recommendations on how to achieve the service levels required through the use of historical data. These recommendations will include replacement cycles for lamps and equipment based on historical data and the use appropriate financial evaluation techniques.

1.4 Importance and benefits of the Study

The benefits of a sustainable maintenance programme for street lighting can be divided into three categories, namely: - Intangible, cost effectiveness and environmental.

1.4.1 Intangible benefits

Preliminary investigations have shown that the maintenance of public lighting is receiving less and less attention, this has led to an increasing number of irate phone calls to senior officials of Local Authorities about poor service. As public lighting is such a noticeable area of municipal services, better service delivery, will relieve the administrative burden of senior officials and allow them to concentrate on core functions, in some instances as much as 30% of phone calls to top level management concern street lighting issues. An Effective maintenance strategy can reduce these complaints by more than 65%.

Research has shown that crime and vandalism levels are reduced with the introduction of public lighting. Improved lighting has also been shown to be instrumental in the social upliftment of communities through perceived improvement of their living conditions. Improved service delivery will therefore impact directly on the general community.

1.4.2 Cost Benefits

An effective maintenance programme will reduce the overall costs of maintenance and enable the better utilisation of resources.

Where energy efficient fittings are used to replace obsolete technology operating costs will be reduced.

1.4.3 Environmental Benefits

The use of energy efficient fittings will also reduce the emission of greenhouse gases and the consumption of natural resources. This issue was high on the agenda at the recent World Summit on Sustainable Development.

Not only will the reduction of greenhouse gases can also bring about improved environmental conditions, there are also financial benefits to LA's through the sale of Carbon Credits. These benefits are difficult to quantify in rand terms as the necessary markets for the sale of Carbon Credits must still come into full operation, these are however expected to come online during 2005.

A large percentage of lamps installed contain Mercury vapour (MV), which can contaminate the environment when incorrectly disposed of, these lamps are also inefficient when compared to other light sources. A sustainable programme of replacement of MV fittings will assist both in the reduction of Mercury contamination and green house gas emissions.

1.5 Research Methodology

Due to time and cost constraints the primary population for this study is the three major metropolitan municipalities in Gauteng (Ekurhuleni, Tshwane and Johannesburg). The study will focus in particular on the Ekurhuleni area as this area is made up of nine former cities and towns each still operating largely independently and utilising a variety of maintenance strategies. Information from the other areas has however been included where available.

Only areas with more than 5000 fittings, which have dedicated public lighting maintenance structures, were considered, as areas smaller than this are most likely to have mixed maintenance teams.

The study is a formal, *ex post facto,* cross-sectional study using both monitoring and interrogation/ communication methods for data collection as discussed below. The purpose of the study is mainly causal with descriptive elements and the environment is a field setting. Due to the scarcity of primary data a single source has been utilised, namely that of Benoni, the study can therefore be likened to a case study.

1.5.1 Samples and Sample Technique

Different samples and techniques are required to meet the objectives of the study. Secondary data sources have been used mainly to gather technical information such as lamp life and lamp efficacy, which will be used to establish optimum replacement cycles in conjunction with 'practical' service levels, determined from primary data collected.

A valuable source of primary data came from the database of a management company responsible for the maintenance of the public lighting in greater Benoni. This company has kept a detailed database of the number of different types of faults attended to with the associated costs over the last 16 months. This information will be extracted and compared to published information from manufacturers to try and quantify the difference between laboratory generated and practical results.

1.5.2 Current and Expected levels of service delivery

A dual approach was followed to gauge the actual service levels and to compare these with public perception. This was achieved by means of a physical audit of the areas and various questionnaires. Three questionnaires were formulated one was issued to the general public, one to industry experts and one to council officials.

1.5.2.1 Physical Audit

Due to the physical size of the areas involved routes were selected which would traverse a number of different areas within the local authority. Route selections included city centres, low-income residential areas, high-income residential, industrial areas and major access routes. As the population along these routes was not known the actual sample size (number of Luminaires) could not be determined with any accuracy prior to the actual physical audit.

The purpose of the physical audit was not to determine the levels of service with any statistical accuracy but rather to gain a general impression of what the quality of maintenance was in the different regions surveyed.

The physical survey produced ordinal data in the form of fitting 'on' or 'off' and some qualitative information such as lighting levels and general appearance to allow for categorisation of the areas.

1.5.2.2 Questionnaires

Different levels of information were gathered from the public, lighting experts and officials involved with public lighting.

a) Public Survey A convenience sample was chosen for cost and time reasons. An original sample size of 100 was chosen with an assumed response of 50% to provide 50 returned questionnaires. The method of distribution was mostly electronic (e-mail) but a number were personally distributed to colleagues and their friends and family. There are obvious statistical weaknesses in this approach, not least the representativeness of the sample but these were deemed to non-critical as stringent statistical evaluation is not required to meet the objectives of this study.

b) Expert Survey There are a limited number of streetlight maintenance experts in South Africa 29 questionnaires were sent electronically or by fax to the major lamp and luminaire manufacturers as well as to people who's names were obtained from the various lighting institutions (ILESA, SANCI and SALA). To supplement these questionnaires some relevant questions were posted on international websites, which had a technical lighting forum (Philips, ILE). The intention was to obtain expert opinion on the aspects posed to the general public so that a comparison could be made between the responses.

c) Public Official Survey Here again the population is limited to very specific individuals, in depth information was required on street lighting maintenance including maintenance budgets and this required access to the right person. The questionnaire also included questions with regard to actual service delivery and whether they thought the service they were providing was sufficient. The questionnaire was sent to 15 Local Authorities predominantly in Gauteng but included Nelson Mandela Metro and Buffalo City.

Informal discussions were also held with senior management of Ekurhuleni and Tshwane Metros in order to supplement the information received.

1.6 Data Analysis

Data analysis is mostly qualitative. Evaluation of service levels with the type of maintenance is done using visual techniques such as a bar-charts and tables. A scattergram of *service level* [%fittings out]) *vs. cost* will highlight the cost effectiveness of the various regions.

A number of hypotheses are tested using predominantly the Chi-square test. With level of significance of 95% ($\alpha = 0.05$).

Financial evaluation of the different maintenance policies is done through the use of project evaluation techniques such as Net Present Value (NPV) and Annual Equivalent Annuity (AEA).

1.7 Qualifications of Researcher

The researcher is a qualified electrical engineer with over 15 years practical experience, a substantial portion of which being in a management role. He is a registered professional engineer whose company is a member of the South African Association of Consulting Engineers (SAACE). In his capacity as director he has consulted on numerous public lighting issues ranging from appropriate technology to optimum design levels and equipment specifications.

2 Background Information and Literature Review

2.1 Introduction

This research dissertation covers a number of different aspects ranging from technical lighting aspects and maintenance practices to financial issues and evaluation of these practices.

For completeness this chapter presents the major aspects that influence street lighting and the maintenance thereof in South Africa. New literature is presented to support/dispute existing practices where available. Technical terms are presented in lay-mans terms to aid the comprehension of non-technical readers.

The effectiveness of public lighting maintenance is primarily dependant on the technology utilised and the application of business management principles. However as public lighting is a 'social' infrastructure, provided by local government, it is often the broader political and economic conditions that dictate the resources that are made available for provision and maintenance thereof. The information presented in this section is therefore very broad in nature in an effort to provide a full overview of the industry.

2.2 The Benefits of Good Street and Area lighting

The SABS Recommended Practice ARP 035:2002, Guidelines for the installation of maintenance of street lighting, opens with the following statement;

> "Because of the ever-increasing density of traffic on our roads and the resultant rise in traffic hazards, the lighting of our streets plays a vital role in road safety. It promotes better traffic flow, it improves the appearance of city centres and residential areas and it is a major deterrent to crime and vandalism."

2.2.1 Accident prevention

> "Statistics obtained from extensive research overseas over the period 1970 to 1990 show that road accidents at night are disproportionately high in number and severity compared with road accidents during daylight............... According to research, if street lighting to national standards (i.e. SABS 098) is

installed, the following benefits can be expected for urban areas:

- Fatal accidents reduced by : 48%
- Casualty accidents reduced by : 34%
- All accidents reduced by : 43%
- Pedestrian accidents reduced by : 42%

………… Because of the ever-increasing costs of accidents, the reductions that can be achieved by the installation of correctly designed lighting are of immense benefit throughout the country." [i] (SABS ARP 035:2002)

A recent article in the Benoni City Times 25th September 2003 reads as follows.

" Recently yet another fatal accident, this time a head on collision on Main Reef Road leaving three dead on the scene and a fourth three days later, highlighted the dangers of the roads between Benoni and Brakpan. 'I travel the road between Benoni and Brakpan every day and on the last count there were 15 streetlights either hit by cars or totally damaged and removed'…………… Poor and in many cases absent street lighting combined with the absence of road marking and dangerous curves are commonplace on the stretches of road combining the two towns."

This article highlights the importance of street lighting and also the proper maintenance thereof. In this case there are streetlights but those that have been damaged have not been repaired.

2.2.2 Crime and Vandalism

Much research has been done on the benefits of street lighting in combating crime and vandalism and there is a substantial amount of information available on the subject. Some extracts from more recent publications are presented here.

" Street lighting is generally accepted as a major deterrent to crime and vandalism. It also creates a feeling of security among the public…………… Unfortunately there are no accurate statistics available in South Africa to determine the exact effect that lighting has on crime reduction, but overseas research shows that it has a very significant effect………… Generally the following effects were noted:

- Burglary of dwellings and outside theft decreased by 29%

- Vandalism, bike theft and vehicle crime decreased by 27%
- Street robbery, bag snatching, physical and sexual assault decreased by 61%
- Threats, insults and women sexually pestered decreased by 37%" [i] (SABS ARP 035:2002).

British Home Office Research Study 251- Effects of improved street lighting on crime is summarised as follows:

> "Eight American evaluation studies met the criteria for inclusion in the review………… Their results were mixed. Four studies found that improved street lighting was effective in reducing crime, while the other four found that it was not effective. A meta-analysis found that the eight studies, taken together, showed that improved street lighting reduced crime by 7 per cent. Why the studies produced different results was not obvious, although there was a tendency for "effective" studies to measure both day-time and night-time crimes and for "ineffective" studies to measure only night-time crimes. However, all except one of these American evaluations date from the 1970s. Five more recent British evaluation studies met the criteria for inclusion in the review. Key features of these studies …….showed that improved lighting led to decreases in crime. A meta-analysis found that these five studies showed that improved lighting reduced crime by 30 per cent. The weighted effect size in all thirteen studies was substantial: a 20 per cent decrease in experimental areas compared with control areas. Furthermore, in two studies, the financial savings from reduced crimes greatly exceeded the financial costs of the improved lighting. Since these studies did not find that night-time crimes decreased more than day-time crimes, a theory of street lighting focusing on its role in increasing community pride and informal social control may be more plausible than a theory focusing on increased surveillance and increased deterrence. The results did not contradict the theory that improved lighting was most effective in reducing crime in stable homogeneous communities. (Home Office Research Study 251; Effects of improved street lighting on crime: a systematic review, David P. Farrington and Brandon C. Welsh Home Office Research, Development and Statistics Directorate August 2002)[ii]

The following is an extract from the British Lighting Industries Federation's annual report for 2002:

> "The new Department for Transport recognises that lighting plays a very important role in preventing and deterring crime. John Spellar MP, speaking at the ASLEC luncheon in October, stated that 'improved street lighting unquestionably plays an important role in making our local highways safer. Safer in terms of traffic usage and equally importantly, all the evidence suggests, safer through a reduction in street crime'. This has led to allocations of funding for replacement street lighting, through the PFI credit system. The effects of lighting on crime and the fear of crime are intrinsic to the Public Lighting Campaign being run by LIF's Public Lighting Section into 2003. Up to 85% of local authority crime prevention budgets are spent on CCTV under the endorsement of government - it has become apparent that changes are needed on both a local and national level to see that lighting is appreciated for all its facets." (Lighting Industries Federation: Annual Report 2002)[iii]

The following is an extract from an article on the Institute of Lighting Engineers UK website – Better Street lighting Reduces Crime.

> "Commenting on Research Studies published by the Home Office on the crime prevention effects of CCTV and lighting, the Institution of Lighting Engineers (ILE) has long argued that better lighting reduces crime.
>
> The ILE believes that street lighting alone cannot solve the problems - but that it is a vital tool in the Government's drive to tackle crime and should be used in conjunction with other measures. This partnership approach should include CCTV, policing, neighbourhood watch schemes and other anti-crime initiatives.
>
> The Home Office studies add impetus to the ILE argument that more funding for new and better street lighting is vital and will benefit UK citizens not only by providing them with safer lighting and better road safety but will also reduce crime.
>
> Whilst recent crime reduction initiatives have focussed on CCTV, the ILE believes that greater investment in street lighting is imperative. This will enable the partnership approach to successfully

address crime while simultaneously providing all the other benefits that good lighting brings to our streets. These include less road traffic accidents and an improved night time environment where the public enjoy the 'feel safe - feel good factor' leading to our economy benefiting from increased night time activity.

An ILE spokesperson said 'These reports show that now, more than ever, funding for street lighting should be prioritised. Street lighting is key to preventing crime. Whether it be by itself or in conjunction with CCTV and other measures, street lighting is the one ingredient we can't afford to ignore.' (http://www.ile.org.uk -Institute of Lighting Engineers UK - Better Street lighting Reduces Crime)[iv]

What is apparent in some recent articles is the effect due to the colour of the lighting and not only the 'quantity' of lighting. (The most energy efficient lighting technology i.e. low-pressure sodium lamps produce a very orange light which affects the way in which colours are perceived by the human eye. A tremendous amount of research is currently being conducted in the area of energy efficiency together with the improvement of colour output.)

"A new study by Urbis lighting shows that the perceived risk of crime can be reduced through the introduction of white light … And an overwhelming 100% of respondents preferred the whiter light to the orange light. ….. When asked if the new street lighting made it easier or harder to recognize facial features 70% thought it was easier and made pedestrians feel more comfortable when out at night………"(Philips Lighting - Lamps & Gear Magazine - White light Reduces Fears)[v]

The latest research contained in an article by Ken Pease OBE, Professor of Criminology, Huddersfield University entitled Lighting and Crime, August 1998[vi] shows that improved street lighting leads to the reduction of daylight crime as well as at night.

"Street lighting improvements, where successful, are associated with crime reductions in daytime as well as during the hours of darkness. This result is of fundamental importance. It means that the effects of lighting work through something more general than improvement in the surveillability of potential offenders at night. The most plausible reasons for this pattern concerns changes in street use, enhanced community pride and sense of area ownership. Re-analysis of data from these studies suggests that lighting effects are greater in chronically victimised areas, which is of particular importance for integration of street lighting in other schemes devised under the provisions of the Crime and Disorder Act 1998;"

Unfortunately in South Africa street lighting itself is subject to vandalism and theft. The theft of cables and conductors, which is prevalent in South Africa, can leave entire areas without lighting. In many areas streetlight poles have been cut down and networks stripped leaving some areas unsafe to pass through at night.

2.2.3 Provision of lighting by Local Authorities

The SABS Recommended Practice ARP 035:2002 was drawn up by a committee that included representatives from the AMEU (The Association of Municipal Electricity Undertakings of Southern Africa which represents the electrical interests of over 300 Local Authorities in South Africa) SANCI (South African National Committee on Illumination and ILESA (Institute of Lighting Engineers of Southern Africa). This document represents the voice of the Local Authorities and professional lighting bodies in South Africa, the following extract details the stance of these stakeholders in street lighting.

> "Street lighting is also a major contributory factor to community character and vitality.
> .... Public street lighting is one of our most important and least expensive amenities and should be provided by all public authorities. They owe it to their ratepayers, business owners and all residents." [I] (SABS ARP 035:2002).

The question is! Why is street lighting generally in such a poor state, is it due to lack of funds and/or resources or is it being poorly managed due to its non- core status?

The problem does however not appear to be local to SA and is apparent in the UK as well. The UK government however appears to be taking action. The following text is taken from the ILE (Institute of Lighting Engineers - UK) website.

> "UK street lighting has been deteriorating for some time and the ILE continues to campaign for more funding. A survey commissioned by the ILE in 1998 revealed that almost 11% of all UK lighting columns were considered as dangerous and in need of urgent replacement. This equated to some 677,000 columns and would cost over£500 million to replace."

> "**MINISTER ANNOUNCES FUNDING BOOST TO MODERNISE ENGLANDS STREET LIGHTS-** The Government is making £300 million available in 2003-04 to help Local Authorities modernise their street lighting, with the promise of more money to follow, the Minister for Transport, John Spellar has announced. The Government estimates that across England there is a £1bn backlog in the maintenance of street lighting, a problem that it is determined to tackle. A survey by the Institution of Lighting Engineers estimated that 27% of street light columns were now over 30 years old." Left unchecked, that situation could lead to danger for all road users. Announcing the new funding, John Spellar said: Our £180 billion Ten Year Plan for Transport gives the commitment to eliminate the maintenance backlog in street lighting. The new funding that I have announced today will lead to a better and safer road network for everyone." (http://www.ile.org.uk - Minister announces funding boost to modernise England's Streetlights)[vii]

2.3 Street lighting Design Considerations

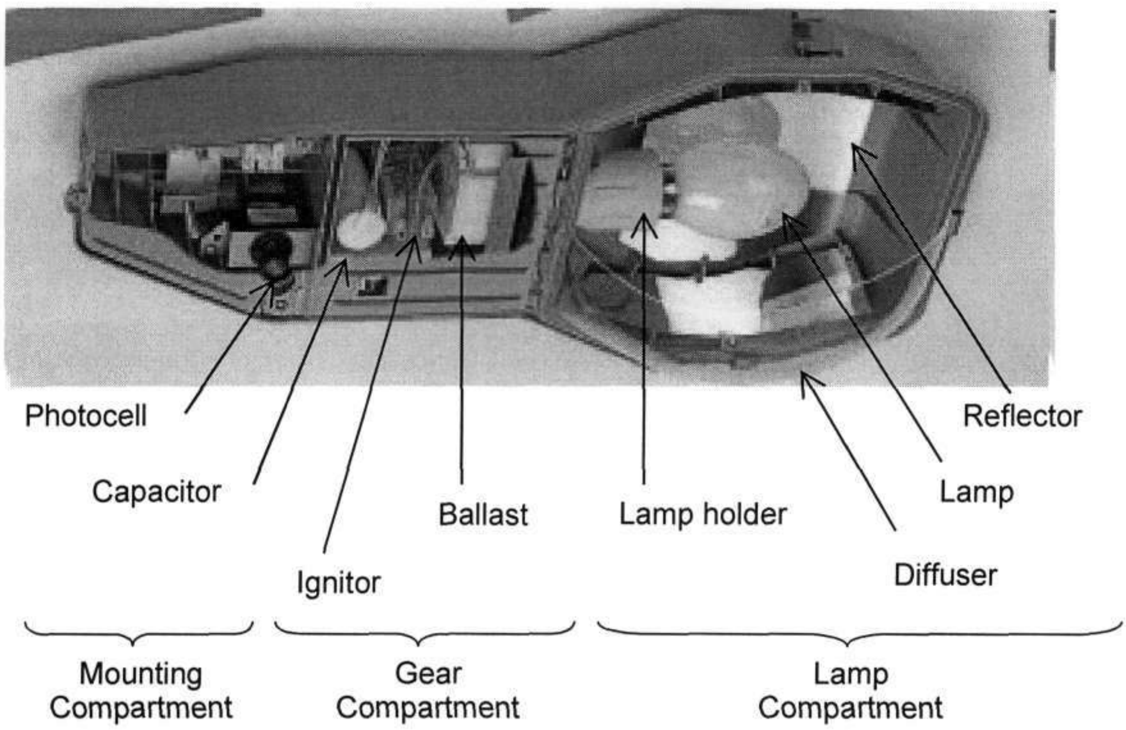
2.3.1 Components of a streetlight installation

A basic street lighting installation consists primarily of the luminaire (or light fitting), which is normally mounted on a pole (or column). The electrical supply to the pole can be by means of underground cables, suspended overhead cable (ABC) or open overhead conductors. The electrical supply to the poles can be controlled in a variety of ways to switch the lights on at sunset and off at sunrise. Streetlights can be switched singularly or in groups by means of either a time switch or photosensitive daylight switch.

The Supply network can often be dedicated to street lighting but in many instances it is an integral part of the electricity network, this is especially true in residential areas.

Figure 2-1: Luminaire Components

The following figure shows the main components of a Streetlight luminaire



- Luminaire body - usually this consists of two main compartments one to hold the control gear and one housing the lamp.
- Diffuser – A transparent outer cover, which allows light through but protects the lamp from the elements.
- Lamp – the lamp converts electrical energy into light.
- Lamp Holder.
- Ignitor – the ignitor helps to 'start' the lamp. Some lamps have an internal ignitor built into the lamp. Other lamps require a separate external ignitor.
- Ballast – the ballast is primarily there to protect the lamp from self-destruction by limiting the current (electrical energy) to the lamp.

- Capacitor – the capacitor 'corrects' the current used by the lamp and ballast to a more efficient form. The capacitor is not essential to the operation of the lamp but without it the installation would use excessive current resulting in additional consumption charges.
- Reflector – Used to reflect the lamp light onto the target area.

2.3.1.1 Types of Faults associated with Street lighting

A Streetlight installation can be subject to a number of different types of faults predominantly these are:

- Supply or Network faults
  - System faults i.e. faults higher up in the supply system.
  - Overloading – where the power drawn by the network is more than the protection system will allow which causes the protective device to operate.
  - Short circuit – where a fault has occurred in the insulating material (in the case of cables or ABC), which has allowed the conductors (wires) to come into contact with each other.
  - Open circuit – where one of the conductors has broken and the electrical circuit is no longer continuous.
  - Lightning – A lightning strike directly to the network or in the vicinity of the network can cause any one of the above types of faults to occur and can also cause damage to the luminaire and control systems.
  - Theft – This is becoming increasingly prevalent in South Africa, conductors and cables are stolen and the copper or aluminium sold as scrap.
- Cable / conductor faults.
- Vehicle Accidents, where poles are damaged by vehicles.
- Vandalism
- Switching or Control faults
- Luminaire faults

In terms of faults it is thought that the bare overhead conductor system is the most prone to developing faults. However, analysis of data from Benoni where approximately 30% of the streetlight network consists of bare conductor indicates that there is no clear evidence to substantiate this.

Faults on the bare conductor network are mostly visible (i.e. twisted or broken conductors can usually be seen when patrolling a line). Cable and ABC installations often require specialised fault finding equipment to locate a problem, as the fault may not be immediately visible.

The age of any network also has an influence on the number of failures one can expect. In SA some networks are in excess of 60 years old and in many cases the original luminaires are still operational.

2.3.2 Ideal Design and Practical Reality

There are many excellent technical handbooks and standards on Street lighting design available from a variety of sources. The reader can consult any of the references provided for further technical information.

Design of a street lighting installation must take into consideration many varying factors such as the "applicable speed limit, the road cross section and the maximum traffic volume during darkness" (SABS ARP 035:2002) the consideration of these factors eventually gives rise to an ideal design, with parameters such as the mounting height (pole length), luminaire spacing and arrangement, overhang and the type of luminaire (including lamp technology). The design of a streetlight installation in South Africa is normally done in accordance with the SABS code of Practice 098:1990

- 098-1 Public Lighting Part 1 - The lighting of public thoroughfares
- 098-2 Public Lighting Part 2 – The lighting of certain specific areas of streets and highways. There are also numerous international standards, which deal with lighting design.

Considering that worldwide there are estimated to be over 1 billion streetlights installed (IAEEL 2000), it is understandable that much research and development is conducted on improving all aspects of street lighting. There is also an abundance of information available on streetlight design, luminaire design and different lamp technologies. There are many local and international bodies involved in lighting such as SANCI (South African Committee on illumination),ILESA (Institute of Lighting Engineers of Southern Africa), SALA (South African Lighting Association), LIF (Lighting Industries Federation – UK), IESNA (The Illuminating Engineering Society of North America) to name a few. Lighting is big business and is driven by aggressive marketing amongst the major players.

In an ideal world a number of alternative designs would be considered and priced. In South Africa very often the cheapest design which meets the minimum requirements is considered, without due consideration of life cycle costs including maintenance and operation costs.

> "Notwithstanding the use of some excellent specifications, it seems that the adjudication and award of tenders are still based upon initial purchase price per unit............ More than 80% of councils, other than metros in South Africa, buy their street lighting requirements on an *ad hoc* basis. .... The successful supplier is often the one that does the best relationship marketing or the one that visits the responsible decision maker, buyer or store man on the most regular basis. Often *ad hoc* procurement is also done through local wholesalers." (G Kritzinger, Energy Service Companies - The solution to Tomorrow's Street Lighting Networks, paper presented to the AMEU annual congress Upington October 2002)[viii].

Very often street lighting is treated as an add-on to the electrical network and must 'fit' into the electrical network infrastructure. A large proportion of the electrical networks in our towns and cities consist of overhead installations i.e. poles with conductors strung between them. These poles are positioned in the most convenient location to allow supplies to consumers to be tapped off, these locations are usually not ideal for street lighting, resulting in many street lighting installations being either over or under designed. In most cases poles are either too far apart or too close to each other, in some cases they are planted too far from the roads edge. Street lighting can only be optimised where it is separated from the rest of the network this usually has a substantial cost implications, which this country cannot afford.

A further problem is that much of the street lighting in urban areas was installed when electrification was first provided to these areas and in many cases the street lighting has not been upgraded or refurbished in some cases for 60 years.

> " The result ....is that most street lighting networks in South Africa can boast a range of products spanning an age from brand new to more than 30 years, and are made up of various models of products, supplied by a host of different suppliers. Many of these suppliers do not exist anymore, and the random installation of products has resulted in poor photometric performance and maintenance being an expensive nightmare. There are no considerations for life cycle costing or consequential guarantees, due to the higher perceived initial capital cost."
> (G Kritzinger, Energy Service Companies - The solution to Tomorrow's Street Lighting Networks, paper presented to the AMEU annual congress Upington October 2002)[ix].

With the national electrification drive much research has gone into the provision of cost effective electrical infrastructure, however little consideration has been given to how street lighting fits into this infrastructure and in many cases public lighting was excluded from the electrification process. This resulted in many cases in the installation of high-mast lighting in many urban townships. In other situations lighting has been retrofitted onto the existing network infrastructure, which as mentioned is not always ideal.

High-mast lighting is an inexpensive means to providing general low-level area lighting and in some communities is preferred to conventional lighting, as individuals don't need to provide their own security lighting. Despite its benefits high mast lighting has two major drawbacks; it cannot replace street lighting from a traffic safety point of view especially where vehicle and pedestrian densities are high and secondly it can be intrusive (high levels of light pollution). High-mast lighting plays a large part in the public lighting provided by authorities and therefore must be properly incorporated in any maintenance strategy.

Considering that on average the capital cost of a luminaire represents only about 10% of the life cycle cost over 20 years with energy costs (45%) and maintenance and operation costs (45%) making up the bulk of the costs, surprisingly little literature is devoted to operating and maintenance. The major cost driver in streetlight maintenance is lamp replacement and lamp efficiency is the major cost driver in streetlight operating costs. With the global movement to sustainable development and environmentally friendly processes much attention is now being placed on improving the efficiency and extending the life span of lamps and luminaires. This will obviously drive the cost of maintenance and consumption down in the long term. Much of the discussion on maintenance revolves around the issue of lamp replacement cycles; however we first look at the issues surrounding efficiency.

2.3.3 The Issue of Efficiency and the Environment

A vast amount of research and development is currently being done in the area of efficiency, the major driving forces for this are;

- Cost of providing additional generation capacity
- Environmental protection.
- In SA the provision of affordable lighting.

2.3.3.1 Efficiency an International Perspective

The best available source of information on the worlds lighting power consumption is the IAEEL (The International Association for Energy Efficient Lighting) they estimate the following.*

> "Globally, electric lighting accounts for more than 2000 TWh electricity and 2900 million metric tons of carbon dioxide emissions (CO2) per year. The global lighting energy bill electric and fuel-based lighting combined amounts to some US$230 billion per year" (http://195.178.164.205/IAEEL/iaeel/newsl/2000/etttva2000/NatGlob a 1-2 00.html IAEEL newsletter 1-2/00 - Global Lighting: 1000 Power Plants)[x]

This is equivalent to the output of 1000 power plants according to the IAEEL who make the following estimates, predictions and statements in their newsletter 1-2/00

* The IAEEL website is no longer maintained as the project has been disbanded (due to lack of funds) however they are looking for more practical ways to revive the function provided by the IAEEL.

"For the industrialized countries with available data, national lighting electricity use ranges from 5% (Belgium, Luxembourg) to 19% (Israel) of total electricity use, while in developing countries the value is as high as 86% (Tanzania).

Global lighting electricity use is distributed approximately 28% to the residential sector, 48% to the service sector, 16% to the industrial sector, and 8% to street and other lighting sectors.

...We have used a number of prior studies showing a conservative commercial sector lighting savings potential in the range of 25% to 40%. This represents a hypothetical policy pathway that includes a combination of modest standards and aggressive voluntary programs promoting cost-effective lighting efficiency improvements with today's technologies. In practice, savings will vary by country, depending on existing baseline conditions, etc.

Two billion people light their homes each day with fuel-based light sources, and in some regions this number is rising as population growth outpaces electrification.

Combining fuel and electricity used to provide lighting raises the global total to 23500PJ, or about $232 billion per year, in lighting energy costs. Due to low lamp efficiencies, per-household fuel-based lighting expenditures in poor households shockingly rival those seen by affluent households who enjoy the vastly higher levels of quality, safety, and services provided by electric light. Electrified households enjoy 300 times higher energy-service levels (measured in lumen-hours per capita) than households dependent on fuel-based lighting. Moreover, the cost per useful lighting energy services ($/lumen-hour of light) for kerosene lighting is 300 times higher than "inefficient" incandescent lighting and 1500 times higher than compact-fluorescent lighting. If the people currently using fuel-based lighting were to shift to electric lighting, with consumption levels equal to those in electrified households today, global household electric lighting energy use would triple.

Given the large known potential for lighting energy savings, it is remarkable how little effort has been expended by most nations to quantify the electricity used for lighting. While the collection of end-use energy data is arguably not a high national priority

> in most countries, this lack of attention is particularly problematic in this instance given that lighting is usually an early and high-visibility target for energy savings campaigns and policies.
>
> It is equally remarkable how little data have been collected in the public domain on the lighting markets themselves (e.g., shares, performance, and utilization of specific types of lighting components in the stock and in new sales). The absence of such information severely limits our ability to formulate precise scenarios of future lighting electricity demand and to identify the savings that could be captured by new policies." (IAEEL News Letter 1-2/00)

The contention is that it is cheaper to invest in energy efficient lighting technology than to provide additional power generation plant and equipment. It is this argument I believe that has prompted many countries to introduce tax or other incentives to companies/ Local Authorities to implement changes to energy efficient technology. Using the above figures a total annual savings of 40% of $232 Billion could be achieved i.e. $92 Billion/ annum.

It has also become increasingly difficult to develop new power generation plants due to the ever-increasing awareness of the environmental issues by the general public. Nuclear and coal fired power stations are particularly under the environmental spotlight albeit for different reasons. Even the 'clean' hydro-electric stations have not escaped the environmentalists due to the disruption of the natural water flow patterns. More and more attention is therefore being paid to developing 'green' power in the form of solar or wind power generation facilities. Some solar powered lighting projects have been initiated in SA however the cost is five to six times that of conventional lighting.

Legislation was promulgated in the United States promoting energy efficient lighting some time ago as indicated by the following extract.

> "In 1988 and 1992, two significant laws were passed that banned the manufacture and distribution of magnetic ballasts and certain fluorescent lamps that had for many years served as a workhorse for commercial lighting applications.
>
> The laws were passed because technology made new energy-efficient choices readily available and because a reduction in national energy consumption was

perceived as in the public interest, both for the conservation of fossil fuels and to reduce air pollution.

In 1992, President Bush signed the National Energy Policy Act, comprehensive energy legislation that initiated deregulation of the electric utility industry, banned the manufacture and distribution of several major fluorescent lamp types, and set minimum efficacy standards for a variety of PAR and R incandescent lamps "(http://www.lightsearch.com/resources/lightguides/)[xi]

Reduction in greenhouse gas emissions is a social responsibility and if needs be must be enforced in SA by appropriate legislation as in the USA.

2.3.3.2 SA Perspective

In a national survey on public attitudes conducted by the HSRC in 2001 the following results were obtained with regard to environmental issues.

"The dominant environmental issue identified in the HSRC's survey was 'access to clean water', with 62% of respondents choosing this issue. Thirty per cent (30%) of the population indicated it as their first choice and another 25% as their second... 16% selected 'protecting the land' as their first choice although, with 40% selecting it overall, it was the third most important issue. The second most important was 'clean air' or the 'prevention of air pollution', which 44% of respondents selected. The fourth environmental issue at a national level was the 'protection of indigenous plants or vegetation' 28%"(Craig Schwabe, Public attitudes in contemporary South Africa, Chapter 10 Environmental Concerns, p113, 2002)[xii].

"These air pollutants are mainly caused by the use of coal as an energy source for heating during the winter months and from veld fires. This, in combination with the inversions that frequent the Highveld areas of Gauteng, make the problem that much more conspicuous. Facts and figures released on Earthlife Africa's web page (http://www.earthlife.org.za/campaigns/toxics/air.htm#facts) confirm that air pollution is a cause for concern in Gauteng. *The Star* newspaper reported in September 1998 that Gauteng was one of the most polluted areas in the world. According to this article, studies undertaken in the province over the years have shown that the total suspended particulate (TSP) matter exceeds the World Health Organization's (WHO) health standards by 2.5 times. Consequently, the number of people, especially children, suffering from respiratory illnesses is on the increase, a phenomenon which will undoubtedly have far-reaching effects for the population." (Craig Schwabe, Public attitudes in contemporary South Africa, Chapter 10 Environmental Concerns, p119, 2002)[xiii]

The dilemma in South Africa is as follows:

- Power generation is predominantly fossil fuel based i.e. coal, which is a very poor source of energy in terms of environmental pollution. (Certainly however much better than uncontrolled fuel based fires)
- Most cities and towns have aging streetlight networks utilising sometimes-obsolete and inefficient equipment, which are becoming increasingly difficult and costly to maintain.
- SA is still classified as a developing country; the imbalances created by the apartheid policy have resulted in many households still being without electricity and therefore a large number of households still using fuel-based energy which is very inefficient both in terms of heating and lighting not to mention the environmental impact including the massive pollution and greenhouse gas emissions. These emissions are reaching unacceptable levels on the highveld during the winter months.
- Many of those households with electricity cannot afford to pay for it so they steal it or they go in search of firewood. It is hoped that the free basic services tariff (BSST) will greatly alleviate this problem; however the tax payer/ consumer will have to foot the bill.

In SA there exists a real catch 22 situation, electricity is desperately needed to provide the impetus to economic growth, coal fired power is the cheapest and most prevalent form of generation in this country but is arguably the most harmful to the environment.

The need to conserve electricity is thus extremely important in SA if not more so than in developed countries, our generation capacity is fast reaching its maximum.

"Electricity consumption is growing too fast for comfort and peak demands get larger every winter. Last year the demand peaked at just less than 32 000MW, with a projection of 33 000MW this year (2003). Eskom predicts that demand will exceed capacity in the winter of 2007, leaving no time for a new power station to be built. The company has therefore adopted a three-part plan to address the looming shortfall, through the *management of consumption for efficient usage;* the exploration of options for clean and renewable energy; and investment in new capacity. (Sparks, Electrical News, July 2003)[xiv]

"It is envisaged that Eskom's excess peaking load capacity will be depleted by the year 2007. This holds dire consequences for the economy, as the energy sector contributes 15 percent per annum to the GDP ...... Energy efficiency is one of the best ways of mitigating the negative impact of energy use on the environment, reducing greenhouse gas emissions, promoting sustainable use of energy resources and reducing energy costs." (Sparks, Electrical News, August 2003)[xv]

Peak consumption periods in South Africa are early morning and early evening (this is especially true during winter). Providing for these relatively short peaks (approximately 2 hours in the morning and 2 hours in the evening) requires a large amount of capital equipment, which lies idle for up to 20 hours a day during winter and during summer is not required. Although lighting is a relatively small component of a country's electricity consumption, it is coincident with the peak consumption periods in winter. If one assumes that there are 2.0 million streetlights in South Africa which on average are 150W[†], then Street lighting makes up <1,0% of the peak value (300MW/32000MW x 100 $\approx$ 0.94%) inclusion of residential, industrial and office lighting will probably push this figure up to $\approx$ 7.5% of the peak requirement. This could be reduced by between 25 and 40% (IAEEL) if all fittings were upgraded to use the latest efficient technologies.

As stated many countries' governments provide tax incentives or capital grants to companies that implement energy efficient lighting projects. The United

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[†] Streetlights range from 35W to 400W with 1000W lamps sometimes used on high masts the average consumption is roughly 150W per fitting.

Kingdom and the USA are examples of this. South Africa will need to implement similar strategies to avoid the impending generation capacity problems. Prudent selection of the appropriate technology for street lighting is therefore of great importance and cannot be overlooked in any maintenance strategy.

In South Africa Bonesa (Pty) Ltd was established to implement the South African component as part of an Efficient Lighting Initiative (ELI) programme in 7 developing countries, worldwide. It is funded by Eskom and the Global Environment Facility (GEF).

"The goals of the ELI are

- Increased penetration of Energy Efficient lighting technologies to meet the ISEP target of peak demand reduction.
- Improve customer service through reduced electricity bills.
- Capacity building and skills transfer.
- Conserve the environment through reduced greenhouse gas emissions and reduced consumption of water at power stations.
- Support the African renaissance, through job creation and poverty alleviation.

The Benefits of ELI

- Meet the ISEP target of 820 MW peak demand reduction by 2019.
- Net benefits through avoided capital and operating supply costs.
- Affordable electricity for all sectors of society.
- Education and capacity building.
- Positive contribution to socio-economic factors affecting the country.
- Increased access to energy. (B Bredenkamp, Presentation to the National Energy Workshop, 17 July 2001)[xvi]

The major drive in the ELI and Bonesa was to promote the use of compact fluorescent lamps as a superior alternative to incandescent lamps which is discussed in detail in the following section.

2.3.3.3 Lamp Efficiency

In lighting terms, lamp efficiency is typically stated as Lumens per Watt or lm/W. What this means in layman's terms is how much light (lm) can we get from a fixed amount of energy (Watts).

Advances in lighting efficiency are continuously being made; take for instance the example of compact fluorescent lamps (CFL's). Many of us are aware of these 'new' CFL lamps, which can be used to replace normal incandescent light bulbs (GLS lamps) in and around our homes. CFL technology is currently receiving substantial press exposure, this is however not a new technology, the first CFL's were introduced more than 20 years ago.

CFL's are at the forefront of most energy efficient lighting initiatives currently being implemented worldwide, including SA.

> "The South African lighting industry is gearing itself towards a complete change in technology, from one that uses inefficient, incandescent bulbs to one that only utilises compact fluorescent bulbs, or energy efficient technologies. The change follows the worldwide trend towards affordable, efficient lighting for all and is in line with international standards for lighting.
>
> The provision of electricity and energy saving lamps is bringing health and other social benefits to South Africans. Eskom's electrification drive means that homeowners can reduce or eliminate the use of coal, wood and dung for cooking and heating, the burning of which is a leading cause of respiratory illness among South African children" (http://www.eli.org.za - efficient lighting initiative)[xvii]

Lamp manufacturers claim the following comparison [xviii]

Table 2-1: Comparison of GLS and CFL efficiency

Consumption in Watts		
GLS Lamp	**CFL Lamp**	**Flux (Lumen)**
40	7	400
60	11	600
100	20	1200
120	23	1500

Lamp efficiency for an incandescent (GLS) lamp is between 10 and 12.5 Lm/W whereas Lamp efficiency for CFL lamp is between 54 and 65 lm/W

The improved performance is fairly obvious added to this the life expectancy of GLS lamps being quoted between 6000 and 15000 hours compared to GLS life expectancy of 750 to 1000 hours, the question is why have these lamps not replaced incandescent lamps entirely?

The main reasons are as follows:

- Colour of the light, older CFL's generally produced a clinical white light, which is often inappropriate in a home environment.
- Older CFL's often required a different lamp holder and separate control gear; they were not always interchangeable with Incandescent lamps.
- CFL's are more expensive (5 years ago you could pay R60.00 for a single CFL vs. R3.00 for an Incandescent lamp). For example a single CFL operated for 4 hours a day would save you R25.00 per annum on electricity charges at today's kWh rate.

Recently things have changed as a result of the increasing drive towards efficiency, today CFL's are smaller, more efficient than older versions and freely interchangeable with most incandescent lamps. Much work has been done on the colour front as well and different tones of white are now available. From a product life cycle point of view the GLS is in decline, where the CFL is in the rapid growth stage. There are now CFL's on the market for under R20.00 and therefore have a definite financial benefit to the homeowner. However as quoted in (Sparks Electrical News, August 2003) the manufacturers claims are not always believable;

> "Like in other industries opportunists have come along and started to flood the market with 'goedkoop' (cheap) versions of these CFL's with the published lamp life printed in ultra small print.
>
> To the man on the street R19.00 for a 3000 hour CFL is just as inviting as R40.00 for an 8000 hour one, not to mention the R80.00 for a 15000 hour CFL."

My personal experience with CFL's can verify this with <u>none</u> of the CFL's installed at my residence surviving the 'stated' burning hours some only surviving a few hundred hours.

In years to come there is little doubt that CFL's will be replaced with even more efficient fittings that last longer. These technologies are already available but still need to be adapted for home use.

In a streetlight installation the driving cost in maintenance is not the lamp cost but rather the lamp life and operating cost, this issue is dealt with in detail in chapter 5. It is critical that those involved in decision-making are given the right financial and technical skills to evaluate the many alternatives available otherwise our street lighting will continue to be substandard and ineffective.

It is Ironic that streetlight installations have been using technology, which in terms of Lm/W output is equal to and better than the current CFL technology yet there is tremendous hype about the CFL's and their efficiency. For example Mercury Vapour (MV) technology, which has been in service for over 50 years, is in terms of efficiency around 50 Lm/W (comparable to CFL's) but in terms of street lighting MV is seen as inefficient in comparison to other technologies. The Low Pressure Sodium technology produces up to 200Lm/W, this light however is very orange in colour and the lamps generally have a shorter lifespan than other technologies. Roughly 50% of SA streetlights use Mercury Vapour lamps[xix] only about 1% utilise the inefficient GLS lamps.

The efficiencies of the various technologies are as follows:

Table 2-2: Efficiency of Different Lamp Technologies

Lamp Type	Lumen Output
GLS incandescent	10 to 12.5 Lm/W
Compact fluorescent	54 to 70 Lm/W
Tubular fluorescent	70 to 80 Lm/W (used in most offices)
Mercury Vapour (MV)	48 to 60 Lm/W
High Pressure Sodium (HPS)	85 to 118 Lm/W
Metal Halide (MH)	70 to 90 Lm/W
Low Pressure Sodium (LPS or Sox)	100 to 200 Lm/W

As stated the Sodium based lamps, which are the most efficient, unfortunately have the worst colour rendering properties and produce a characteristically yellow to orange light. LPS lamps in particular are not suitable where colour rendition is important i.e. where there are a large number of pedestrians such as in city centres.

2.3.4 Mercury and the Environment

Another aspect, which is attracting substantial attention from an environmental perspective, is the use and disposal of mercury. This together with the inefficiency of the Mercury Vapour technology has led to the phasing out of MV lamps in most developed countries.

The following extracts from an article on the Sylvania.com website highlight the prevalent use of Mercury in most types of discharge lamps.

> "Due to the heightened concern about mercury build-up in the environment, there have been several recent legislative or regulatory actions targeted at all mercury-containing products. The general objective is to reduce or remove the mercury content of products in the belief that this is more cost-effective than applying "tail pipe" emission control strategies at the point of disposal. However, mercury is an essential material for the operation of most discharge lamps, and there is a threshold below which the performance of the lamps will be impacted.
>
> Fluorescent Lamps
>
> All efficient fluorescent lamps contain mercury. Fundamentally, these lamps are a discharge in mercury vapour. When excited, the mercury vapour discharge is an extremely efficient source of ultraviolet radiation; this is converted to visible light by the phosphor powder that coats the interior walls of the lamp."

It should be noted that CFL's fall under this group of lamps and also contain mercury.

> "Another approach to decreasing the mercury burden on the environment is to increase the lamp life or light output for a given mercury content. This also has the effect of reducing the volume of solid waste.
>
> HID Lamps
>
> For the high-pressure sodium and metal halide lamps, mercury is used to initiate and maintain the discharge. Once started, the light output generated by the sodium, or by the metal halides, dominates the discharge. Particularly for metal halide, mercury is needed to maintain the electrical operating parameters in the range compatible with magnetic ballasts.

For the high-pressure mercury lamp, which is becoming obsolete, mercury is fundamental to the production of visible light. Light is produced directly from the mercury by operating the discharge at a higher pressure than in a fluorescent lamp. A fluorescent coating is used generally to enhance light output and CRI….

There are better prospects for mercury-free HID lamps. OSRAM SYLVANIA already has mercury-free high-pressure sodium lamps available up to 150 watts, with higher wattages under development. This has been achieved by re-engineering the arc tube geometry and fill pressure such that an initial mercury discharge is not necessary to excite the sodium. The lamps will retrofit into existing sockets and operate on existing ballasts.

Disposal

The EPA mercury report to the U.S. Congress in 1997 identified combustion sources (coal-fired utilities, waste incineration and boilers) as the three major sources of manmade mercury emissions in the U.S. Together they represent 87% of the total. By contrast, lamp disposal represented <1% each for lamp breakage and lamp recycling.

It is ironic that the use of efficient mercury containing lamps is the number one choice for reducing power demand and thereby influencing utility emissions.

Lamp disposal by incineration with other municipal wastes is a relatively recent phenomenon in some states. This represents the riskiest form of disposal with >90% mercury emission into the atmosphere where no controls exist on the incinerator. Recycling of large quantities of lamps, where they are shipped intact to the recycling location, represents one of the lowest environmental emissions." (www.sylvania.com/businesslighting&ballasts/Industryinformation)[xx]

Policies in South Africa regarding the disposal of Mercury containing lamps and the implementation thereof are not enforced. As all HID lamps are imported lamps are not recycled at source.

It must be highlighted that it is not the quantity of mercury per se that is released but rather the uncontrolled disposal thereof which, can result in over concentrations and contamination. Nature itself releases huge amounts of mercury on a daily basis far more than is involved in the minute quantities contained in HID lamps.

2.3.5 Cost Drivers in a Streetlight Installation

The cost drivers in a streetlight installation are:

- Capital cost of infrastructure – This can vary substantially dependant on the type of network. For a dedicated streetlight network this will include the luminaire, pole, outreach arm, cable and controller. For a combined overhead distribution and street lighting network the luminaire and outreach arm are the main expenses. In 2004 terms a dedicated streetlight installation cold cost anywhere between R2500.00 to R4000.00 per fixture, for a combined overhead system the cost could be as low as R300.00 per fixture. Luminaires have a lifespan of roughly 20 years; poles can last upward of 50 years.
- Energy cost - this is the cost of electricity consumed over the lifespan of the fitting. Obviously the more efficient the lamp technology used the lower this cost will be assuming that the technologies being compared have more or less the same light output.
- Component Life – It is generally accepted that during the lifetime of the luminaire the electrical components will need to be replaced, obviously the longer the components last the fewer replacements required over the lifetime of the luminaire. Component life is generally measured in operating hours, which average about 4100 hours per year. The various components have varying expected life spans.
    - Lamps – High Intensity Discharge (HID) Lamps have a rated average life anywhere between 2000 hours (6 months) and 24000 hours (6 years) depending on the type of technology. More on this issue later.
    - Ballasts – good quality ballasts (electronic and magnetic) have an average life of 50000 hours (12.5 years)

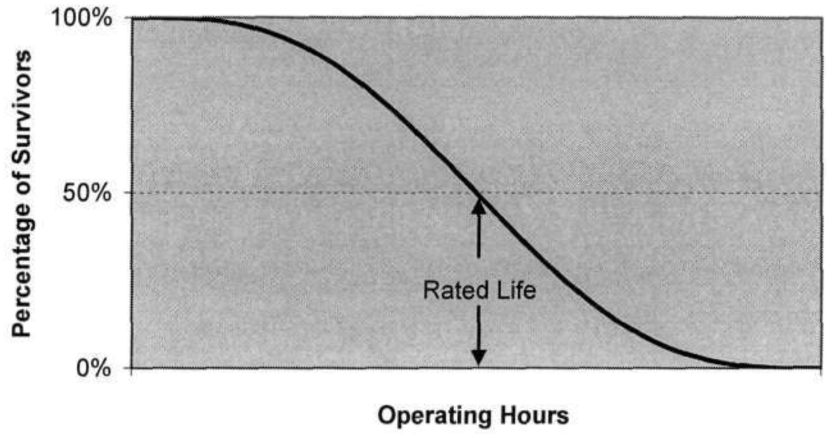
- Capacitor – approximately 24000 hours (6 years), it should be noted that failure of the capacitor does not necessarily mean that the luminaire will not work. It does however mean that the luminaire will draw additional electrical current, which is unwanted.
- Ignitor – Approximately 50000 hours provided lamps are replaced soon after failure.

2.3.5.1 Lamp Life and Lamp Lumen Depreciation

With lamps having the shortest expected life of all the components it can be expected that the lamp replacement cost (material and labour) will dominate the maintenance budget. The maintenance costs of any lighting installation can be significantly reduced by increasing the lamp life.

An aspect that is somewhat misleading is the concept of lamp life. One would expect that the quoted lamp life would be the time until a particular lamp fails and that similar lamps would fail after roughly the same period. The popular definition of lamp life is the time in which 50% of a large group of lamps would have failed. In other words if the quoted lamp life is 12000 hours then in a group of 1000 lamps, 500 would have failed after 12000 hours of operation. This is illustrated in the figure below.

Figure 2-2: Typical Lamp Survival Curve



Lamp life is often quoted by manufacturers as the average life or rated life or economic life. Maintenance planners need to be aware of this when planning maintenance schedules.

A contentious issue is that the rated life of lamps is nowhere near the actual life achieved in practice. Due to the lack of information about the actual quantities installed and systems to keep track of performance, lamp manufacturers are getting off lightly and may be exploiting the situation to their own benefit by supplying substandard lamps. Mention of the same problem with CFL's was made earlier.

It must be borne in mind that the quoted life of lamps is determined under 'ideal' laboratory circumstances. In practical installations lamp-life can be affected by a number of external factors such as;

- Supply Voltage – It is a well known fact that supply voltage has a dramatic effect on the life of GLS lamps and numerous graphs showing life expectancy versus voltage are available in most handbooks or manufacturers catalogues. It is also known that voltage has an effect on the HID lamps used for public lighting, however very little literature is available on this subject. When querying this issue with a major lamp manufacturer I was advised that no studies had been done on this issue but the lamp-life could be de-rated at 1% for every 1% over-voltage up to a maximum of 10 %. The following extract from a presentation to the SANCI (South African National Council on Illumination) AGM by Adriaan Smuts of Tshwane Metropolitan municipality highlights this issue.

  > "It has always been known to the author that lamp life in the erstwhile Pretoria wasn't what it should be. Investigations showed that closer to twenty percent of lamps failed annually rather than the ± 5% claimed by lamp manufacturers on lamp mortality curves."[xxi]

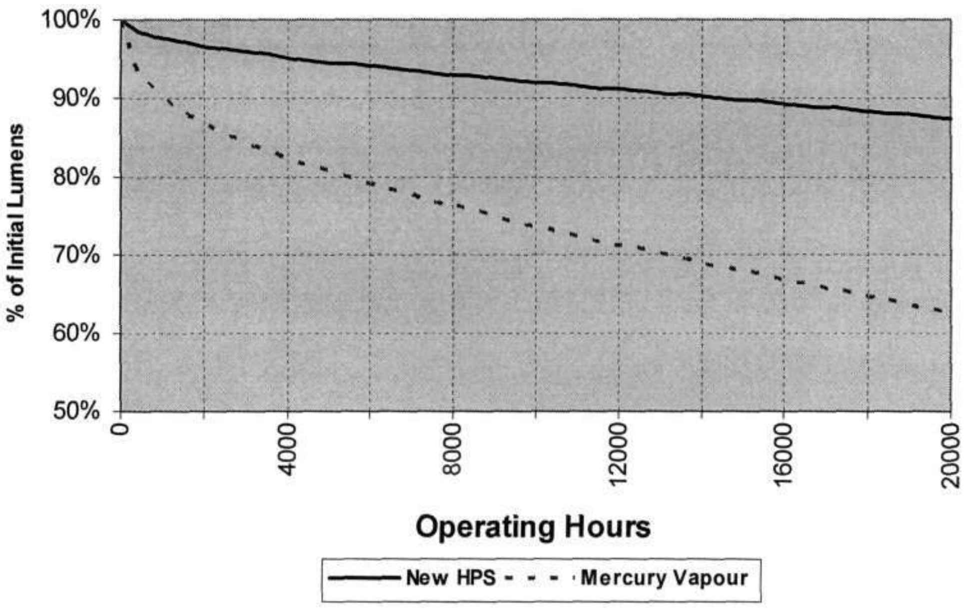
- Ambient temperature – high ambient temperatures can affect the current drawn by a lamp thereby reducing its expected life.

- Luminaire design – the design of a luminaire can affect the equilibrium temperature of the lamp which in turn raises the voltage on the lamp terminals with a resultant reduction in lamp life.
- Vibration –The effect on lamp life is considered to be small.
- Lightning and surges – A direct strike can have disastrous effects on both lamp and luminaire.
- Ballast Fault – HID lamps have a negative resistance characteristic i.e. the higher the lamp temperature the more energy the lamp draws without the ballasts protection lamps will literally destroy themselves

With the high ambient temperatures, severe lightning storms and high voltage fluctuations (±10% is allowed on our networks) in South Africa, the practical lamp life is expected to be substantially less than that quoted under laboratory test conditions.

Modern discharge lamps can survive for many thousands of hours, but during that time the light output steadily decreases so that if lamps were to be left until electrical failure, the light output could be less than 50% of the initial output. The effect is shown in the figure below.

Figure 2-3: Typical Lumen Depreciation Curve



Also the luminaire (or more correctly its reflector and diffuser) collects dirt and discolours due to various factors and the output from the luminaire diminishes over time. The combined depreciation luminaire and lamp can be substantial depending on a variety of factors such as, diffuser material, reflector material, Ultra Violet light radiation from both the sun and the lamp and dirt build up on surfaces.

Typically a lighting design will be based on the total expected output after a certain number of hours, say 12000 hours. It will therefore take into consideration depreciation in lamp (Δ_{lamp}) and luminaire ($\Delta_{fitting}$) output (known as the maintenance factor).

$Lm_{design} = Lm_{initial} \times \Delta_{lamp} \times \Delta_{fitting}$ (at 12000 hours this is typically between 70 & 80% of initial output)

This design methodology also assumes that lamps will be replaced when they drop below the design requirements for that particular road, this however seldom happens.

In South Africa the majority of lamps used are mercury vapour, which differ from other lamps in that they do not 'burn out', but continuously depreciate until very little light is produced.

> "MV lamps in particular can operate for tens of thousands of hours while generating very little light, becoming dimmer and dimmer with time. To avoid situations where luminaires appear to be on (and in fact use full power) but only produce enough light to glow while hardly lighting the street below, lamps must be replaced according to the original design principles used."[xxii]

> ".. (MV Lamps) useful life ends before the lamp actually fails" [xxiii]

In South Africa there is a general attitude to only change the lamp when it fails or if someone complains about the poor lighting. It is noticeable in many areas that the lights are working but levels have dropped way below the original design level. We design to the highest international standards but that is where it ends, there is no follow through.

High Pressure Sodium Lamps (HPS) lamps on the other hand have a definite end of life and start to cycle on and off shortly before failing completely. The cycling time however can be fairly long (15 minutes) and failing lamps can easily be missed by scouts.

There are two basic methods of lamp replacement

- Replace on failure (or complaint) this is equivalent to a run to breakdown strategy with zero preventative maintenance. This procedure is known as spot replacement or burn to extinction.
- Planned replacement at predetermined intervals. This is generally referred to as group replacement or bulk re-lamping.

All lighting handbooks make the claim that it is more effective to adopt a group replacement strategy than doing spot replacements. (I have not found one that substantiates this with a worked example) Some of the advantages are as follows.

- Labour costs can be reduced as replacement takes place in a specific area and not over the entire geographic area of the LA.
- Lamps will be of matching types in terms of lumen output and colour.
- Replacing lamps before electrical failure can increase the life of other luminaire components specifically the ignitor.
- Fewer materials are required on a continuous basis as the spot failures are substantially reduced after group replacement.
- Easier to administrate and follow up on guarantees on premature failures.
- The diffuser and reflector can be cleaned at the same time thereby increasing the total output.

From a visual point of view it would appear that, Local Authorities do not practice group replacement as their primary maintenance strategy. Further chapters look at the benefits of Group vs. Spot replacement taking into consideration practical aspects such as reduced lamp life and other component failure. It must be noted however such a comparison must be based on the premise that spot replacement includes those lamps whose output has dropped below the design level, if this is not the case spot re-lamping cycle can be extended substantially and one would not be comparing like with like.

As a lamps output depreciates with time its power consumption remains more or less the same i.e. the lamp efficacy (Lm/W) is reducing continuously. The technically correct way of comparing re-lamping strategies for similar installations would be on a lumen per watt basis, this is however not practical to achieve over extensive geographic areas.

2.4 Status of the Existing Networks

Street lighting is an integral part of any electrical reticulation network and is therefore highly dependant on the condition of this network. SA has generally adopted high standards in the installation of electrical networks and much of our networks rival the best practices of developed countries. Some network components have an expected economic life of 50+ years and can survive without proper maintenance for a substantial period of time, but there comes a point where lack of maintenance begins to show and there are increasing numbers of faults and outages – In SA many networks have now reached this point.

I recently attended the National Electricity Distribution Industry Maintenance Summit called by the Minister of Mines and Energy in conjunction with the National Electricity Regulator (NER). The extract of the Minister's Keynote Address details a broad overview of the status of SA's networks.

> "It is no secret that we have seen more blackouts and brownouts in the last months than we would like to see.
>
> It is clear in the past, in our drive to ensuring universal access to electricity; we have ignored to invest in our assets. The Department of Provincial and Local Government issued a report recently indicating that only 7% of the budget is spent on

maintenance of infrastructure. The study that was conducted by City Power on the status of their networks shows some great insight to the challenges faced by the electricity distribution business.

Electricity distribution business is the lifeblood of economic development, social welfare upgrading and inward investment in South Africa. Most governments are generally concerned with electricity generation and transmission and no attention is given to the distribution business and its customers. The general condition of the networks is a grave concern - there is not sufficient re-capitalisation of these networks. Power interruptions, some of them in economic hubs are indications of this and further deterioration could grind the economy to a halt.

Government's objectives of electrifying the poor of the country must be supported by the availability of such power. Long duration interruptions frequently do not support a better life for the poor or for business for that matter.

It is the constitutional obligation of the municipalities to ensure that customers receive electricity and to recognise the needs of the customers they serve and to meet such needs - both industrial and domestic consumers.

Utilities should commit to spending the money, which is allocated in the tariff review process for the purposes of maintaining the networks accordingly. The constraint with regards to availability of funds is recognised but electricity businesses should not be seen as cash cows. It is in everybody's best interest and particularly the utilities to ensure their networks are healthy so that it's potential for future revenue is not jeopardised."[xxiv]

The following figures were quoted by Mr Vally Padayachee, Vice President: Operations, City Power at the abovementioned summit. (City Power is the company responsible for the electrical networks in the former municipalities of Johannesburg, Sandton, Randburg, Roodepoort, Midrand and others including areas of Soweto and Lenasia)

- 70% of the City Power Network is 20-40 years old
- 7% is older than 40 years

- 80% of the overhead network requires major replacement, with 50% requiring immediate attention
- 15% of interruptions are caused by theft and vandalism

Other issues raised by various speakers at the above summit are summarised as follows;

- R24bn is owed to Local Authorities approximately 17% of this is due to Electricity
- Electricity is seen as the Cash Cow of Local Authorities used to cross subsidise other functions such as parks
- Budget deficit/business bottom line protected by readjusting maintenance expenditure
- Benchmark on maintenance costs by some utilities indicate a substantial budget gap between actual and required
- Staff shortages prevalent everywhere – up to 60% understaffed in the skilled technical categories
- Some utilities don't even meet OSHACT requirements for government certificate of competency (GCC) engineers.
- Most Utilities don't have accurate asset databases
- Lack of Spares
- Maintenance budget is a function of last years budget escalated
- Basic Maintenance is not done
- Maintenance is mostly of the Run To Breakdown type, there is a lack of planned or preventative maintenance routines
- Authorities are trying to operate equipment 'beyond its maintainable life' due to capital constraints
- There are excessive numbers of callouts to the same piece of equipment

The above items are applicable to the supply networks, which generate substantial income for Local Authorities and are seen as part of the core business of electricity departments. Street lighting as mentioned is an integral part of these networks but is viewed as a non-core service, from this it should be evident that street lighting installations are in a similar if not worse condition.

A major problem facing many authorities is lack of information regarding the number and type of luminaries in their network, without this crucial information it is very difficult to find a suitable basis on which to compare the costs of the different methods employed. This also impacts on maintenance planning and the provision of optimum levels of spares.

2.4.1 Standard of Maintenance Personnel and Safety Aspects

The first line of defence so-to-speak in any maintenance service is the frontline staff that does the physical maintenance tasks. Not only are these technically qualified staff in very short supply as mentioned, but the standard of general maintenance personnel involved in street lighting is very poor in this country.

The reasons for this can be ascribed to the following:

- Street lighting does not provide any (direct) income to Local Authorities and in many cases is considered to be non-core business, with the core business of electricity departments being the provision of power to the paying consumer.
- Because of this and given that streetlight maintenance is a fairly mundane task, very often street lighting is delegated to newly qualified and inexperienced staff and in many cases is performed by unqualified staff due to the lack of technical staff.
- Very little training is provided in the areas of faultfinding and safety aspects.

This is verified by my personal experience where I come into almost daily contact with 'qualified' and sometimes experience personnel carrying out unsafe working procedures. There are a large number of accidents and fatalities on South Africa's electricity networks and many of these can be ascribed to human error/ negligence or lack of training, the following extracts attest to this:

> "Over the past few months a number of accidents have occurred………. some of which have highlighted weaknesses in operating procedure………. A lighting column was being lowered for maintenance purposes. During the operation, using a winch, the operator was caught up in the slack of the lowering cable and was injured. The preliminary investigation has highlighted

operational errors which need to be addressed."(AMEU News: June 2002: Accidents, page 5)[xxv]

"On his way home one night………… a reader was surprised to see a streetlight come crashing down over the bonnet of his car. Apparently the municipality had been digging a hole for new traffic lights…………, and had dug the hole to close to the streetlight (pole), making it unstable" (Sparks, Electrical News, August 2003)[xxvi].

The photo accompanying this article also shows that no attempt was made to screen-off the hole as required in the OHS Act; anyone could have stumbled into the hole at night. Another letter from a concerned citizen was published in the Vector magazine, an extract thereof follows:

"I recently witnessed first hand how the Tshwane appointed sub-contractors go about disconnecting non-paying consumers… They proceeded to lean (a 5m ladder) against the pole and one poor soul had to climb up to the disconnecting switches…His partner did not support the ladder…. The ladder was too short to reach all the way up, so the poor fellow had to grab onto the lower leg of the cantilever and monkey climb higher up the steel pole… He then had to reach through the maze of conductors until he was able to reach the circuit breaker in question. At no time was he wearing a safety harness, a set of overalls, safety shoes or gloves… Other colleagues in the industry have experienced similar events………" (Vector, April 2003 page 9)[xxvii]

Such letters are often found in industry magazines and attest to the poor discipline applied to both contractors and staff in many Local Councils.

Many of the personnel employed in streetlight maintenance (and other areas) do not have the basic knowledge of how the luminaires work and what the function of the different components is. Fault repair is most often done by trial and error starting with installing a new lamp and working their way from component to component until the fault is cleared, clearly this is unproductive and wasteful.

2.5 Industry Instability

In South Africa there are two major factors which are having a profound impact on the delivery of electricity related services, firstly the transformation of Local Authorities from the racially segregated entities into fully representative municipalities and secondly the restructuring of the Electricity Distribution Industry.

2.5.1 Municipal Restructuring

The restructuring and integration of Local Authorities is still underway some 3 years after the municipal elections. Municipal officials have had to re-apply for their positions of which a great many have not been finalised yet, the result is that decision are motivated by the need to survive and not by technical and business principles. With employment equity quotas being applied in many instances the effect on white officials is very pronounced. The following extracts highlight the issues involved.

> "Since the municipal elections of December 2000, many municipalities have experienced serious difficulties in adjusting to the new demarcation and the new requirements posited in the Municipal Systems Act. These difficulties are not because the fundamental vision regarding municipal government is at fault…. But there is a sense of a lack of overarching strategic direction and integration in the alignment of municipalities within their new developmental role.
>
> Such a lack of strategic direction and integration is, in itself, probably not surprising. South Africa is undergoing change at a phenomenal rate, and the number of experienced change agents and management specialists in a developing country is always very small… the low level of real experience regarding municipalities within the higher echelons of government is a cause for concern."(Doreen Atkinson et al, HSRC publication on Third Generation Issues Facing Local Government in South Africa, p11, June 2002)[xxviii]
>
> "The impression is gained that the sheer scale of the administrative integration process, caused by the new demarcation, has been radically underestimated by decision-makers. The integration of administrative, financial and information technology systems of several previously autonomous municipal

> administrations, has proven to be time-consuming, complex and difficult. Some of these problems are due to the sheer logistics of very different municipal administrative systems. For example, staff with very different task descriptions, and who received different levels of remuneration, have had to be integrated into a common organogram." (Doreen Atkinson et al, HSRC publication on Third Generation Issues Facing Local Government in South Africa, p12, June 2002)[xxix]

It is also interesting to note that according to the Auditor General only 27% of municipalities' submitted financial statements for the 2001 financial year by the due date with 5% still outstanding 1 year after the due date. This indicates that many municipalities are still floundering; service delivery under these conditions is obviously going to suffer as a result.

> "Municipalities spend too much money on the wage bill (more than 40% of their budgeted operating expenditure) because they have bloated administrations, but at the same time a lot of work (most of it of a routine nature) does not get done. They have too many people with inappropriate skills. A second part of the problem is the lack of proper supervision.... Also, managers do not manage, for numerous reasons: because they do not know how to manage, or because councillors manage their departments on their behalf, or because the trade unions have become the *de facto* manager, or because they do not care, or because they are spending all their time assisting under skilled subordinates. But the underlying reason is also because they do not face the consequences of poor or non-existent management - nothing bad will happen whether they do or they don't." (Doreen Atkinson et al, HSRC publication on Third Generation Issues Facing Local Government in South Africa, p28, June 2002)[xxx]

> "In the wake of the December 2000 election, new staff appointments have been the order of the day. These have exerted enormous, and often chaotic, influence on the appointment of municipal staff, with the result that the existing fragile skills base of municipalities has been even further eroded. Many of the new appointments have been justified in terms of affirmative action, although the impression is gained that many appointments are also based on political patronage by dominant political parties". (Doreen

Atkinson et al, HSRC publication on Third Generation Issues Facing Local Government in South Africa, p17, June 2002)[xxxi]

Two major objectives of the transformation of LA's are firstly to improve service delivery and secondly to create the environment whereby development is encouraged.

"A new culture of municipal governance is envisaged by recent municipal legislation. New service delivery models include strategies that should:

- Be customer oriented;
- Have a strong emphasis on performance;
- Measure performance within the organisation, as well as against other municipalities and private sector organisations;
- Work in partnerships in service delivery with the broad community, including the private sector;
- Allocate and use funds on the basis of measurable results;
- Tie all resource systems to rewarding results;
- Provide for continuous evaluation of results through performance audits, and
- Use results as a basis for continuous quality improvement.

These are formidable strategic guidelines for new municipalities in a developing country." (Erwin Schwella, New models for service delivery in Local Government, *IMFO* March/April 2001)[xxxii]

The Local Authorities are subject to a number of Acts and other legislation namely:

- Constitution of South Africa (ACT 108 of 1996)
- Local government structures Act (Act 117 of 1998)
- Local government Systems Act (Act 32 of 2000)
- Local government Transitions Act (Act 209 of 1993)
- Preferential Procurement Policy Framework Act (Act 5 of 2000)
- Rationalisation of Local Government Affairs Act (Act 10 of 1998)
- Green Paper on Public Sector Procurement Reform in South Africa
- Ten Point Plan for Public Sector Procurement Reform in South Africa

It is little wonder that the progress has been so slow!

2.5.2 The Restructuring of the Electricity Distribution Industry

Government is committed to the restructuring of the electricity distribution industry (EDI). This will be accomplished by the formation of six Regional Electricity Distributors (Red's). To achieve this Eskom's distribution division is to be divided into six regions and combined with the Electricity Departments of all the Local Authorities (municipalities) within these regions. This effectively means that all the electrical staff and infrastructure would no longer be part of the Local Authorities, and they will be left with no in-house means of maintaining the public lighting network.

Primarily the EDI is divided into three main Sections;

- Generation – production of electricity is by means of power stations in this country the major sources of energy used in power stations are (coal, hydroelectric, nuclear, natural gas). Eskom generates >95% of the local requirements.
- Transmission – the 'transport' of power from power stations to where it is required. This is usually done by means of high voltage transmission lines. Eskom is the major player in this area.
- Distribution – Bulk power is distributed to the end user in various voltages suitable for use by industrial and residential consumers. Distribution is shared between the Local Authorities and Eskom. There are over 300 licensed distributors in SA.

Under the restructuring of the EDI only the Distribution Sector will be restructured into six Regional Electricity Distributors (RED's).

In broad terms the distribution infrastructure of Eskom and the LA's will be pooled together in each of the six RED's. These RED's will then become the licensed distributor within its own region. This represents a reduction of license holders from >300 to 6 with the idea of streamlining the industry and making it more cost effective.

As the electricity sales are highly profitable to the Local Authorities, proceeds are used to cross-subsidise other non-taxable social responsibilities undertaken by LA's. Understandably loss of this cash cow is potentially disastrous to many

LA's which are cash strapped. To compensate for this loss of income LA's will become 'shareholders' of their RED in relation to the distribution assets transferred to the RED. LA's will receive a dividend payment in relation to their shareholding.

Together with the pooling of infrastructure, electrical personnel from the LA's and Eskom will also be pooled and be employed by the RED's. This leaves the Local Authorities without an electrical department. Electricity departments over and above their core function of providing electricity perform the following non-core functions for other departments.

- Electrical maintenance to Council buildings. (civil dept)
- Electrical maintenance to pump stations, water purification (potable water) plants and water treatment (sewage) plants. (water dept)
- Maintenance of Road traffic signals. (roads dept)
- Maintenance of Public and Street lighting. (roads dept) – [not seen by all councils as non-core]

The problem this creates for LA's is how to provide maintenance to the non-core services reliant on the electricity department. There are three main options open to LA's namely;

- Establish an electrical maintenance department.
- Negotiate with the RED's to undertake the maintenance on the LA's behalf.
- Outsource the maintenance function.

It is my contention that utilising the RED's to undertake maintenance of non-core functions will detract the RED from its core business, eventually resulting in a substandard service to councils. This will be especially so during the transformation process, which could take up to 5 years to finalise, leaving councils badly exposed. Establishing internal maintenance departments would be time consuming and also costly, leaving outsourcing in my opinion as the only real answer. Outsourcing however is not without its problems and if not properly managed can become costly.

A number of publications are available on the establishment of the Regional Electricity Distributors, which has received a fair amount of public exposure. The available literature includes the Price Waterhouse Coopers investigation on the restructuring of the electricity supply industry. This study was conducted in response to a call for proposals by the Department of Mines and Energy (DME) in 1998. This study has resulted in the issue of a white paper by the Government and the putting into place the interim structures to oversee the transformation.

Various other articles on the Red's have been published in journals such as the, Elektron (the official magazine of the SA institute of Electrical Engineers, SAIEE) and the AMEU news (the quarterly newsletter of the Association of Municipal Electrical Undertakings); in addition seminars and workgroups have been conducted to highlight work opportunities during and after the transitional period.

A number of setbacks have delayed the implementation of the white paper. One of these setbacks was a Constitutional Court application by the Cape Town Metropolitan Municipality. The application is based on the constituted rights of the Local Authorities to distribute electricity to consumers within their area of jurisdiction. This application has been recently turned down making the way open for the establishment of the RED's albeit substantially behind the original timeframe. According to the Engineering News - "Red's, are now likely to be implemented in early 2004"[xxxiii] (Engineering News, volume 22 no 28, 26 July 02) as opposed to the original programme of 2001/2002.

The latest available time frame is that the RED's will only be fully functional during 2009 with transition beginning in 2004.

The delay in putting the EDI restructuring in place is placing a lot of strain on personnel within LA's. At the end of the municipal restructuring a further round of job applications await the electricity department staff. From an outside perspective morale is low and work performance is substantially down, this is substantiated by the physical deterioration of the electricity networks highlighted at the National Electricity Distribution Industry Maintenance Summit.

A further problem is that LA's are channelling funds from the electricity revenue to fund non-electrical projects in preparation for the loss of this income. Many LA's have not yet undergone the prescribed ring fencing and asset valuation procedure which, will be used to determine the dividend payment to these councils. At this stage the amount of income that will be foregone by the LA's due to the restructuring is still anyone's guess.

The above is confirmed by a recent press article;

> "Meanwhile, uncertainty generated by the prolonged restructuring process left question marks hanging over electricity projects, said the DA.
>
> According to the DA, the question of what income Local Authorities will get from the proposed regional electricity distributors and the R2.4 bn a year mooted in the restructuring committee's report must be clarified and resolved by the Government before the process can be finalised" (DA minerals and Energy Spokesman Ian Davidson, quoted in the article by Bernard Sathekge, DA: Settle on-off lights deal, The Citizen, 6 January 2004)[xxxiv]

2.6 *Outsourcing and Public-private partnerships*

A Public Private Partnership (PPP) in infrastructure can be defined as

> "A collaborative agreement over one or more phases of the life cycle of a project between a government or its agency and one or more private sector parties" adapted from (T.E Manchidi and A Merrifield, Empowerment through Economic Transformation, Chapter 14 Public Private Partnerships, Public Infrastructure Investment and Prospects for Economic Growth in South Africa, 1999)[xxxv]

There are many types of PPP's; the common types for infrastructure are Outsourcing and Concessions.

Outsourcing: Where a service normally rendered by a municipality (LA) is contracted out to a service company who undertake the service on behalf of the LA. With an outsourcing agreement the capital assets remain the property of the LA. Varying degrees of outsourcing can be implemented from a simple labour only arrangement to a comprehensive fully managed service.

Concession: Where a service normally rendered by an LA is implemented and operated by a private company. In a concession the private company would provide the necessary capital for the required infrastructure, construct the necessary facilities and operate them for a predetermined period on behalf of the LA. Normally at the end of the period the infrastructure becomes the property of the LA. A variety of options exists such as BOOT (Build Own Operate Transfer) or BOO (Build Operate Transfer). (T.E Manchidi and A Merrifield, 1999)

In the municipal environment the term Municipal Service Partnerships (MSP's) is often used as a substitute for PPP

Government has set up the PPP unit at National Treasury and also established the MIIU (Municipal Infrastructure Investment Unit) to facilitate the establishment of these partnerships.

Public and street lighting maintenance is a service that can be easily outsourced and in the case of some LA's has been to a greater or lesser extent with varying degrees of success. There is however reluctance in many LA's to embrace this route due to a number of reasons which are well summarised in the following extract.

"• Ideologically, the idea of partnerships often meets with opposition from the larger municipal unions, as illustrated by the implementation of the Nelspruit water partnership. The whole idea of "alternative service delivery" (ASD) is likely to raise more political problems than many Councils are prepared to face at this stage.
• Many municipalities cannot address any partnership options, because their decision-making processes are not at a sufficiently strategic level. According to Gugu Moloi (Head of MIIU), "political leadership is a very important ingredient in the process". Many Councils are pedalling hard simply to stay upright, and do not

have the skills, time or staff to investigate more strategic partnerships.

- One of the key elements in a successful partnership is an effective contractual arrangement. Contracts should be structured so that everyone wins: The service provider secures a return on investment that is commensurate with the risks; the municipality maintains its monitoring and regulatory role, but has the opportunity to attract new investment to reduce critical backlogs; and consumers get better standards of service and value for money. However, in Councils with relatively inexperienced councillors, such win-win solutions may not be easily identified. Many councillors, especially those without previous business experience, are uncomfortable with a situation in which a private company makes a profit from a municipal function." (Doreen Atkinson et al, HSRC publication on Third Generation Issues Facing Local Government in South Africa, p72-73, June 2002)

From an international perspective streetlight maintenance has been outsourced for some time, in the UK for example 55% of LA's utilise contractors for street light maintenance. Many of these contracts are medium term contracts between 3 and 6 years; a few are long term for periods of 20 years usually where investment capital is involved. (Institution of Lighting Engineers, Lamp Replacement Policy in Local Authority Street lighting Services, p 66, 1998).[xxxvi]

The Rationale behind infrastructure PPP projects is as follows;

- Operating expertise/enhanced efficiency – The private sector has access and exposure to technology and operations management that the public sector may not have. Efficiency in the private sector comes from greater accountability and financial discipline, which are underlain by the principle of profit maximisation and shareholder value increase.
- Access to capital – The private sector has access to numerous forms of capital that the public sector does not. The public sector is often restricted in the methods it may use to fund capital assets. Also the private sector will tend to impose capital market discipline and rigorous budget controls over the projects which discipline and controls are often missing from publicly funded projects.

- Addressing social needs – The provision of additional finance through PPP's enables economically justifiable projects to be freed from public expenditure constraints and to be brought forward in time, thus generating economic benefits.
- Leading-Edge Technology – PPP projects have the potential to transfer new technology and expertise to South Africa. This includes innovation in financial technology.
- Investment Promotion – PPP projects by virtue of their long term capital investments will lead to the stimulation of the local capital markets and increase the investment potential of local participants. Adapted from (T.E Manchidi and A Merrifield, Empowerment through Economic Transformation, Chapter 14 Public Private Partnerships, Public Infrastructure Investment and Prospects for Economic Growth in South Africa, 1999)[xxxvii]

2.7 Summary

When people ask me what the topic of my dissertation is, I reply that it is on the maintenance of street lighting the response has most often been –

"Oh! That should be easy! How difficult is it to maintain a streetlight?"

To the uninitiated it may seem so on the surface, however the preceding information should hopefully dispel this myth. Lighting maintenance is not just about changing light bulbs.

To add a financial perspective, the average annual maintenance and operating cost for a luminaire is around R400.00, with approximately 2.0 million public lighting luminaires installed the total annual M&O cost is approaching R 800 million. Streetlight maintenance is not effectively managed by Local Authorities, proper maintenance and use of efficient lighting can easily reduce this figure by 25% which is equivalent to R200 million per annum. This is tax and ratepayers money, which can be utilised effectively on more needy social benefits such as job creation and electrification.

The guideline to streetlight installation and maintenance in South Africa is the SABS code of Practice ARP035, which states that for a Local Authority (LA)

"To be able to render a service that complies with broad national and international standards (world class) and that consistently meets expectations of the local communities, service levels should be measurable and be monitored……… The following are useful measures of performance:

- Percentage of lights burning at one time
- Response times
- Light levels
- Reporting facility
- Cost" (SABS ARP035, 2002)

The Code of practice does not go as far as to state what these levels should be and suggests that LA's conduct their own survey. With the state of the industry in such flux and with street lighting considered by most as non-core (despite its tremendous social benefits) it is my opinion that this will never happen if left up to the LA's.

Many public officials admit to not knowing how many streetlights are installed on their network, if this is the case there can be no control of materials and costs.

Although public lighting is viewed as non-core, it is probably the most visible service provided by LA's and is often used by political parties as a show of service provision immediately before election time. The past elections were no exception with a scramble to install lighting in yet un-serviced areas, in many cases in an uncoordinated fashion with little or no thought to the above considerations.

3 Research Methodology

3.1 Introduction

The research objectives of this study are primarily to establish the current maintenance strategies utilised and levels of service being provided by LA's in South Africa, and to measure these against public and expert opinion taking into consideration the many technical, economic and political aspects addressed in chapter two. From this information to provide additional recommendations to supplement the information contained in SABS ARP035 with regard to options available and the cost implications. It is also intended to provide benchmarks, which LA's can use to compare their service delivery with other LA's.

Due to time and cost restraints the population for this study was originally planned to be the three major metropolitan municipalities in Gauteng (Ekurhuleni, Tshwane and Johannesburg) due mainly to their proximity to the researcher. However additional information from the Nelson Mandela Metropolitan Municipality and Cape Town has been included. The research focuses in particular on the Ekurhuleni area as this area is made up of nine former cities and towns each still operating largely independently and utilising a variety of maintenance strategies. These former towns provide a window of opportunity to evaluate the different strategies, which will eventually disappear as the strategies of the metropolitan municipality as a whole are aligned.

Only LA's with more than 5000 fittings, which have dedicated public lighting maintenance structures, were considered for the study. Areas smaller than this were not considered as they generally do not have dedicated public lighting maintenance teams making cost comparison difficult.

The research undertaken was a formal, *ex post facto,* cross-sectional study using both monitoring and interrogation/ communication methods for data collection as discussed below. The environment is a field setting. The collection of all primary data and secondary data was done by the author.

3.2 *Samples and Sample Technique*

Different samples and techniques were required to meet the objectives of the study. Secondary data sources have been used mainly to gather technical information such as lamp life and lamp efficacy, which will be used to establish optimum replacement cycles in conjunction with 'practical' service levels, determined from primary data collected.

A valuable source of primary data comes from the database of a management company responsible for the maintenance of the public lighting in greater Benoni. This company has kept a detailed database of the number of different types of faults attended to with the associated costs over the last 12 months. This information will be extracted and compared to published information from manufacturers to try and quantify the difference between laboratory generated and practical results. Additional information such as comparisons between overhead and underground networks and the different lamp technologies will also be made using this data. As the detailed information has only been kept for approximately 16 months (Feb 2003 to Date) the information cannot yet provide information regarding 'economic life' of lamps but does to provide good information on failures on a system using a burn-to-extinction replacement strategy.

3.2.1 Current and Expected levels of service delivery

A dual approach was followed to gauge the actual service levels and to compare these with public perception. This was achieved by means of a physical audit of the areas and various questionnaires. Three questionnaires were formulated one was issued to the general public, one to industry experts and one to council officials.

3.2.1.1 Physical Audit

Primary data was collected on the physical status of the networks by means of physical observation (survey) as follows:

Due to the physical size of the areas involved routes were selected which would traverse a number of different areas within the local authority. Route selections included city centres, low-income residential areas, high-income residential, industrial areas and major access routes. As the population along these routes was not known the actual sample size (number of Luminaires) could not be determined with any accuracy prior to the actual physical audit.

The purpose of the physical audit was not to determine the levels of service with any statistical accuracy but rather to gain a general impression of what the quality of maintenance was in the different regions surveyed so that they could be categorised. Samples were however between 1% and 6.5% of the estimated populations. Estimated populations were obtained from public officials of the different LA's to be surveyed and ranged from around 7,000 to over 180,000 luminaires.

The following predetermined categories were specifically chosen to match the public perception survey results with the physical survey results.

a. Excellent – very high level of system availability and good lighting levels
b. Good – high levels of system availability and good lighting levels
c. Fair (1) - acceptable level of availability but poor lighting levels
d. Fair (2) – low level of availability but good lighting levels
e. Poor – low levels of availability and lighting levels

The rationale behind the two 'Fair' options was to give an indication of whether a group or spot replacement strategy was being followed in that area.

The physical survey produced ordinal data in the form of fitting 'on' or 'off' and some qualitative information such as lighting levels and general appearance to allow for categorisation of the areas.

3.2.1.2 Questionnaires

Different levels of information were gathered from the public, lighting experts and public officials involved with public lighting. The actual instruments used are included in the addenda of this dissertation.

a) Public Survey

A convenience sample was chosen for cost and time reasons. An original sample size of 100 was chosen with an assumed response of 50% to provide 50 returned questionnaires. The method of distribution was mostly electronic (email) but a number were personally distributed to colleagues and their friends and family. There are obvious statistical weaknesses in this approach, not least the representativeness of the sample. The responses received however included a number from formally disadvantaged areas. This approach was adopted for its convenience but also because it was deemed sufficient to achieve the desired objectives, which do not require formal statistical evaluation of the results, a qualitative approach was appropriate.

The questionnaire was designed to establish the general public awareness of the street lighting in their area, whether they had reported streetlight faults recently, how their complaint was handled and how quickly the fault was repaired. The questionnaire also set out to obtain the general public opinion on what levels of service are acceptable to them.

b) Expert Survey

There are a limited number of streetlight maintenance experts in South Africa 29 questionnaires were sent electronically or by fax to the major lamp and luminaire manufacturers as well as to people whose names were obtained from the various lighting institutions (ILESA, SANCI and SALA). To supplement these questionnaires some relevant questions were posted on international websites, which had a technical lighting forum (Philips, ILE).

The intention was to obtain expert opinion on the aspects posed to the general public so that a comparison could be made between the responses. Addition questions were included in this questionnaire with regard to technical lighting aspects such as acceptable levels of lumen depreciation of both lamp and luminaire.

c) Public Official Survey

Here again the population is limited to very specific individuals, in depth information was required on street lighting maintenance including maintenance budgets and this required access to the right person. The questionnaire included questions with regard to actual service delivery and whether they thought the service they were providing was sufficient.

Additional Issues that were included in these questionnaires were:

- Opinion regarding the future of Street lighting with the impending establishment of the Red's
- The number type and quantity of fittings.
- Quantity of labour utilised.
- Cost of maintenance including management, labour, equipment and materials.
- Method of maintenance used i.e. in-house, outsourced or managed outsourcing.
- Type of maintenance i.e. planned, fixed-cycle or breakdown and various combinations of these.
- Causes of poor maintenance performance i.e. availability of materials, budget restrictions, staff restrictions.
- Level of management and management commitment to Streetlight Maintenance.
- Method of determining budgets.

The questionnaire was sent to 15 Local Authorities predominantly in Gauteng but included Nelson Mandela Metro and Buffalo City. The initial response was poor and the questionnaire was followed up with a telephone or direct interview with some of the selected sample.

Informal discussions were also held with senior management of Ekurhuleni and Tshwane Metros in order to supplement the information received.

3.3 Data Analysis

Data analysis presented in the following section is mostly qualitative. Evaluation of service levels with the type of maintenance used is done using visual techniques such as a Bar charts or scattergram of *service level* (interval [poor – to – excellent] and ratio [%fittings out]) *versus* *cost* (ratio).

Comparison of the different costs will be done on the basis of total maintenance cost per fitting per month.

Financial evaluation of the different maintenance techniques (planned, preventative and breakdown) and cost saving methods (replacement of existing fittings with more energy efficient fittings) will be done on the primary and secondary data collected by means of project evaluation techniques such as Net Present Value (NPV) and the Annual equivalent Annuity (AEA).

3.3.1 Hypotheses

The following hypotheses are evaluated using Chi-square and significance level $\alpha = 0.05$. Calculations are presented in full in Annexure H, results are presented under the relevant sections in Chapter 4.

3.3.1.1 Hypothesis 1 - H_{01}

There is an expected difference of opinion between members of the public and lighting experts with regard to actual service delivery (i.e. perception of delivery), this is expected due to the daily involvement of the experts who would have a greater understanding of the practical implications of day to day service delivery over an extensive geographical area.

> **Null Hypothesis H_{01}; $O_i = E_i$.** Experts and public have the same <u>perception</u> of service delivery.
> **Alternate hypothesis H_{A1}; $O_i \neq E_i$.** Experts and public have a different <u>perception</u> of service delivery.

Rationale: It is important to identify whether this difference is significant in order to recommend practical solutions in the cost effective implementation of service delivery on streetlight installations.

3.3.1.2 Hypothesis 2 - H_{02}

This hypothesis is similar to the first it however distinguishes between service delivery i.e. number of fittings out of service and the general appearance of the streetlight network.

> **Null Hypothesis H_{02}; $O_i = E_i$.** The public have same perception of maintenance provided than they do of general appearance.

Alternate hypothesis H_{A2}; $O_i \neq E_i$. The public have a different perception of maintenance provided than they do of general appearance.

Rationale: The difference between service delivery and general appearance is an important aspect the general appearance focuses more on the visible 'neatness' of the network, i.e. the number of skew poles and light fittings which even if functional can create a poor impression. A good maintenance programme should not only focus on keeping the lights working but also on rectifying visible defects.

3.3.1.3 Hypothesis 3 - H_{03}

This hypothesis will identify if there is a difference of opinion between public and experts with regard to expected service delivery.

Null Hypothesis H_{03}; $O_i = E_i$. Experts and public have same expectations of service delivery.

Alternate hypothesis H_{A3}; $O_i \neq E_i$. Experts and public have different expectations of service delivery.

Rationale: The rationale for this hypothesis is similar to that of the fist hypothesis.

3.3.1.4 Hypothesis 4 - H_{04}

This hypothesis will identify whether there is a difference between the perception and expectation of service delivery. It is anticipated that the public's perception and expectations are different as they would normally perceive service delivery to be poor, in other words there is always room for improvement.

Null Hypothesis H_{04}; $O_i = E_i$. Perception and Expectation of service delivery are the same.

Alternate hypothesis H_{A4}; $O_i \neq E_i$. Perception and Expectation of service delivery are different.

Rationale: Should the perception and expectations be different this will allow the adjustment of the service delivery so that the perceived delivery is "equivalent" to the expected delivery, if the alternate hypothesis is true it would theoretically be possible to reduce the service delivery to the point where perceptions meet expectations.

3.3.1.5 Hypothesis 5 - H_{05}

This hypothesis will identify whether there is a difference between the perception of service delivery and the actual network status as per the physical survey. It is anticipated that the respondents will overestimate the actual system availability.

> **Null Hypothesis H_{05}; $O_i = E_i$.** The perception of system availability is the same as the actual system availability.
>
> **Alternate Hypothesis H_{A5}; $O_i \neq E_i$.** The perception of system availability is different to the actual system availability.

Rationale: As for hypothesis 4, should the perception and actual availability be different this will allow the adjustment of the service delivery so that the actual delivery is "equivalent" to the expected delivery.

3.3.1.6 Hypothesis 6 - H_{06}

It is generally thought that the number of faults on an overhead reticulation network is higher due to the number of factors which can effect exposed conductors. Detailed information from the Benoni database will be used to verify if this is indeed so.

> **Null Hypothesis H_{06}; $O_i = E_i$.** The proportion of Streetlight failures is independent of the type of supply network.
>
> **Alternate Hypothesis H_{A6}; $O_i \neq E_i$.** The proportion of Streetlight failures is dependent of the type of supply network.

Rationale: Should there be a significant difference in the number of faults a further evaluation will be done to see if the additional costs would warrant the replacement of overhead networks or vice versa.

3.4 Summary

The data and information collected are indicative more than predicative due to the small sample sizes. The information received from the various sources is evaluated in the following chapter.

4 Results and Findings

4.1 Introduction

Where available the results obtained from the physical survey and the three questionnaires are compared with each other under the relevant headings.

The following questionnaires were issued and returned.

Table 4-1: Questionnaires Returned

Survey	Issued	Returned	% Returns
Public Survey	105	44	42%
Expert Survey	29	13	45%
Officials Survey	15	4 ‡	27%

The returns from the Public Survey by region were as follows.

Table 4-2: Public Survey Returns by Region

Region	No Returns	% By Region
South Africa	**38**	
Tshwane	17	38.6%
Johannesburg	12	27.3%
Ekurhuleni	4	9.09%
Cape Town	3	6.82%
Durban	2	4.54%
International	**6**	
Namibia	3	6.81%
Ireland	1	2.28%
England	1	2.28%
New Zealand	1	2.28%

‡ Where available informal responses have been included – only 4 official responses were returned a further 4 un official responses have been included for the questions presented in this paper

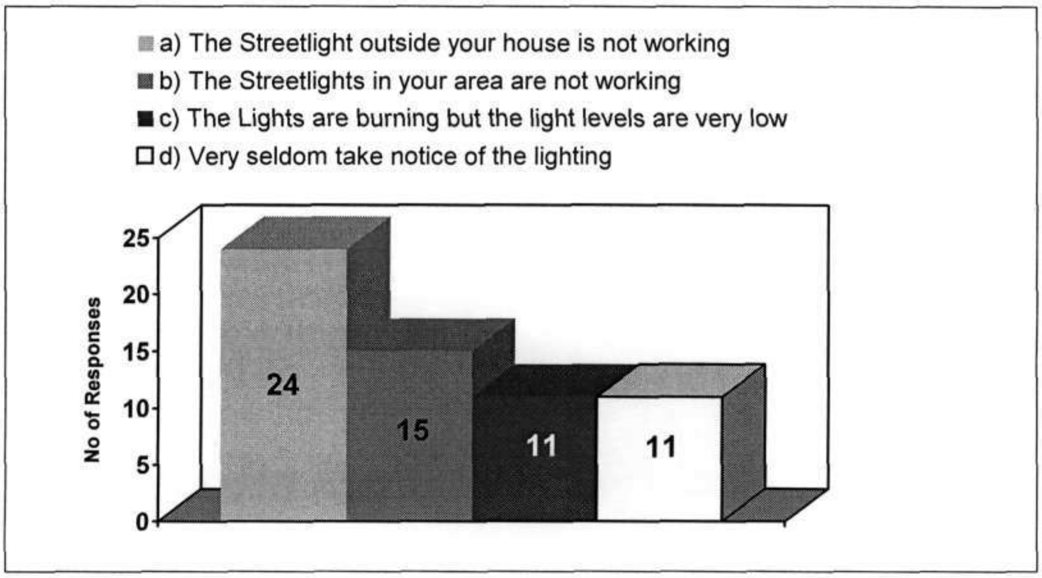
4.2 Awareness and Fault Reporting

The following questions were asked to test the public awareness of street lighting. In questions Q4 and Q5 the Expert responses are compared to the public responses to establish if there is a difference between expert and public perception of service delivery. These results are later compared with the results of the physical audit to establish if there is a difference between the perception of delivery and the actual delivery.

Q1. Do you notice any of the following when walking or driving in your area?

Figure 4-1: Public Awareness of Streetlights not working

This figure shows the number of responses received from the public for Q1

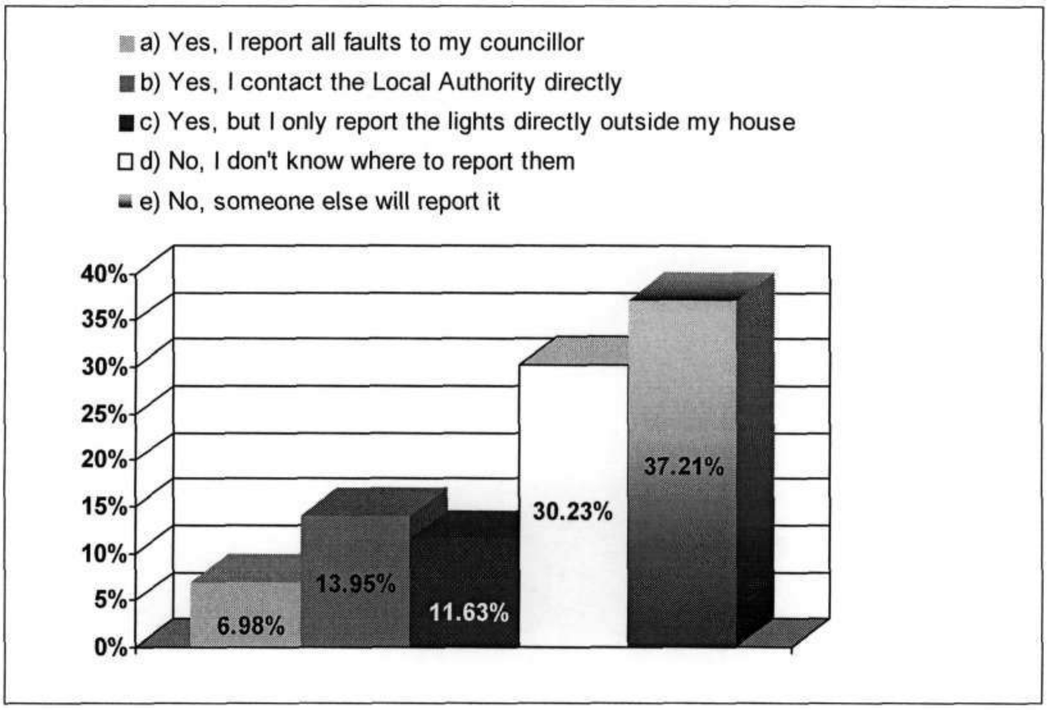


Of particular interest is that 11 of the 44 respondents (25%) stated that they very seldom take notice of the street lighting, this indicates a fairly high degree of apathy with regards to service delivery. Six respondents (14%) said they took notice of a, b and c, i.e. their 'own' streetlight ***and*** the areas lights ***and*** the level of lighting. 55% of respondents said they noticed the streetlight directly outside there home. Feedback obtained from call centres is that most calls received relate to the streetlight directly outside the callers house, with very few people reporting outages in main thoroughfares. Call Centre data has not been collected to verify this but the responses received seem to bear this statement out.

Q2. If you notice a light (or lights) out of order do you report this?

Figure 4-2: Publics Willingness to Report Failures

This figure shows the publics willingness to report failures based on the percentage of the total responses received.

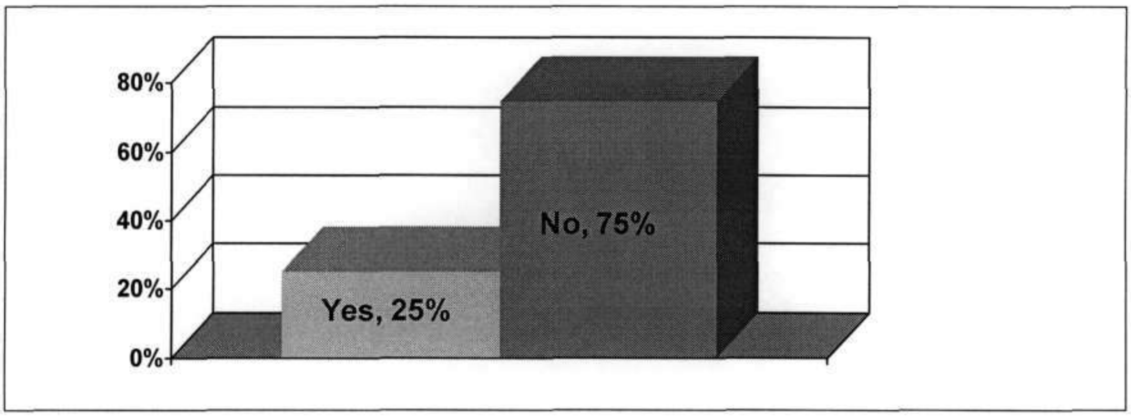


The majority of respondents 67% said they would not report faults. Again indicating a fairly high degree of apathy amongst the public – with the attitude somebody else will do it. This aspect is important to LA's and indicates that they cannot rely on the public to report all faults. In order to provide a high level of service, alternative measures such as regular surveys are required to supplement calls received from the public especially along the major thoroughfares.

Q3. Have you reported a fault (or defective fitting or area) in the last 12 months?

Figure 4-3: Failures Reported by Public Respondents

This figure shows the percentage of the respondents who stated that they had reported a failure



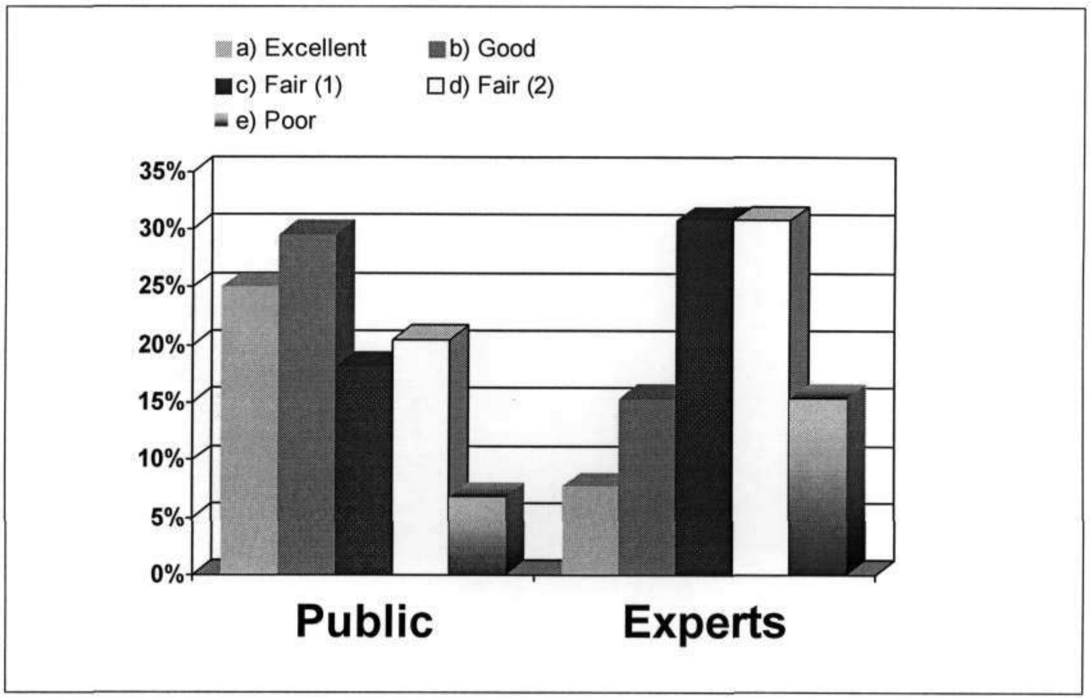
Of the eleven respondents that said they had reported a fault, one of them said they would not report a fault in question 2 and one said they seldom took notice of the street lighting in question 1, which indicates that there are some irregularities with the answers provided by the public.

25% of respondents claim to have reported faults in last 12 months. It is difficult to reconcile this information with information received from the call centres operated by the Local Authorities which, suggest that complaints range from 0.3% to 1.2% of the total number of installed fittings per month (the monthly mean in Benoni is 0.36%). This equates to between 3.6% and 14.4% per annum which is substantially lower than the 25% response. Call centre information also points, specifically in low cost areas, to high numbers of reports from councillors or conscientious individuals; this would tend to lower the number of 'individuals' who actually report faults. This discrepancy may indicate that respondents to the questionnaire *are more likely* to phone in complaints (respondents are less apathetic than non-respondents). This may indicate that the survey method and instrument have introduced a bias to the responses.

Q4. With regard to SLM how would you describe the maintenance provided in your area?

Figure 4-4: Perception of Service Provided

This figure shows the differences between how the public and experts rate the quality of general maintenance provided.



Null Hypothesis H_{01}; $O_i = E_i$. Experts and public have the same perception of service delivery.

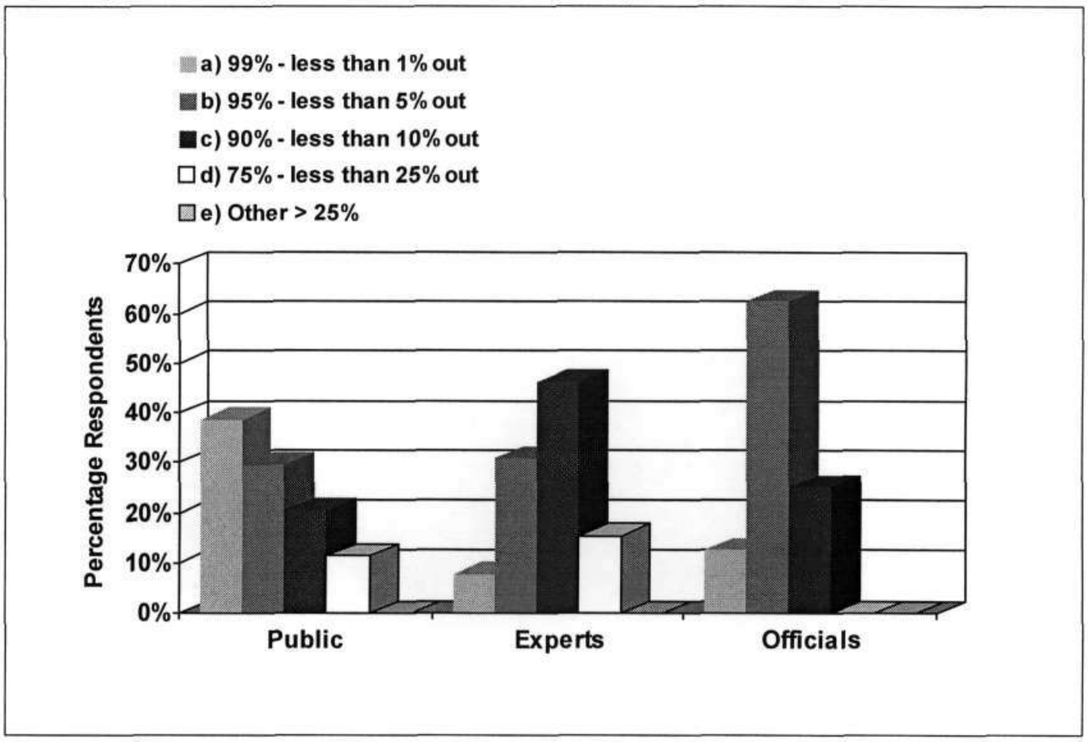
Alternate hypothesis H_{A1}; $O_i \neq E_i$. Experts and public have a different perception of service delivery.

There is a marked difference between the public and expert opinion on this issue, this is due to a greater awareness of the experts as a result of their daily involvement with lighting. To obtain sufficient frequencies for the Chi-square test responses have been grouped (a+b) and (c+d+e), the test indicates that $\mathbf{H_{01}}$ is rejected and $\mathbf{H_{A1}}$ is accepted, the public and experts have different perceptions (χ^2 critical value for d.f 1 is 3.84 and the calculated value is 3.94 with p = 0,046 for α =0.05). From this it could be inferred that the public are more satisfied with the current service delivery than the experts.

Q5. What percentage of Streetlights, in your area is working on average?

Figure 4-5: Perceived System Availability

This figure shows the percentage responses received from the three groups with regard to the perceived system availability.



Graphically there appears to be a substantial difference between the groups. However because of the low number of official and expert responses it was necessary to group them together to satisfy the expected frequency assumptions of the Chi-square test. With this grouping the Chi-square test shows that $\mathbf{H_{01}}$ cannot be rejected (χ^2 critical value for d.f 3, is 7.81 and the calculated value is 5.69 with p = 0,127 for α =0.05) There is therefore no difference in public and expert perceptions when system availability is measured on a percentage basis. The most likely inference here when comparing the results with Question 4 above is that the public have difficulty in identifying the actual percentage value, whereas the concept of general appearance is more readily understood.

4.3 Expectations of service levels

The various groups of respondents were asked what they considered to be acceptable service levels in terms of time taken to attend to complaints and outage levels. Responses are shown in graphical format. These responses will determine the appropriate level of service required. The following hypothesis is tested.

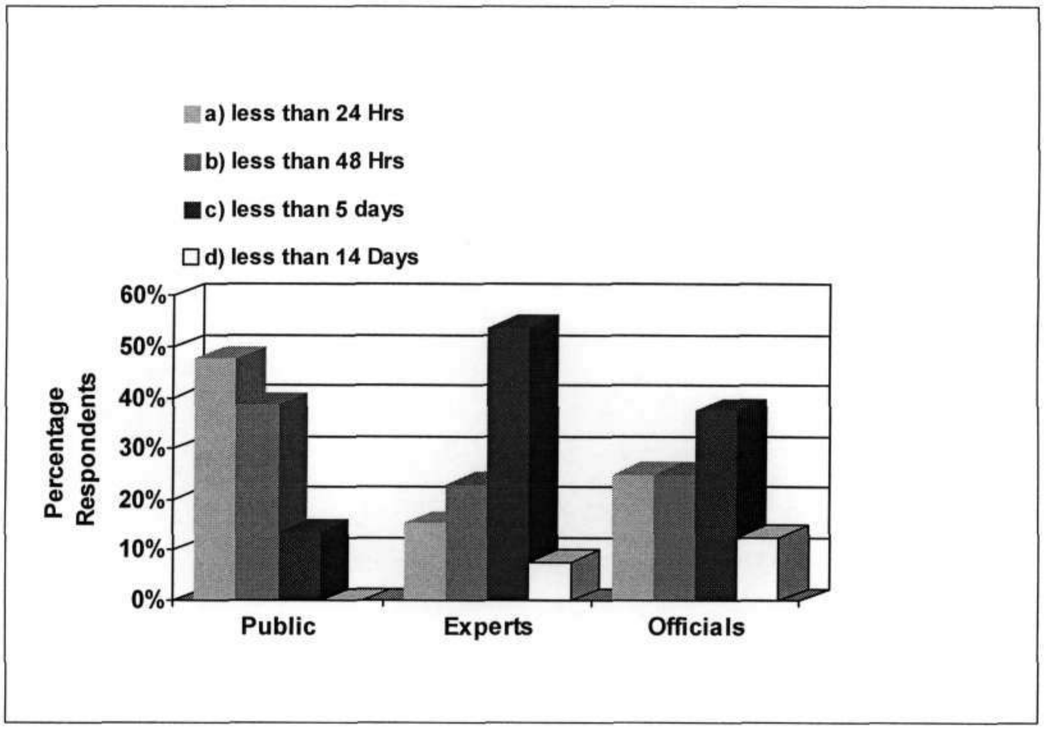
Null Hypothesis H_{03}; O_i = E_i. Experts and public have same *expectations* of service delivery.

Alternate hypothesis H_{A3}; $O_i \neq E_i$. Experts and public have different *expectations* of service delivery.

Q6. What in your opinion is an acceptable time for a Local Authority to attend to public complaints?

Figure 4-6: Expectations of Response Times for Complaints by Public

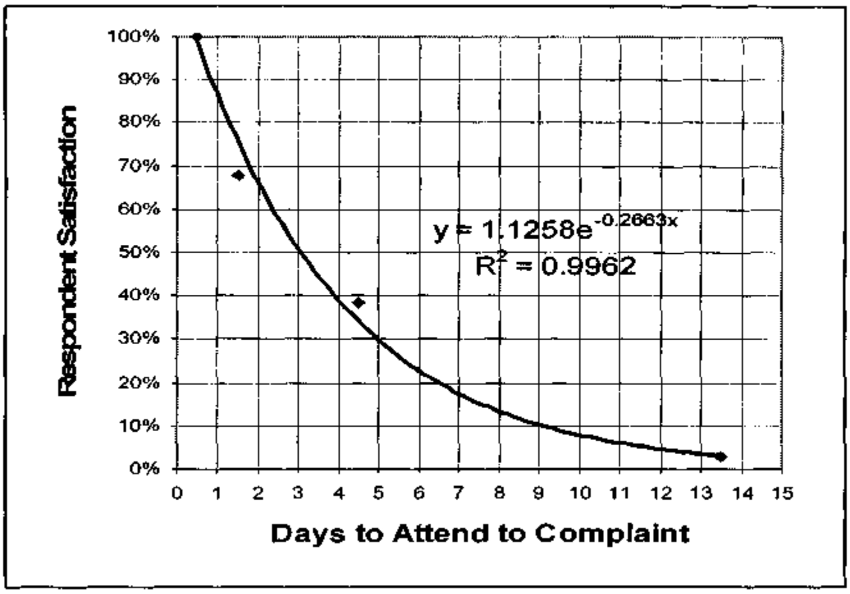
This figure shows the opinions of the three groups on a percentage basis with regard to their expectation of response times.



Graphically there appears to be a substantial difference between the experts and the public. This is substantiated by the Chi-square test; the null hypothesis **H_{03}** is rejected (χ^2 critical value for d.f 2, is 5.99 and the calculated value is 13.67 with p = 0,00107 for α =0.05) From this it can be inferred that the experts have a more realistic understanding of the logistic requirements to provide such a rapid response time.

Figure 4-7: Response Expectations

This figure shows an exponential regression of the responses received with regard to acceptable response times of all groups.



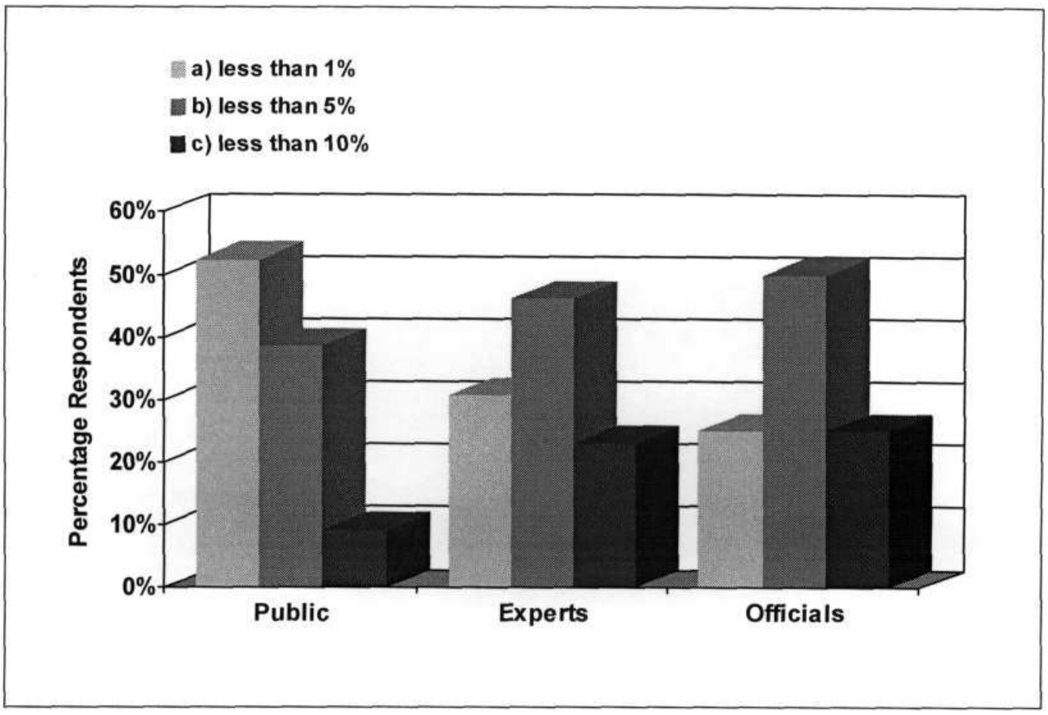
Extrapolating the responses it is estimated that approximately 65% of the population would be satisfied with a response time of less than 48 Hours, and close to 90% of the population would be satisfied with a response time of less than 24 hours, as shown in the following figure.

With regard to system availability the following results were obtained from the groups.

Q7. What in your opinion is an acceptable level of streetlights out at any given time?

Figure 4-8: Expectations Regarding System Availability

This figure shows the opinions of the three groups on a percentage basis with regard to their expectation of system availability



In this case Chi-square shows no difference between public and expert/official expectations (χ^2 critical value for d.f 2, is 5.99 and the calculated value is 4.29 with p = 0,117 for α =0.05) so the null hypothesis $\mathbf{H_{03}}$ cannot be rejected.

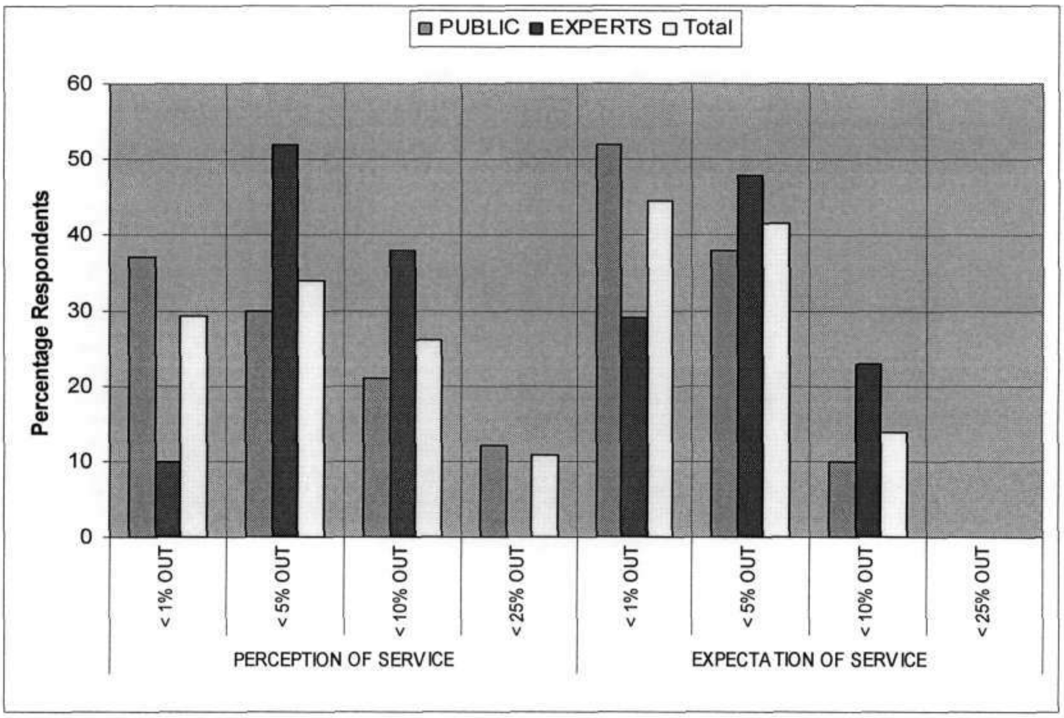
It becomes very apparent in the next section that the public interpretation (perception) of the actual service levels is poor i.e. 38% of respondents to Q5 said that the system availability is less than 1%. The physical survey shows that in most cases the service levels are substantially below this mark with the average availability being below 89%.

Null Hypothesis H_{04}; $O_i = E_i$. Perception and Expectation of service delivery are the same.

Alternate hypothesis H_{A4}; $O_i \neq E_i$. Perception and Expectation of service delivery are different.

Figure 4-9: Comparison of Expectations and Perceptions

This figure indicates the difference between perception and expectations of service delivery.



The graphical representation shows a clear difference between the groups which, is substantiated by the Chi-square test over the combined groups. (χ^2 critical value for d.f 3, is 7.81 and the calculated value is 12.06 with p = 0,007 for α =0.05). The null hypothesis $\mathbf{H_{04}}$ is rejected the implication of this is that service delivery is expected to be poor.

4.4 Physical Survey Results

The intention of the physical survey was to obtain a visual indication of the actual status of the networks in various areas; the primary emphasis was to determine the system availability of the various areas.

The physical survey yielded the following results:

4.4.1 Tshwane

Table 4-3: Physical Survey Results for Tshwane Metropolitan Area

Fittings	Old East	New East	Central	Centurion	Total
Out	78	81	31	104	294
Working	480	562	130	948	2120
Total	558	643	161	1052	2414
% Out	13.98%	12.60%	19.25%	9.89%	12.18%
Estimated Total no of fittings					78000
Sample Size % of Population					3.09%
Estimated total no of fittings Off					9500

Comments:

As with most public lighting installations the Tshwane infrastructure consists of old and new fittings with arrangements from dedicated street lighting installations to combined distribution and street lighting networks. In general however, the luminaires are not as old as those of some of the east rand cities in Ekurhuleni. In the old east and central Pretoria areas residential lighting is predominantly older type125W Mercury Vapour (MV) fed from combined overhead networks Most of these 125W MV fittings do not have diffusers. Main roads are mostly High Pressure Sodium. The installations in the new east and in much of Centurion are newer, the fittings are therefore newer and generally of the same manufacture.

The general appearance varies from area to area, the central town can be said to be in reasonable condition. There are areas in poor condition with up to 30% fittings out and other areas in good condition with less than 5% out. The Centurion area is in the best overall 'condition' with less than 10% out on average. Residential areas appear to have a higher percentage of fittings operational than the main routes, which could be as a result of the higher number of complaints received for residential areas and also because of the prevalent use of Mercury Vapour technology.

In many areas numerous different shapes and sizes of fittings are installed on the same stretch of road, this combined with the use of different pole types and lengths creates an untidy appearance.

4.4.2 Johannesburg

Table 4-4: Physical Survey Results for Johannesburg Metropolitan Area

Fittings	Sandton	Central	East	Midrand	Roode Poort	Total
Out	187	178	183	13	67	628
Working	512	612	519	442	365	2450
Total	699	790	702	455	432	3078
% Out	26.75%	22.53%	26.07%	2.86%	15.51%	20.40%
Estimated Total no of fittings						180000
Sample Size % of Population						1.71%
Estimated total no of fittings Off						36725

Comments:

It is noticeable in Johannesburg that the former towns are still being maintained in the same fashion as they were before the amalgamation, some areas i.e. Midrand has an average outage of 2.86% which is good, Roodepoort 15.51% which is below average and Sandton 26.75% which is extremely poor.

The maintenance in most areas except Midrand is extremely poor. Sandton, which is a relatively new area in comparison with central Jhb, is in a poor state even after the massive facelift it received prior to the 2002 Summit on Sustainable Development. There are large sections where no lights are working at all. Arguably the worst area surveyed is the area east of the city centre where there are not only a large number of fittings out but the lighting levels are very poor (typically old Mercury Vapour Lamps), fittings and poles are skew with many diffusers either hanging loosely, badly cracked or black with dirt.

There is an effort by Jhb to upgrade their installation with large areas being retrofitted with new fittings, but even in these areas there are high numbers of fittings out, which is indicative of a poor maintenance strategy.

With an average outage of 20.4% Jhb is by far the worst of the three major Gauteng areas.

4.4.3 Ekurhuleni

Table 4-5: Physical Survey Results for Ekurhuleni Metropolitan Area

Fittings	Benoni	Brakpan	Boksburg	Springs	Nigel	Alberton	Germiston	Total
Est. per area	21500	8510	15000	22500	6949	13400	26570	114429
Out	3	145	154	46	59	18	147	572
Working	489	324	397	489	356	821	665	3541
Total	492	469	551	535	415	839	812	4113
% Out	**0.61%**	**30.92%**	**27.95%**	**8.60%**	**14.22%**	**2.15%**	**18.10%**	**13.91%**

Estimated Total no of fittings in above areas	114429
Sample Size % of Population	3.59%
Estimated total no of fittings Off	15917

Comments:

Ekurhuleni is a combination of nine former municipalities. At the time of writing these areas were still being maintained 'independently' in the same way as prior to the amalgamation. This practice will change as metro-wide policies are implemented. These towns also present an interesting case study with three major types of maintenance strategies in place. Conventional in house maintenance is practiced by Brakpan, Springs, Nigel and Alberton. Germiston is outsourced to contractors who are managed by council officials, Benoni is also outsourced but they make use of an independent management company to supervise and control the contractors on the council's behalf.

Alberton: This area is well maintained with an average outage of 2.15%. Alberton's lighting is predominantly Mercury Vapour technology (over 70% of the area surveyed was MV).

Benoni: This area is very well maintained with a high availability within the surveyed area of more than 99%. This is not withstanding the fact that there are areas with very old fittings (40 to 50 years). Lighting levels in some these areas are low as a result of fitting inefficiency rather than poor maintenance. Approximately 30% of Benoni is served by an open overhead system.

Boksburg: This area has a more modern infrastructure than the surrounding towns indicating that a fair amount of refurbishment and upgrading has taken place over the years. The percentage of fittings out is however high at over 27% on average, some areas were considerably higher than the average with large sections out.

Brakpan: This town has the worst outage level of all the areas surveyed, above 30% on average, there are some areas with more than 50% of fittings out, other areas such as the town centre have availability levels of better than 90% (10% out). A large percentage of Brakpan's fittings have no diffusers and in general the system is in a state of disrepair. Most fittings are old with little upgrading and refurbishment done since installation.

Germiston: This area is outsourced, it is apparent that the service provider does not perform as well as that of Benoni. There is an average availability of 82% (18% outage). There are mostly Mercury Vapour Fittings installed and there is a substantial portion serviced by bare overhead conductors.

Nigel: When surveyed the Nigel area had a number of large sections out, however in those areas where the lights were burning availability was above 95% and indicates that there is regular maintenance taking place, the sections out bring the average availability down considerably. Much of the street lighting of the main access roads to Nigel has been newly installed and is in good condition. Most residential areas utilise Mercury Vapour fittings.

Springs: The general appearance of Springs is reasonable with an average availability of better than 91%. Most areas are well maintained however there are some areas, especially those serviced by Low Pressure Sodium (LPS) fittings, which are poor with a high number of fittings out and a large percentage with missing diffusers. Unfortunately LPS was predominantly used in the past for major access routes and hence the approach roads into Springs create a bad impression and also lower the average availability of the town's street lighting. (LPS technology although very energy efficient is expensive to maintain and is largely being phased out in this country)

4.4.4 Other Areas

Surveys were also done on the following two areas:

Table 4-6: Physical Survey Results for Krugersdorp and Nelson Mandela Metro Areas

Krugersdorp		
Out	77	
Working	701	
Total	778	
% Out	9.90%	
Estimated Total no of fittings		12000
Sample Size % of Population		6.48%
Estimated total no of fittings Off		1188

Nelson Mandela Metro (Port Elizabeth)		
Out	8	
Working	761	
Total	768	
% Out	0.911%	
Estimated Total no of fittings		41242
Sample Size % of Population		1.04%
Estimated total no of fittings Off		376

Comments:

Krugersdorp: This area also has a varied mixture of old and new fittings; there is still a high prevalence of LPS technology. It is in these LPS areas where the highest number of outages occur which weakens the average. In general the maintenance can be classed as average.

Nelson Mandela Metropolitan Municipality: Only the main centre (Port Elisabeth) was surveyed. The network is in excellent condition with very few outages, many fittings are of the newer type indicating a good degree of refurbishment and continued maintenance.

4.5 Comparison of Physical Survey with Perceived Delivery

By transforming the percentage data from the physical survey into ordinal data a comparison between the actual service delivery and the perception of delivery can be made and the following hypothesis can be tested.

Null Hypothesis H_{05}; $O_i = E_i$. The perception of system availability is the same as the actual system availability.

Alternate Hypothesis H_{A5}; $O_i \neq E_i$. The perception of system availability is different to the actual system availability.

Chi-square test indicates that H_{05} is rejected (χ^2 critical value for d.f 3, is 7.81 and the calculated value is 8.73 with p = 0,033 for α =0.05). Perception and actual delivery are not the same. This will allow some leeway when deciding on appropriate service levels.

4.6 Maintenance Practices

The size of the population of knowledgeable officials is small (generally one per town) response to the questionnaire was also poor with only four completed response out of twelve submitted. To supplement the information received informal discussions were conducted with a number of senior officials. The information presented below is a combination of returned information and informally gathered information.

4.6.1 Network Information

In order to properly control the costs of any facility it is necessary to know to some degree of accuracy what is actually installed on the networks. The following questions were asked to assess the availability of information in the hands of decision makers.

4.6.1.1 Number of Phoned in complaints received

This information is typically recorded at the call-centres and is made available to officials. It was therefore not surprising that all of the officials indicated that they knew what this figure was.

Although not directly asked officials indicated that they evaluate the performance of their SL maintenance division on the number of complaints received. In my opinion this results in more attention being given to residential areas (Based on information from Benoni most complaints received relate to the light directly outside the complainants residence) and also the continued use of Mercury Vapour lamps in residential areas (Mercury Vapour tends to carry on burning albeit at a fraction of the original output). During the physical survey it was noticeable in some areas that the residential networks are better serviced than main routes and town centres, Mercury Vapour are also predominant in most residential areas.

4.6.1.2 Total number of faults attended

Respondents were only asked whether they knew how many faults are attended to on a monthly basis. Here the response was also positive with all the returned responses confirming they knew the quantity of faults attended.

4.6.1.3 Quantity of different types of faults

Respondents were asked if they could quantify the different types of faults attended, those who did not know were asked to estimate the quantities.

Of the official responses three of the four indicated that they knew the figures Brakpan provided an estimate. The responses were as follows.

Table 4-7: Quantities of Fault Occurrences

Description	Brakpan (Estimate)	Nelson Mandela	Tshwane	Benoni (Calculated)[§]	Average
Lamp Replacements	55%	29%	50%	65%	49.75%
Ignitor Replacements	10%	5%	5%	0.2%	5.05%
Ballast Replacements	20%	0.5%	5%	3.7%	7.3%
Fitting Replacements	2%	16%	20%	6.4%	11.1%
Cable/Circuit/Control Faults	2%	12%	5%	9%	7.00%
Pole Replacement/ repair	2%	1%	5%	1.8%	2.45%
Other	9%	36.5%	10%	13.9%	17.35%
Totals	100%	100%	100%	100%	100%

There is a large variation in the data provided, which makes sensible comparison of the figures difficult. It was indicated by the Nelson Mandela Metro (NMMM) that a large number of the 'Other faults' included lamp holders (24.5%), which is almost as high as lamp replacements. The reason for the high number of lamp holder faults is not immediately apparent but is possibly due to the coastal climate of the NMMM, which can impact on the expected life of lamp holders. Only the figures from Benoni can be substantiated through accurate data collection.

Respondents were also asked to indicate what percentage of the above figures was due to accidental damage and vandalism. The results are as follows.

[§] The Benoni information was calculated from primary data (see **Error! Reference source not found.**).

Table 4-8: Fault Quantities by Major Category

Description	Brakpan (Estimate)	Nelson Mandela	Tshwane**	Benoni (Calculated)††	Average
Accident Damage	2%	0.85%	5%	1.8%	2.41%
Vandalism	8%	0.05%	5%	0.5%	3.39%
Normal Maintenance	90%	99.1%	90%	97.7%	94.20%
Totals	100%	100%	100%	100%	100%

4.6.1.4 Reconciliation of faults and Materials

One way to verify the accuracy of the figures given in 4.6.1.3 above would be to verify these against material usage. The reconciliation of materials is also important to control costs and limit shrinkage. The following responses were received from the officials.

Table 4-9: Responses Regarding Material Reconciliation

Area	Reconcile materials with no of faults attended
Brakpan	NO
NMMM	NO
Tshwane	YES
Benoni	YES

After discussions with officials from Tshwane it is apparent that although material usage is monitored it is not strictly reconciled with the actual number of faults attended.

4.6.1.5 Quantities of Fittings

It has been implied that LA's do not know what is installed on their networks, accordingly officials were asked how many fittings were installed on their network and how accurate this quantity was, the responses received are shown in tabular format. Quantities marked with a star were obtained from other sources.

Table 4-10: Fitting Quantities by Area

** The Tshwane figures appear to be an estimate from the precise values given

†† The Benoni information was calculated from primary data (see **Error! Reference source not found.**).

Area	Quantity of Fittings	Accuracy
Brakpan	8,510	95%
NMMM	41,242	98%
Tshwane	100,000	85%
Benoni	21,640	99%
Alberton	13,400*	NR
Boksburg	22,915*	NR
Germiston	26,750*	NR
Nigel	6,949*	NR

In discussions with officials it is apparent that accurate records have not been kept of new installations and often the quantities quoted are estimates handed down over the years and escalated by a percentage every year to allow for growth of the network. For example the officials at Centurion have various estimates ranging from 22000 fittings to over 30000 fittings (± 35% variation). When Benoni decided to outsource their SLM they estimated a total of 14000 fittings were installed, after a detailed survey by the managing company it was found that this figure was closer to 17000 fittings (21% more than the estimate).

4.6.2 Determination of Budgets for Streetlight maintenance

Common practice in many Local Authorities is to escalate the previous year's budget by a figure close to the inflation rate (or the agreed salary increase rate). There are two principal reasons for this:

- This approach seems to attract the least resistance in getting budgets approved.
- Budgets are based on staff and equipment employed because officials do not have sufficient information to substantiate the budget with hard facts and figures about quantities of fittings, number of faults, etc. Salaries also make up the Lions share of the budget.

The following responses were received from the Officials on how their budget for SLM is usually determined.

Table 4-11: Responses Regarding Budget Determination

Response	NMMM	Brakpan	Tshwane	Benoni
Escalate Previous years Budget	Yes		Yes	
Analysis of personnel, equipment and material costs from past usage	Yes	Yes		
Other				Per fitting

Officials were also asked whether they compared their maintenance costs with other cities and towns, the responses were as follows:

Table 4-12: Response regarding – Cost Comparison between areas

Response	NMMM	Brakpan	Tshwane	Benoni
No	Yes			
Yes, compares favourably		Yes	Yes	Yes
Yes, more expensive but better maintained				
Yes, but compares poorly with neighbours				

In later discussions with Tshwane Metro officials It was indicated that it is difficult for officials to determine budgets for a specific function; firstly because the budgets are split into many different categories i.e. (salaries, materials, vehicle maintenance, petrol) often without clear allocation to the associated function. As a result of this they do not know with certainty what their direct costs for Streetlight maintenance are and subsequently could not make any accurate comparison of costs.

Maintenance budgets are next in line to capital refurbishment budgets for cuts to ensure that the business bottom line is met. This aspect was highlighted at the National Electricity Distribution industry Maintenance Summit. Capital and Maintenance budgets were cut drastically in Ekurhuleni during 2001 to 2003. Electrical capital expenditure and Maintenance budgets were lower in 2003 than they were in 2000 (Unconfirmed source).

4.6.3 Maintenance Practices

The following questions were asked to ascertain the way in which streetlight maintenance is carried out in the various areas.

Q8. How would you describe your departments' maintenance strategy?

Table 4-13: Pro Activeness of Maintenance strategies

Response	NMMM	Brakpan	Tshwane	Benoni
Very Proactive				X
More Proactive than Reactive				
More Reactive than Proactive	X	X		
Mostly Reactive			X	

Benoni follow a strict regime of 'night spotting' whereby the entire area is surveyed every two weeks. A Reactive strategy is one that relies to a large degree on complaints received; Pro-active strategy means additional means of fault identification is employed i.e. regular surveys, this is indicated by the responses below.

Q9. How would you best describe the type of strategy used?

Table 4-14: Survey and Repair Cycles

Response	NMMM	Brakpan	Tshwane	Benoni
React to complaints	X	X	X	X
Group replacement strategy				
Cyclical repair strategy				
Regular Survey and repair	<1 month	<3 months	<1 month	<1 month

From my regular visits to the towns in Gauteng the absence of regular maintenance is very apparent, some areas in Johannesburg have been noted to be out for in excess of six months. The area in which I live in Tshwane does get attended to on average once every three months.

Q10. Which of the following most aptly describes your operational structure?

Table 4-15: Operational Structure of Streetlight Maintenance

Response	NMMM	Brakpan	Tshwane	Benoni
Complete Outsourcing with management agent				X
Outsourced but with internal management				
Internal resources only	X	X		
Combination of internal and external resources used			X	

Unfortunately no official response from Germiston was received, as Germiston has been outsourced directly to contractors who are managed by internal LA staff. Discussions have however been held with Germiston officials which have allowed the inclusion of this strategy in the comparisons made in later chapters.

Q11. Are lamps whose lighting levels have depreciated below the applicable recommended level replaced?

Table 4-16: Replacement policies for old Lamps

Response	NMMM	Brakpan	Tshwane	Benoni
Proactively replace lamps which have deteriorated				X
Group Replacement followed				
Yes, only in areas where complaints have been received	X		X	
No, wait until lamps fail	X	X		

As described earlier in chapter 2 Mercury Vapour lamps tend to deteriorate quickly in comparison with other light sources. In most areas included in this paper there are many Mercury Vapour fittings, which are operating at as low as 10% of their original light output. There is a common saying among the officials of Tshwane which goes - "You need to light a candle to see if the light is still burning." As this diminished output from the lamp still requires the same amount of power as a new lamp it is clearly inefficient to leave such lamps in operation, however the general consensus is that it's ok as long as no-one complains. Often the success of the streetlight maintenance strategy is measured against the number of complaints that get through to senior management, with South Africa being an apathetic society in general; poor maintenance has become accepted practice.

4.6.4 Rating of Performance

Officials were asked to rate the performance of their Streetlight Maintenance Policies The questions and responses were as follows.

Q12. What is the average time taken to attend to complaints by the public?

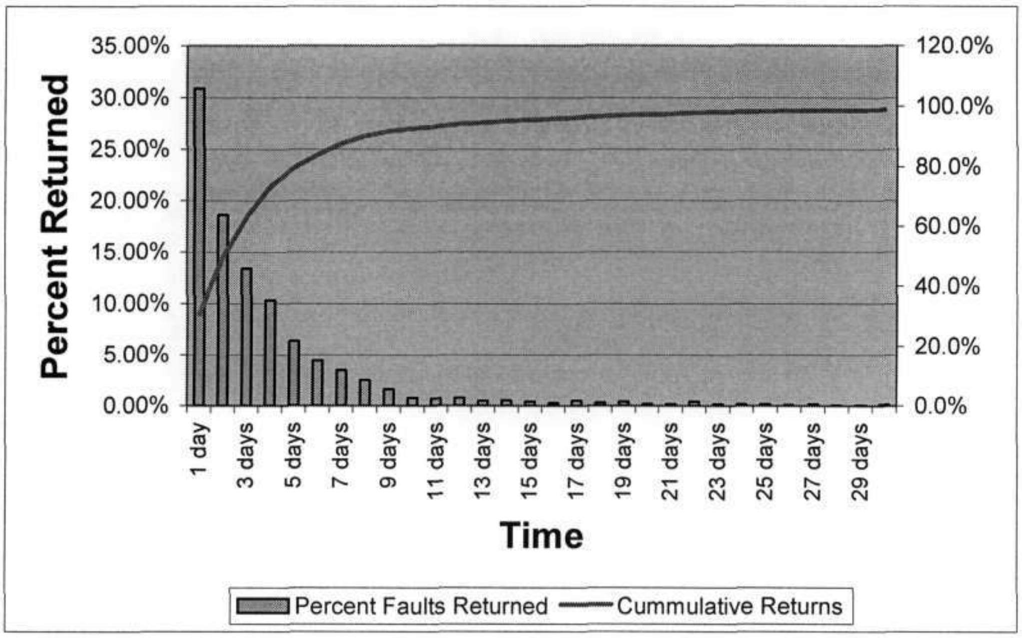
Table 4-17: Response Times to Complaints from Public

Response	NMMM	Brakpan	Tshwane	Benoni
Less than 24 hours				
Less than 48 hours			X	50%
Less than 5 days	X			75%
Less than 14 days		X		95%
Less than 1 month				
Other				

It is difficult to compare these figures with the responses received from the public, the feeling is that the officials over estimate their system availability. None of the officials could substantiate their claims with any records except for Benoni. The figures shown for Benoni come from their database, which documents all faults (both complaints and self identified) from the time they come in to the time they are completed.

Figure 4-10: Benoni Response times to faults

This figure shows the response times to reported failures in Benoni from February 2003 to May 2004.



Officials were asked the following with regard to their maintenance strategies.

Q13. How effective do you think your maintenance strategy is?

Table 4-18: Rating of Own Maintenance Service

Response	NMMM	Brakpan	Tshwane	Benoni
Very Effective			X	X
Effective but can be improved	X			
Ineffective		X		

Q14. On average what percentage of your street lighting is out of service at any given time?

Table 4-19: Rating of Own System Availability

Response	NMMM	Brakpan	Tshwane	Benoni
Less than 1 %				X
Less than 2.5%	X		X	
Less than 5%		X		
Less than 10%				

From the physical survey results Tshwane's response to the last two questions is optimistic to say the least. Brakpans estimate of system availability is also very optimistic, the physical survey showed approximately 31% outage. From a cost point of view both NMMM and Tshwane proved to be expensive.

4.6.5 Performance Limiting Factors

Officials were asked to rank five factors in the order which most-negatively impacted on implementation of Streetlight maintenance the following responses were received.

Table 4-20: Performance Limiting Factors to effective Maintenance

Factor	NMMM	Brakpan	Tshwane	Benoni
Budget Constraints	4	4	1	2
Insufficient maintenance personnel	5	1	4	4
Ineffective utilisation of resources	3	5	3	3
Insufficient management resources/time	2	2	5	5
Lack of material availability	1	3	2	1

By calculating the mean and mode responses we can rank these in order as follows;

Table 4-21: Ranking of Limiting Factors

Factor	Mean	Mode	Rank
Budget Constraints	2.75	4	2
Insufficient maintenance personnel	3.5	4	4
Ineffective utilisation of resources	3.5	3	3
Insufficient management resources/time	3.5	2 & 5	5
Lack of material availability	1.75	1	1

This would indicate that materials and budget constraints are the most important factors limiting the provision of Streetlight Maintenance.

The availability of materials is often problematic in the municipal environment; this is mostly due to the red tape involved in issuing of orders to suppliers, and poor stock control systems. Materials are not replenished automatically when stock reaches a critical level with the result that often materials are not available when required and then it can sometimes take many weeks to finalise the order for new materials. In some cases service delivery can come to a standstill.

Budgets are constrained because they are based largely on salaries and wages, which are paid whether service delivery takes place or not. There are no internal mechanisms in Local Authorities to pay for work completed at market rates, unless the service is outsourced.

4.7 Regional Electricity Distributors

With the impending implementation of the RED's Officials were asked the following questions. Responses received are tabulated directly after the question.

Q15. Does your organisation consider street lighting to be a core function of the electricity department?

Table 4-22: Streetlight Maintenance as a Core Function

Respondent	Response
NMMM	No
Brakpan	No
Tshwane	Yes
Benoni	No

The general consensus from discussions with a number of other Local Authorities is that Street lighting is a non-core function. (Informal responses were obtained from Buffalo City, Cape Town, Johannesburg and Ekurhuleni Head Office)

Q16. With regard to Streetlight Maintenance how do you think this will be achieved after the RED's have been implemented?

Table 4-23: Responses to Where SLM will find itself after RED's establishment

Alternatives	NMMM	Brakpan	Tshwane	Benoni
Will remain as core function of the RED				
Will be maintained by the RED under a maintenance agreement with the LA	X		X	
LA will establish a separate SLM division as part of the Roads division		X		
LA will outsource SLM				X

From the above it would appear that there is still some uncertainty regarding where SLM will find itself. The latest draft agreement between LA's and the RED's, which is currently being circulated for comment, stipulates that street lighting will remain with the LA's. This means that the LA's will need to develop an official strategy on how SLM will be handled in the future.

It does appear that some LA's are now starting to formulate implementation plans. The policy, which has been adopted by Ekurhuleni, is that Street lighting will become a function of the roads department and will most likely be outsourced in the managed format adopted in Benoni.

Recently both Tshwane and Cape Town have started to research the possibility of outsourcing SLM, as the implementation of the RED's becomes more of a reality. Buffalo City (East London and Mdantsani) is also in the process of issuing tenders for SLM on an outsourced basis.

4.8 Bulk Replacement Strategy

Officials were asked whether they used bulk (group) replacement strategies as part of their overall SLM strategy, the responses received were as follows.

Q17. Does your organisation use a bulk replacement strategy as part of your overall SLM policy?

Table 4-24: Responses to the use of Bulk Replacement Strategy

Respondent	Response
NMMM	No
Brakpan	No
Tshwane	Yes
Benoni	No

Respondents who answered NO to the above question were asked why they had not implemented a bulk replacement strategy the following responses were received.

Table 4-25: Responses as to Why Bulk Replacement Policy not utilised

Respondent	Response
NMMM	Believe it is more effective but we are not set up for it at this stage
Brakpan	Believe it is more effective but don't have the resources to implement BR
Benoni	Budget constraints limit the starting of BR as it requires upfront expenditure. Compared to a burn-to-extinction policy BR is not always cheaper especially if light output is allowed to deteriorate below design levels in the Burn to extinction strategy.

Tshwane were the only LA to indicate that they followed a bulk replacement policy and stated that they believed that BR was more cost effective, but did not have any proof to substantiate this.

4.9 Outsourcing

Of the survey responses received only Benoni actively practices the complete outsourcing of their Streetlight maintenance. Tshwane indicated that they made use of external contractors to perform certain maintenance tasks but the entire system had not been outsourced.

The reason given by NMMM for not outsourcing was that previous attempts had been a failure. The degree and format of the outsourcing contract utilised was not elaborated on and it is therefore not possible in this paper to determine why it had failed.

The reason given by Brakpan for not outsourcing was that it was against council policy. The Ekurhuleni Metro into which Brakpan now falls, have adopted a more open policy on outsourcing especially the non-core functions.

Germiston is outsourced to contractors, which are controlled directly by the LA. It is apparent that this contract was not properly drawn up and control has slipped. This has resulted in escalating costs with declining service delivery. The cost of the various entities for maintenance is provided in the following section.

4.10 Comparative costs

Officials and Experts were asked to identify the most practical way to compare Streetlight Maintenance costs between LA's. Two methods were offered

1. Cost per Kilo Lumen output per year.
2. Cost per fitting per month/ annum.

The first method is technically the most correct and includes for lumen depreciation as well as Luminaire and Lamp efficiency. Practically however this method would almost be impossible to calculate as Lumen output is a continuously varying factor and also given that many LA's don't know how many fittings are installed on their system or the condition of these fittings let alone how many different types of lamps utilised. This method is a good instrument for theoretical comparison of different designs for a new installation. As light is the product of a street lighting installation future contracts may be drawn up around guaranteed light output, this type of contract would require a considerable amount of policing and auditing. With improving technology it is foreseeable that this information can be provided by means of 'intelligent' fittings fitted with communication devices.

The second method is fairly straightforward but does require knowledge of the number of fittings installed. The costing allocation can be taken one step further by comparing maintenance costs of the different types of fittings, this however would be difficult to achieve without good records of the number of faults attended and the material used. At present it is difficult to obtain this basic information from the LA's because of the budgeting procedure and lack of reliable data.

The second method i.e. cost per fitting per month is adopted to compare and Benchmark costs across the various LA's.

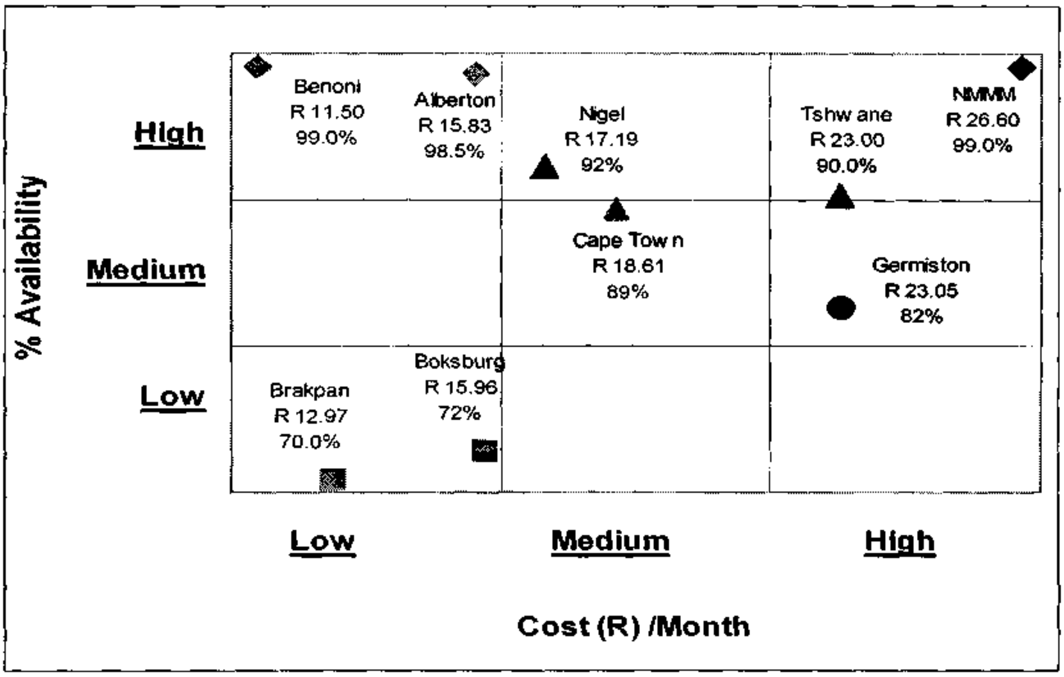
The information presented in the following tables and graphs is approximate but provides a good comparison of the costs for the various LA's.

Table 4-26: Table of Costs versus System Availability

Area	Quantity of Fittings	Annual Maintenance Cost per Fitting	Avg. Cost Per Fitting Per Month	System Availability Physical survey
Benoni	21,640	R 2,986,320	R 11.50	99.0%
Brakpan	8,510	R 1,325,000	R 12.97	70.0%
Cape Town	127,000	R 22,669,500	R 14.88	89%
Alberton	13,400	R 2,544,850	R 15.83	98.5%
Boksburg	22,915	R 4,387,432	R 15.96	72%
Nigel	6,949	R 1,433,828	R 17.19	92%
Tshwane	100,000	R 27,600,000	R 23.00	90.0%
Germiston	26,750	R 7,398,062	R 23.05	82%
NMMM	41,242	R 13,166,020	R 26.60	99.0%

Figure 4-11: Costs versus System Availability

This figure shows a scatter plot of cost versus availability for the areas above.



Only two of the nine areas appear in the top left square i.e. availability better than 90% <u>and</u> cost less than R16.00 per fitting per month. There are no areas in the bottom right square i.e. high cost low availability. From this figure only Benoni (externally managed) and Alberton (internally managed) can be classified as being cost effective.

4.11 Additional Primary Data

Since the beginning of 2003 the company, which manages the maintenance of Benoni's street lighting, has kept an electronic database of all faults that have been attended to. The number of records available on the system at the end of February 2004 was approximately 9000. Evaluation of this data provides information with regard to a number of issues, such as lamp failures in a non-laboratory situation. To the authors knowledge this is the only database of its kind in the country.

The Benoni network consists of approximately 21640 fittings, the estimated accuracy of this figure is better than 99%. The Benoni maintenance strategy is one of Burn-To- Extinction (BTE) for HPS lamps. As far as Mercury Vapour lamps are concerned, these lamps are changed only after considerable deterioration or when complaints are received from the public.

Unfortunately this detailed information only spans 16 months and can therefore only provide comparisons with manufacturers claims over this period (remember that new lamps have an expected life of 3 to 4 years). Also materials are generally sourced from council stores with the resultant being that lamps from a variety of different manufacturers are installed. The data does not distinguish between lamp manufacturers hence no comparison on this level can be made. The following information has been 'gleaned' from the database, which provides a starting point to establishing material usage and stock levels and average failures to be expected on a typical South African network.

4.11.1 Monthly Failures

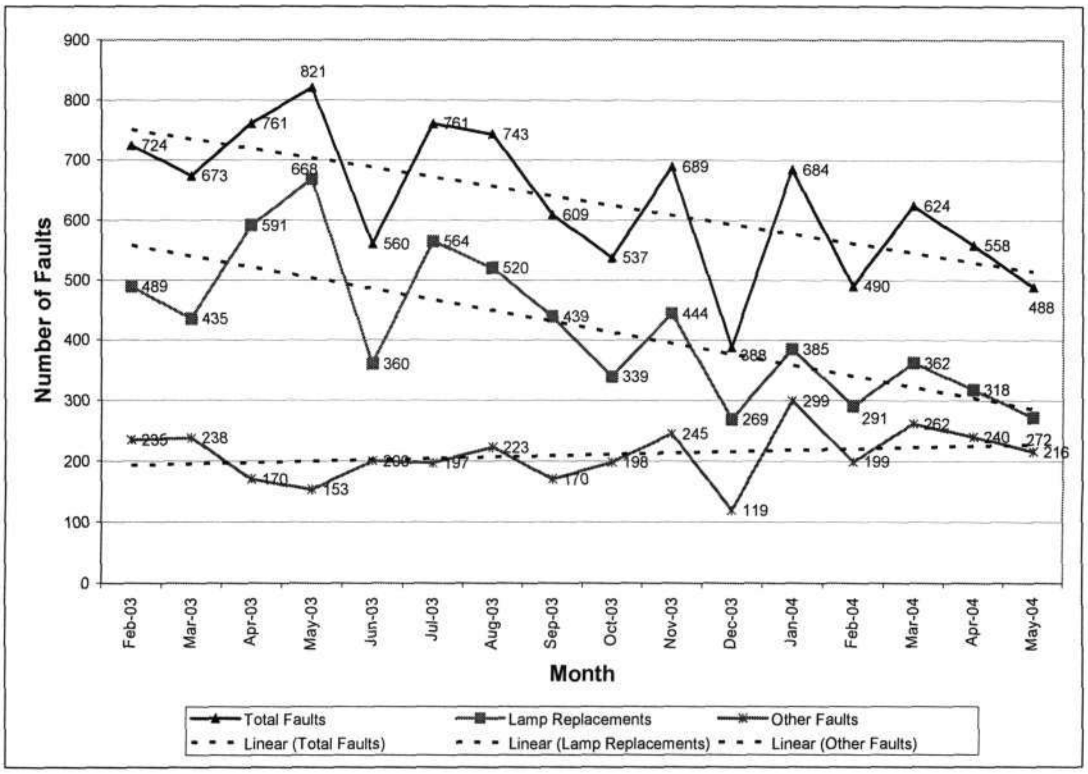
It has been accepted by many that the number of failures during the summer rainfall season is higher than during the winter months. This is due to the higher incidence of thunder storms with the associated wind and lightning.

The information from Benoni below indicates the volume of total faults attended per month as well as those faults due to lamp failure and 'other' faults.

An obvious trend on this graph is the general reduction in the number of faults attended, the reasons for this can be attributed to a general tightening of management control to reduce the number of repeat faults (see 4.11.4).

There is no apparent trend that indicates that more failures occur in the summer rainfall months. It must be noted that the Benoni system is predominantly switched by means of a central control signal (using ripple relays) and is therefore less reliant on photocell switching. Photocells are quite sensitive to lightning and a system controlled by photocells may show different results. The above results are very different to those depicted in SABS ARP 035, which show a clear decline during winter.

Figure 4-12: Number of Faults by Month - Benoni Network



4.11.2 Comparison of Failures between Network Types

It has previously been accepted that overhead systems are more prone to faults than underground networks.

> **Null Hypothesis H_{06}; $O_i = E_i$.** The proportion of Streetlight failures is independent of the type of supply network.
>
> **Alternate Hypothesis H_{A6}; $O_i \neq E_i$.** The proportion of Streetlight failures is dependent of the type of supply network.

The Benoni Data reflects the following.

Table 4-27: Comparison of Underground versus Overhead Network Faults

Type of Network	Network Percentage	Fault Percentage
Overhead	28.6%	28.1%
Underground	71.4%	71.9%

Chi-square test indicates that the null hypothesis $\mathbf{H_{05}}$ cannot be rejected (χ^2 critical value for d.f 1, is 3.84 and the calculated value is 0.63 with p = 0,0.428 for α =0.05) There is no difference in the number of faults for the different network types.

Further analysing the two most predominant fittings i.e. 70W HPS and 125W MV which together make up 75% of the total number of fittings installed the following results are obtained.

Table 4-28: Analysis Network Type Faults for 70W HPS and 125W MV fittings

Fitting Type	Type of Network	Network Percentage	Fault Percentage
125W_MV	Overhead	2.7%	3.2%
125W_MV	Underground	97.3%	96.8%
70W_HPS	Overhead	74.2%	72.0%
70W_HPS	Underground	25.8%	28.0%
125W +70W	Overhead	37.3%	37.5%
125W + 70W	Underground	62.7%	62.5%

- These figures show a different mix for the network types i.e. MV fittings are predominantly supplied through underground networks and HPS are mostly fed from overhead networks. The differences between network type and quantity of faults are very small, the statistical significance of which is tested using the Chi-square test. The hypothesis $\mathbf{H_{05}}$ is applicable however it has been applied to the different fitting types namely 125W MV and 70W HPS.

Chi-square indicates that $\mathbf{H_{05}}$ cannot be rejected in either case (125W case - χ^2 critical value for d.f 1, is 3.84 and the calculated value is 0.71 with p = 0,399 for α =0.05) and (70W HPS case - χ^2 critical value for d.f 1, is 3.84 and the calculated value is 2.67 with p = 0,102 for α =0.05)

4.11.3 Comparison of Faults attended by Type

There are a number of types of faults, which can occur on a system (see 2.3.1.1) it is necessary to classify the types and quantities of faults in order to correctly estimate future costs.

The faults by major category on the Benoni Network are as follows (From 12 Jan 03 to 9 Mar 04)

Table 4-29: Number of Faults by Major Category for Benoni

Fault Category	Number	Percent
Accident	172	1.84%
Control/Switching	189	2.02%
Fitting	7637	81.82%
Network	637	6.82%
Other	699	7.49%
Total	9334	100.00%

The faults can be subdivided in smaller categories for the same period, the results are as follows.

Table 4-30: Number of Faults by Sub-Category for Benoni

Fault Sub Category	Number	Percent of Total
Pole	172	1.84%
Contactor	6	0.06%
Daylight Switch	183	1.96%
Ballast	344	3.69%
Capacitor	132	1.41%
Diffuser	289	3.10%
Ignitor	19	0.20%
Lamp	6077	65.11%
Lamp Holder	179	1.92%
Fuse/Circuit Breaker	637	6.82%
New Fitting	597	6.40%
Other	699	7.49%
Total	9334	100.00%

It should be noted that these are the total number of faults attended; in some cases this does not mean that the particular fitting is not working i.e. some fittings are replaced as part of network upgrading.

The term 'critical fault' is used in the remainder of this dissertation to describe a fault where the lamp is not burning as opposed to a non-critical fault, which means the fitting is still operating but needs attention for some other reason.

4.11.4 The Problem of Repeat Failures

What has become very apparent with the information produced by the Benoni information system is that there are a very high degree of 'repeat' faults i.e. the repairs done are ineffective, resulting in the contractor having to return to the particular fitting a number of times before finally resolving the problem. A number of issues have been identified which are causing these repeat faults, namely;

- The quality of the fitting installed
- The age of the fitting
- The age of the network
- The spotting cycle utilised
- The poor skills level of maintenance personnel

It is difficult to isolate the major cause of repeat faults but the inability of the contracting personnel to identify when a fitting has become unserviceable and to take corrective action is a major factor.

It would be difficult to extrapolate this information to other LA's because of the different maintenance strategies used. Benoni operates a 14-day cycle during which the entire area is surveyed for failures. This cycle time results in a repeat failure being picked up relatively quickly, if the fault is then not properly repaired the second time around it resurfaces again (and again), a longer cycle time would reduce the number of times that the fault is reported resulting in a lower number of repeat faults. The following data has been extracted from the Benoni database with regard to the number of repeat faults.

Table 4-31: Quantification of Total Repeat Faults – Benoni

No of Poles with Faults	No of Faults	No of Repeat Faults	Percent Repeat Faults
6605	8960	2355	35.7%

Again this is the total number of faults on these poles, some of which are not critical faults. The percentage repeat faults are very high and a major cause for concern, the managing company has identified this issue and has adopted a number of strategies to combat this problem. Figure 4-12 indicates that the implemented policies are successful the number of faults has reduced from around 720 in Feb 03 to approximately 500 in May 04. The number of lamp replacements has also declined from 500 to around 300 over the same period. Lamps account for 66% of the total faults attended and analysing these faults (which are all critical) provides further insight to the magnitude of the problem.

Table 4-32: Quantification of Repeat Lamp Faults – Benoni

No of Poles With Lamp Faults	Total No of Lamp Faults	No of Repeat Lamp Faults	Percent Repeat Lamp Faults
4901	6025	1124	22.93%

Taken at face value this figure indicates that 22.9% of new lamps fail in less than 12 months (<4000 hours) this is dramatically higher than figures quoted by manufacturers.

On further investigation however it appears that repairs are not done systematically and very often the lamp is changed as a first approach, if the fitting then works it is assumed that the lamp was the problem. In an effort to reduce this unacceptably high percentage of premature lamp failures, the managing company in Benoni now tests all lamps returned from the field to ascertain if the lamp has genuinely failed or whether it has been replaced unnecessarily. The figure for February 04 is as follows.

Table 4-33: Quantification of unnecessary Lamp Replacements

Lamps Replaced Feb 2004	Lamps Found Working	Percentage unnecessary lamp Replacements
422	84	19.9%

Only with detailed information such as this can informed decisions be made, there is little doubt that most LA's have the same repeat problems but they cannot measure the effects and take the corrective action required, hence maintenance costs spiral.

5 Application of Information

The information covered and data collected in the preceding chapters covers a wide range of aspects, ultimately this information needs to be presented in a condensed easily understandable format for use by LA's or their streetlight maintenance service providers. Before we do this however we need to look at the viability of the following strategies if they are to be included in the recommendations.

5.1 The replacement of fittings

The primary objective of any maintenance programme is to keep maintenance and operating costs as low as possible. The decision to replace existing luminaires must depend on a total cost approach, which should include at least the following aspects.

- Maintenance costs of old versus new luminaires
- Reduction in operating costs through the use of energy efficient luminaires
- Increased output of newer technology and other intangible benefits.

5.1.1 Maintenance cost and Equipment Age

Typically the accepted life of a streetlight luminaire as quoted by the manufacturers is between 15 and 20 years. However, a luminaire is a fairly simple device and if the body of the fitting is sound it can be kept functional almost indefinitely by replacing three to four items. This is typically what is happening in South Africa, there are numerous fittings installed that are well over 40 years old which are still operational.

Older fittings however are often of poor design (in terms of lumen and thermal efficiency) the reflectors have become non-reflective and the diffusers badly discoloured. This has the result of decreasing the lamp life and also increasing the probability of repeat failures, which ultimately increases the maintenance costs on these fittings. It is necessary to determine what the impact of fitting age on maintenance cost is, and what the ideal replacement cycle is.

The Benoni database does not distinguish between the manufacturer and age of the fittings to allow the calculation and apportionment of these increased costs; however the database allows some comparisons to be made in terms of areas (or even streets). By careful selection of these areas a comparison can be made between various fittings of known installation date.

Three sample areas of approximately 250 fittings each were selected from the database, the age of the areas (according to installation date) is 4, 12 and 18 years. The data yielded the following results.

Table 5-1: Quantification of Faults vs. Fitting Age

	4 year area (14 Months data)	12 year area (14 Months)	18 year area (14 months)	
Number of Fittings	251	264	236	A
No of Faults	70	96	103	B
Percentage Faults To Total fittings	27.80%	36.36%	43.64%	C = B/A
Poles with Faults	66	74	66	D
Percentage Lamp Faults to Total fittings	23.50%	28.03%	27.97%	E
Percentage Repeat Faults to Failed fittings	5.71%	22.92%	35.92%	=(B-D)/D

An additional comparison of the types of faults between the different sample areas can also be made, the results are as follows

Table 5-2: Contribution by Subcategory of Faults to Fittings of Differing Age

Fault Sub Category	4 year area	12 year area	18 year area	Percent Total Network
Pole	2.50%	1.90%	1.81%	1.84%
Contactor	--	0.00%	0.20%	0.06%
Daylight Switch	--	2.40%	2.40%	1.96%
Ballast	--	2.20%	3.70%	3.69%
Capacitor	--	0.60%	1.51%	1.41%
Diffuser	3.00%	4.00%	3.20%	3.10%
Ignitor	--	0.15%	0.20%	0.20%
Lamp	81.70%	69.10%	65.10%	65.11%
Lamp Holder	1.40%	1.20%	2.10%	1.92%
Fuse/Circuit Breaker	11.40%	7.80%	6.20%	6.82%
New Fitting	--	4.80%	6.60%	6.40%
Other	--	5.85%	6.98%	7.49%
Total	100.00%	100.00%	100.00%	100.00%

The latter comparison clearly indicates that most maintenance costs on new fittings are lamp related. In the older fittings other factors also contribute to the maintenance costs although lamp replacement is still the dominant cost driver.

To calculate the difference in maintenance costs for the sample areas the material and labour costs can be determined using market related prices for each of the identified faults. The resultant costs are as follows:

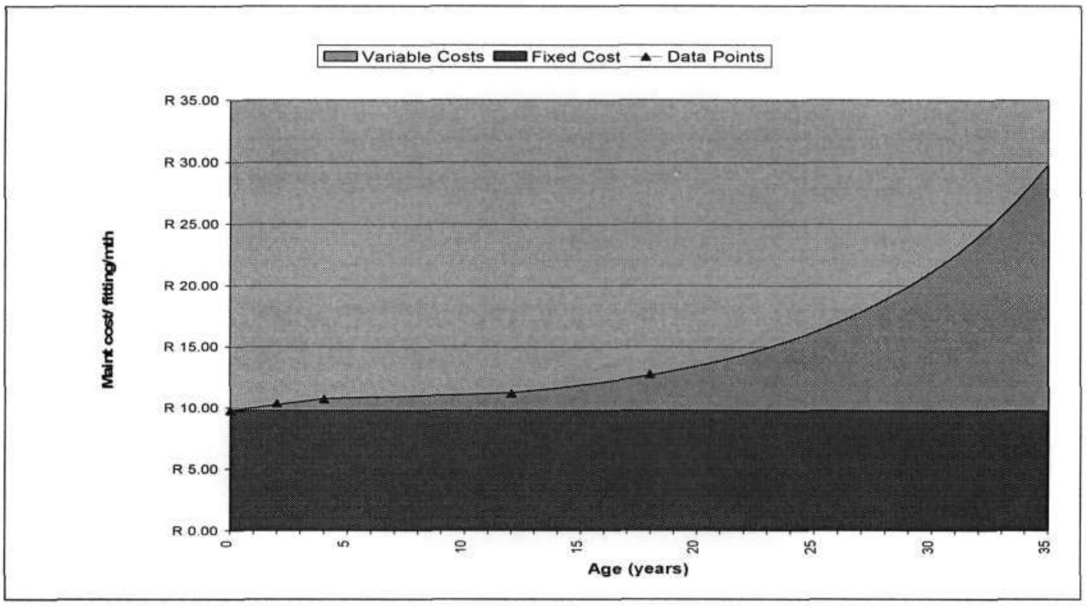
Table 5-3: Maintenance Cost by Fitting Age

Cost Type	Rand value per fitting per month				
Luminaire Age	0 Years	2 Years	4 Years	12 Years	18 Years
Fixed overhead costs	R 3.50	R 3.50	R 3.50	R 3.50	R 3.50
Management	R 3.50	R 3.50	R 3.50	R 3.50	R 3.50
Faults common to old and new luminaires	R 2.75	R 2.75	R 2.75	R 2.75	R 2.75
Total ' Fixed Cost'	**R 9.75**	**R 9.75**	**R 9.75**	**R 9.75**	**R 9.75**
Age dependant luminaire maintenance cost	R 0.00	R 0.50	R 1.00	R 1.48	R 2.92
Total Maintenance costs	**R 9.75**	**R 10.25**	**R 10.75**	**R 11.23**	**R 12.67**

Plotting the abovementioned points in graphical format produces the following results.

Figure 5-1: Average Maintenance Cost vs. Age – Benoni

This figure shows the rise in costs as fittings age



To find the optimum replacement cycle the variable maintenance costs and an average new fitting cost of R500.00 have been used to calculate the annual equivalent annuity (AEA) of various cycle times. The relevant calculations are shown in Annexure E, the results are as follows:

Table 5-4: Calculation of Optimum Fitting Replacement Cycle - Age Related costs

Cycle Time Years	PV of Maintenance	Purchase price of new fitting	PV	(5%) Annuity Factor	Annual Equivalent Annuity
15	R 162.80	R 500.00	R 662.80	10.3797	R 61.53
16	R 178.27	R 500.00	R 678.27	10.8378	R 60.11
17	R 194.32	R 500.00	R 694.32	11.2741	R 58.99
18	R 210.98	R 500.00	R 710.98	11.6896	R 58.14
19	R 228.28	R 500.00	R 728.28	12.0853	R 57.52
20	R 246.23	R 500.00	R 746.23	12.4622	R 57.11
21	R 264.87	R 500.00	R 764.87	12.8212	R 56.88
22	R 284.23	R 500.00	R 784.23	13.1630	R 56.84
23	R 304.31	R 500.00	R 804.31	13.4886	R 56.95
24	R 325.17	R 500.00	R 825.17	13.7986	R 57.23
25	R 346.81	R 500.00	R 846.81	14.0939	R 57.65
30	R 468.07	R 500.00	R 968.07	15.3725	R 61.91
35	R 614.24	R 500.00	R 1,114.24	16.3742	R 69.86

The calculations above indicate that a replacement cycle of 22 years is optimal, there is however only a small cost difference between the 20, 21 and 22 year cycles. The effect of an increase in the discount rate used would result in a lengthening of the replacement cycle and visa versa.

The National Treasury departments PPP unit utilises a money discount rate for LA's of between 10 and 12% per annum, if the real discount rate of 5% is combined with an anticipated inflation rate of 6% an equivalent money discount rate of 11.3% is achieved. For this reason a **real** discount rate of 5% per annum has been used in all the AEA calculations as this eliminates the need to 'estimate' the inflation rate.

By increasing the number of points and introducing additional sample areas the accuracy of the figures and trend line can be improved. However, given the time frames required to accumulate usable data and the lack of accurate records/inventory available in SA it is unlikely that these figures can be improved on at the present moment.

5.1.2 Energy Savings

As detailed there are energy savings which can be introduced through the use of energy efficient light sources, in South Africa the High Pressure Sodium (HPS) Lamps have become the technology of choice in energy efficient installations even though Low Pressure Sodium lamps are more energy efficient. This is due to the shorter life span and high lamp costs of LPS lamps and the relatively low energy charges in S.A. In Europe, there is prevalent use of Low pressure sodium (LPS) lamps, mainly as a result of the higher energy charges in these countries.

The objective is to determine at what stage the introduction of energy efficient lighting is optimal. To calculate this one needs to evaluate the total lifecycle costs of a particular luminaire. These costs however depend on the chosen maintenance strategy and regular maintenance costs. The two major strategies that can be followed are as follows;

- Burn to extinction (B-T-E)
- Group Replacement (Bulk)

With a B-T-E strategy it is difficult to compare life cycle cost between Mercury Vapour and HPS lamps, due largely to the fact that MV lamps can burn for many years (albeit at a greatly reduced output) i.e. no defined end of life, whereas the HPS lamps fail completely at the end of life. Leaving MV lamps to burn long after the light output has become unacceptable is common practice in this country, which makes cost comparison almost impossible between the two technologies. In order to compare the costs one must assume that MV lamps are replaced after their output has dropped below an acceptable level.

Further complicating the issue is the differing life expectancy of different HPS lamps (average life varies from 12000 to 24000 hours depending on manufacturer and specification). The procurement policy of most LA's is such that the lowest cost item is usually purchased with little regard to quality and expected life, this results in a myriad of different types of lamps installed which, makes accurate analysis extremely difficult.

A preliminary comparison can be made by assuming a replacement cycle of 16000 operating hours (± four years) for both HPS and Mercury Vapour lamps.

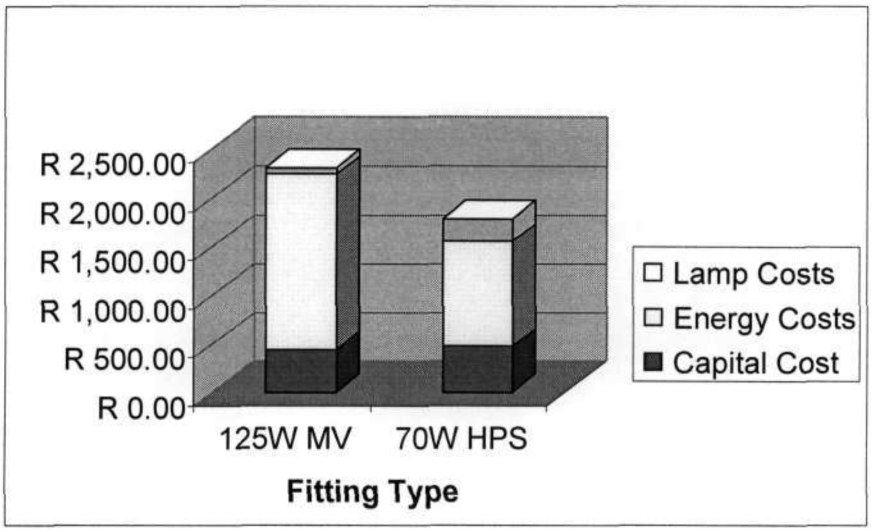
The following additional assumptions are used in the calculations presented below:

- Energy costs of 16c/kWh
- Burning hours per annum 4000
- Lamp Replacement cycle 16000 hours for both MV and HPS
- Fittings Compared
  - 125 W Mercury Vapour – output 6500 lumen
  - 70 W HPS – output 6300 lumen
- Lamp Costs R15 for MV and R47.50 for HPS
- Luminaire Replacement Cycle – 20 Years
- A 'real' discount rate of 5%

Table 5-5: Life Cycle Costs of 125W MV vs. 70W HPS

Life Cycle Cost Comparison		
	125W MV	**70W HPS**
Capital Cost	R 445.00	R 470.50
Energy Costs	R 1,792.00	R 1,075.20
Lamp Costs	R 75.00	R 237.50
Undiscounted Total Costs	R 2,312.00	R 1,783.20
Present Value @ 5% 'Real' discount rate	R 1,604.98	R 1,277.81

Figure 5-2: Life Cycle Cost of 125W MV vs. 70W HPS Fitting



The above shows that the 125W MV is clearly more expensive than the 70W HPS over a 20 year lifecycle.

Based on the above the replacement approach for fittings older than 20 years is obviously to replace the MV fitting with an HPS fitting. However where the MV fittings are less than 20 years old we need to determine the optimal age for converting to energy efficient technology.

To calculate the optimum replacement cycle a comparison is made between a number of cycles i.e. where the HPS fitting is introduced at various times. Note: an age-related replacement cycle of 20 years has been adopted from 5.1.1 above. The relevant calculations are shown in Annexure F, the results are as follows:

Table 5-6: Optimum Replacement Cycle for conversion to Energy Efficient Luminaire

Replacement Strategy	Cycle Time Years	PV	(5%) Annuity Factor	Annual Equivalent Annuity
Immediate Replacement	**20**	R 1,277.81	12.4622	R 102.53
Replacement after 1 Year	**21**	R 1,302.29	12.8212	R 101.57
Replacement after 5 Years	**25**	R 1,401.46	14.0939	R 99.44
Replacement after 10 Years	**30**	R 1,498.82	15.3725	R 97.50
Replacement after 15 Years	**35**	R 1,575.51	16.3742	R 96.22
Replacement after 20 Years	**40**	R 1,618.64	17.1591	R 94.33

The interpretation of the above is that existing 125W MV luminaires should be allowed to run to the end of their useful life (20 – 22 Years) before being replaced, at that stage they should be replaced with the most efficient technology available (in terms of total life cycle cost). This optimum cycle can be shown to be different for higher rated luminaires (i.e. 250W MV) where the optimal introduction of energy efficient fittings is after about 17 years.

5.1.3 Other Considerations

The introduction of new technology is not always welcomed by the community, particularly where there is a perception that the lighting levels have diminished due to the lower colour rendering properties of this new technology. This may even be the case where in actual fact the lighting levels have improved significantly. Unfortunately the energy efficient HPS lamps have a lower colour rendering index than MV lamps. This is more pronounced in the lower Wattage lamps (50W and 70W HPS). The impact of this should be measured before embarking on wholesale replacement of MV lamps especially in residential areas.

Lamp technology is developing at a rapid pace and longer life lamps with improved output and colour rendering properties are continuously being introduced by manufacturers. If LA's wish to embark on a replacement strategy a phased approach using the most up-to-date technology at the time will allow the LA to move with these new developments and not lock itself into one technology which may become obsolete in a few years time.

When replacing fittings a proper reclassification of the road types and lighting levels should be undertaken as road usage often changes, the simple replacement of the existing luminaires with energy efficient types of the same lumen output may not be sufficient. Where areas have been upgraded architecturally, structurally or the usage has changed, lighting installations should be provided which are suitable for the new purpose. This will ensure that the levels of accidents, theft and vandalism are kept to a minimum, through proper lighting design.

5.2 Re-Lamping Policy

As detailed the two primary re-lamping policies utilised are Burn to Extinction and Bulk (Group) re-lamping.

According to a study by the Institution Lighting Engineers into Lamp Replacement policies in Local Authority Street Lighting Services[xxxviii], There is no substantive proof that the one policy is superior to the other. This is contrary to claims made by lamp manufacturers, who encourage the implementation of bulk re-lamping strategies. The issue appears to attract substantial debate with no clear winner, although most agree that where traffic control is problematic the Bulk replacement policy is the policy of choice.

The following extract from the ILE publication, page 15, summarises the situation quite clearly;

> "On a national basis very few Local Authorities have the ability to evaluate lamp replacement policy choices in a robust and rational manner using their own information systems. This is primarily because of the limited amount of accurate field data individual authorities have on lamp mortality and the costs of carrying out different replacement activities".

There are Pros and Cons to both policies, the following table summarises the strengths and weaknesses of the two re-lamping policies.

Table 5-7: Strengths and Weaknesses of Major Re-lamping Policies

Bulk Replacement	
Strengths	**Weaknesses**
Consistent (and high) lighting quality	'Expensive' policy
Lower Lamp Failures	Cost of lost lamp life/ waste
Low Risk to the community, authority	Reliance on Manufacturers' data
Integrated with Planned Maintenance	Environmentally 'unfriendly' (glass disposal)
Easily integrated with design Specifications	Limited evaluation to support policy
Predictable workloads/ ease of planning	
Limited public complaints	
Burn to Extinction	
'Cheaper' Policy	Lumen Depreciation
Maximises lamp life	Increased Lamp Failures
Environmentally friendly (glass disposal)	Increased control gear failures
Responds to improved technology/ lamp performance	Increased administration
	Failure to meet design standards
	Increased risk to the community
	Constant Energy cost for reduced output
	Uncertainty in budgeting and costing

In S.A the situation is worse in terms of available data and accuracy of inventories, so the comparison of the two policies on the basis of historical data is not feasible. An approximate comparison can be made using the statistical data from Benoni for the B-T-E policy and comparing this to 'theoretical' bulk replacement strategies of 3 and 4 years. This comparison for an installation of 20000 identical fittings is as follows. Calculations are presented in Annexure G

Table 5-8: Cost Comparison of Re-lamping Policies

Replacement Strategy	Cycle Time Years	PV	(5%) Annuity Factor	Annual Equivalent Annuity
Burn to Extinction	-	R 562,057.41	-	R 562,057.41
Bulk Replacement 3 year	3	R 2,439,974.15	2.7232	R 895,995.21
Bulk Replacement 4 year	4	R 2,532,044.39	3.546	R 714,056.51
Bulk Replacement 3 year	5	R 2,724,329.33	4.3295	R 629,248.03

Assumptions that are made to obtain the above are as follows;

- B-T-E lamp failure rate of 2.08% per month (25% per annum), this equates to a total lamp replacement cycle of 4 years. Spot replacement Labour cost R60.00 and Lamp Cost R55.00 per lamp. The mean lamp replacement rate in Benoni is 1.95% per month, including repeat faults, which indicates a slightly longer cycle period (51 Months) in practice which would reduce the cost of this policy.
- 3 Year Bulk replacement, Labour cost R25.00 (bulk) & R60.00 (spot) Lamp cost R55.00. Failure rates assumed (2% -year 1; 5% - year 2; 43% - year 3) i.e. this relates to 50% failure over 3 years which is in line with the definition of average lamp life.
- 4 Year Bulk replacement, Labour cost R25.00 (bulk) & R60.00 (spot), Lamp Cost R55.00. Failure rates assumed (1% -year 1; 2% - year 2; 10% - year 3; 37% - year 4).
- 5 Year Bulk replacement, Labour cost R25 (bulk) & R60.00 (spot), Lamp Cost R55.00. Failure rates assumed (1% -year 1; 2% - year 2; 10% - year 3; 37% - year 4 and year 5).

The predominant factor in the above calculations is the initial capital required to convert from an existing B-T-E to a bulk replacement strategy. The bulk strategy has many advantages and is not significantly more expensive than a B-T-E policy if it is enforced from the outset and maintained throughout the lifetime of the fittings. However, once the bulk strategy has been allowed to slip, the B-T-E will be less expensive. It is interesting to note that with a bulk re-placement strategy of a minimum of 1.5 times the number of lamps is used compared to a B-T-E strategy. The advantages to the lamp manufacturer in promoting bulk strategies are therefore obvious.

There are additional factors to consider such as reduced spotting requirements, reduced overheads for years two and three (less stock, fewer staff and less equipment) due to the lower number of faults. These issues complicate the calculations substantially and need to be made using the actual LA's (or contractors) costing structure.

5.2.1 Lumen Depreciation

With the B-T-E policy lamp age should eventually reach equilibrium at the average life point (i.e. at the point where 50% of lamps have been replaced and 50% survive). This means that given a 12000 hr average life some lamps may be up to 24000hrs where others are newly installed. Where the difference in lumen output between the old and new is more than 25% it is noticeable to the eye. With a bulk replacement strategy, the average lamp-age will continuously decrease up until the point of planned re-lamping, if this takes place at the average rated life no lamp will be more than the average-age older than its neighbour.

Remember that the power consumption of a lamp remains constant even though the lumen output has decreased. From the point of energy efficiency bulk re-lamping provides more lumen per Watt than does the B-to-E policy.

From a practical viewpoint MV lamps must be replaced between 12000 and 16000 hours otherwise the light output will drop below 65% of the original, which is unacceptable. HPS lamps are therefore more suitable for a B-to-E policy as the lumen depreciation is not as dramatic as the Mercury Vapour fittings.

6 Conclusions and recommendations

6.1 Introduction

The information presented in the previous chapters has detailed and expanded on the aspects highlighted in the problem statement. This chapter attempts to summarise the issues and where possible make recommendations.

6.2 The Future of Streetlight Maintenance

During the timeframe of preparing this paper strong indication has been given that streetlight maintenance will remain with the Local Authorities. It will therefore be up to the LA's to decide on how the ongoing operation of street lighting will be accomplished. There is also a growing sentiment that LA's will not provide the maintenance function in-house, but rather that it will be outsourced in some shape or form.

There is a strong possibility that many LA's will follow the path of least resistance and simply hand over the function to the local RED. In the authors opinion this would be a grave mistake as the RED's will consist of former municipal electrical staff and Eskom distribution staff. The track record of both these bodies in the maintenance of street lighting is not good as is evident from the physical survey results. As street lighting has unofficially always been viewed by many LA's as non-core business and Eskom has for some time indicated that it is not in the business of providing or maintaining street lighting, the maintenance of street lighting by the RED's will certainly not achieve priority status.

Over and above this there is a proposed transition period of about four years before the RED's are fully entrenched and operational as a single entity. This will no doubt lead to severe disruptions in service delivery even in core areas, street lighting will no-doubt receive very little attention during this time.

There are several forms of public private partnership models both internationally and locally that can be utilised to provide cost effective streetlight maintenance, and also provide much needed capital to upgrade old and inefficient streetlight networks. The Benoni model is an outstanding local example of such a partnership. There are however many pitfalls in outsourcing and a poorly structured contract agreement can also lead to rising costs and poor delivery as manifested in Germiston.

It is recommended that LA's appoint suitably experienced transaction advisors to research and propose alternative solutions for the full outsourcing of streetlight maintenance. The alternative of setting up an internal department solely for the maintenance of street lighting would in the authors opinion be inefficient due to the constraints of operating within the local government environment.

6.3 Network Information

The information collected from council officials indicates that there is a serious lack of accurate information with regard not only to streetlight inventory but the electricity network in general.

Without accurate information it is difficult to properly plan an effective maintenance programme. *"If it can't be measured it can't be effectively managed." (Vally Padayache, VP City Power, 2004)*

More seriously however many councils do not have a clue what their streetlight maintenance is costing them in terms of annual or monthly cost per installed fitting, realistic budgeting is not possible with the information currently available.

6.3.1 Budgeting and Benchmarking

Without accurate information, councils cannot benchmark their costs against one another the resultant is that costs for the maintenance of street lighting for the areas covered ranged from around R11.50 to R26.50 per fitting per month, a difference of over 230%. There is evidence in some areas that costs may exceed R40.00 per fitting per month. This gross disparity comes about through lack of proper management and is in effect a waste of tax-payers money.

The new municipal finances Act that comes into operation in June/ July 2004 will require that LA's regularly benchmark their cost structures against similar LA's, this is hoped to eradicate the inefficient utilisation of resources. This legislation will hopefully promote accountability, which is drastically lacking in most local government structures.

In the light of this it is imperative that LA's collect accurate information regarding their street lighting network and implement systems to keep this information up-to-date. This data should be put in place as soon as possible as it is indispensable when drawing up a comprehensive maintenance policy. The establishment of the inventory can be included in the transaction advisors scope of responsibilities.

6.3.2 On Going Record Keeping

Once the inventory has been established accurate record keeping of both material usage and the types and quantities of faults should be maintained. This historical data will allow the streamlining of stock levels and promote accurate budgeting and resource planning.

6.3.3 Requirements for Corrective Work

A comprehensive survey of the existing infrastructure will also provide information regarding the status of the network and the condition of the luminaires. This will allow the establishment of a capital budget for 'normalisation', which is required in many areas to bring the network (infrastructure <u>and</u> luminaires) back to acceptable and safe standards.

Where the road usage has changed since the original street light installation, the lighting design should be amended and if necessary the network changed accordingly.

Most LA's are cash strapped and often claim to have no money to upgrade the network, a comprehensive analysis of the network will allow them to prioritise areas and also to put a planned capital upgrade programme in place. Through the adoption of an effective maintenance policy there is a substantial amount of money that can be saved. This money should then be made available for capital upgrading, where necessary private funding can be obtained through a formal PPP procedure.

6.4 Basic Policy for Streetlight Maintenance

6.4.1 System Availability

From the responses received a system availability of 99% is expected by over 52% of the public and an availability of better than 95% is expected by 38% of the public. It has however been shown that there is a poor perception by all groups of the actual network status indicating a substantial over estimation of the actual delivery which is less than 90% in most areas.

The approach adopted to establish a benchmark for system availability in the light of this information is a therefore a practical one. The data from Benoni indicates that on average with a Burn-to-Extinction policy in a 'stable' network approximately 2.92% failures (of the total installed base) occur on a monthly basis. This would indicate that a spotting/repair cycle which covers the entire area once a month would maintain the system at better than 97% availability. A spotting cycle of 14 days and a mean repair cycle of 5 days can therefore maintain an availability of better than 98.0%. With the poor public perception this outage rate should satisfy most of the public.

An availability of 98% is therefore relatively easy to achieve and is the recommended *minimum* standard, which LA's should aim for. Should LA's want to achieve an better average status a faster cycle time will be required and the cost implications need to be evaluated, the law of diminishing returns will apply in this situation.

Where a bulk replacement policy is employed, the number of failures will gradually increase as the age of the lamps increases. The bulk replacement strategy however only reduces the lamp failures, the other faults i.e. network, accident and vandalism will logically be similar for whichever policy is adopted. The figures from Benoni indicate that the total monthly failure rate for non lamp faults is 0.97% (≈ 1%). Therefore To maintain a system availability of better than 98% with a bulk replacement policy a spotting cycle of 2 months would be sufficient for the first year. This cycle would however need to be increased so that by the third year a 14 day cycle is again in place, to allow for the increasing failure rate. This approach will however result in fittings not being repaired for up to 2 months which would in many cases be unacceptable, especially where poles have been knocked down, or an unsafe condition exists.

As spotting is a relatively small portion of the total maintenance costs it is recommended that a minimum spotting cycle of 1 month be maintained for either re-lamping policy. A cycle of 14 days however is preferred as it has the added benefit of significantly reducing public complaints as faults are reported and repaired before the public reports them and it limits the length of time which unsafe conditions will be present on the network.

6.4.1.1 Public Complaints

The public is known to more readily complain about the street lighting in close proximity to their residence. The call centres where complaints are logged very seldom receive complaints about lighting on major routes.

With this in mind spotting cycles can be tailored to cover the major routes more frequently than residential areas. This would be particularly effective where a bulk re-lamping policy is used in residential areas where mercury vapour fittings are installed.

6.4.2 Acceptable Response Times

Over 48% of the public thought that 24 Hours was an acceptable response time and a further 38% thought that 48 hours was acceptable. In practice to achieve these times is not that easy, particularly because the area that a single maintenance crew can cover is usually quite expansive. Typically a single team can maintain an area of 15000 luminaires, which is roughly 750km of network. At a failure rate of ≈ 3% per month each team would need to attend to 450 faults monthly which averages out at ≈ 23 faults per working-day which can be comfortably achieved. Complaints are usually of a random nature and can occur anywhere in a particular area; to purely attend to complaints would be an ineffective utilisation of these resources, as they would need to cover large distances between faults. To be at their most productive maintenance teams would follow the spotting cycle and attend to faults in one particular location before moving to the next.

Where a good spotting policy is in place the public complaints are substantially reduced, in the Benoni case by over 75%. The average number of complaints per day in Benoni is less than three for an area of ≈ 22000 fittings.

If the requirement of 24 hours were to be achieved this would mean additional maintenance teams. If the area is large enough a single team could be dedicated to addressing complaints while the other teams carry out normal maintenance, there is however a cost implication. which needs to be considered. Street lighting is a not a critical service and response times are crucial, the additional cost of providing 24 hr response times is in the authors opinion not justifiable.

Benoni have adopted a repair cycle of 5 days this has resulted in ≈ 50% of faults being attended within 48hrs this includes the repair of faults identified by the spotters. With improved material availability this could be improved dramatically to approximately 80% within 48 hours. A practical benchmark would be 66% of faults repaired within 48 hours and better than 95% in 5 days.

6.4.3 Capital Upgrading

There are two aspects to the above, namely the need for regular fitting replacement and the need to install energy efficient lighting.

6.4.3.1 Regular Capital Replacement

It is a well recognised fact that regular capital replacements result in lower maintenance costs and high system availability. The calculations presented in chapter five indicate that a replacement cycle of 20 years (22 to be exact) is optimal.

In SA no such replacement schedule has been implemented resulting in many luminaires installed which are difficult and expensive to maintain. This situation needs to be rectified firstly, and then a regular replacement cycle of 5% per annum should be implemented. This will ensure that maintenance costs will remain manageable.

To manage this good record keeping is required and equipment should be marked with the installation date.

6.4.3.2 Introduction of energy efficient luminaires

The calculations in chapter 5 show that in most cases existing Mercury Vapour fittings should only be replaced once they have reached 'retirement age' (20 Years). In SA however there are substantial numbers of fittings which are older than this cut off age and it is recommended that these fittings be replaced as a priority. This however would require considerable capital outlay which most LA's cannot raise. The case for private funding through a PPP model is therefore evident where the LA does not have the financial resources.

LA's should however not embark on the wholesale replacement of MV fittings where these fittings have been recently installed. A scheduled phasing out of these 'new' MV luminaires appears to be the most financially viable option.

With the increasing drive towards energy efficiency additional funding may be available which would speed up the migration to energy efficient technology. Sources of funding should be continuously explored by the LA or their advisors. The Eskom funding programme now provides grants of up to 50% for qualifying projects.

6.4.4 Re-lamping Policy

The re-lamping issue is a complex one. The following recommendations provide a practical starting point until such time that more information is made available through the collection of historical data.

6.4.4.1 Mercury Vapour

Due to the rapid lumen depreciation of mercury vapour lamps and their tendency to continue burning almost indefinitely MV lamps should be replaced between 12000 and 16000 hours. If the information system utilised can keep tack of individual lamp ages it could automatically request replacement of specific MV lamps at a pre-determined age. As there is currently no LA in the country which utilises a sophisticated information system (besides Benoni) this is unlikely to happen in the near future. A more appropriate approach is to adopt a bulk replacement policy for areas with mercury vapour lamps. Although this is a more expensive approach it will ensure that lighting levels do not drop below the levels required by the SABS in accordance with the designated road classification.

6.4.4.2 HPS Lamps

The output of HPS lamps does not drop as significantly as does MV technology, HPS lamps also have a definite end of life. Because of this characteristic and because It has been shown to be expensive to change from a Burn to Extinction policy to a bulk replacement policy, it is recommended that where an effective B-to-E policy is in place it should not be changed, despite the advantages offered by a bulk replacement policy. Each situation however needs to be weighed up on its individual merits.

Where large scale upgrading is done (i.e. phasing out of MV fittings) a bulk replacement policy should be adopted in these areas because of the advantages provided by this policy.

Where a bulk replacement policy is in place it should be maintained, it is costly to swap between policies.

6.5 Additional Good Practice Recommendations

The following items are recommended to ensure that costs are controlled and service levels are achieved with maximum efficiency.

a. Dating of equipment

   As street lighting is dispersed over an extremely wide area and there are large quantities of luminaires, lamps etc that need to be replaced on a daily basis. It is recommended that all equipment installed is dated prior to installation. There are a number of reasons for this namely

   - It allows record keeping of premature failures in a field setting which can be compared to manufacturer's claims. This allows tighter control of materials to ensure optimum delivery without excessive stock holding.

- It allows the return of items still under guarantee; some manufacturers will not only replace the defective item but will also cover additional labour charges for the reinstallation of the item.
- If an item is returned within a certain predetermined period (i.e. 12 months for Lamps) a testing procedure should be initiated to determine whether the item is still operational and has been replaced unnecessarily. If it is found to be working this usually means the actual problem has not been solved and additional failures can be expected on that fitting. Such a finding should initiate a corrective action procedure on the particular fitting in question.

b. Rationalisation of Materials

Most LA's have over the years purchased various types of luminaires through numerous different contracts/ sources the result is that a host of various materials have been installed on the networks, sometimes these items cannot be replaced as they are no longer manufactured. A process of consolidation whereby the quantity of different types of luminaires, poles, outreach arms etc, are reduced to an absolute minimum. This not only reduces the number of items required to be kept as spares, it also standardises the network it greatly simplifies ordering and accounting.

c. Ensure that materials ordered are correct in terms of technical parameters of the supply network i.e. voltage. This will help reduce the premature failures and prolong equipment life.

d. Identify fittings which are repeatedly failing and take corrective action, in Benoni it was not uncommon for a fitting to have three or four new lamps installed over a period of six months. The problem was invariably found to be the lamp holder. This is extremely costly and should be understood and system should be put in place to minimise such faults – it is often cheaper to replace the fitting than to repeatedly return to it for maintenance.

e. Training

The best laid plans and information systems do not make up for proper training of field staff. Good repairmen will identify the problem quickly and take the correct action. Luminaires in normal circumstances should only be attended to once in every three to four years. Maintenance should be preventative rather than just fixing the problem.

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Annexure A

General Public Questionnaire

SURVEY ON PUBLIC LIGHTING MAINTENANCE DELIVERY

Introduction

This survey forms part of my MBA thesis, which is centred on the effectiveness of public lighting maintenance practices of Local Authorities (Municipalities).

The purpose of this questionnaire is to obtain the opinion of the general public in the area of streetlighting and the maintenance thereof in the Gauteng area.

The guideline to streetlight installation and maintenance in South Africa is the SABS code of Practice ARP035, which states that for a Local Authority (LA)

> " *To be able to render a service that complies with broad national and international standards (world class) and that consistently meets expectations of the local communities, service levels should be measurable and be monitored. .... The following are useful measures of performance:*
> - *Percentage of lights burning at one time*
> - *Response times*
> - *Light levels*
> - *Reporting facility*
> - *Cost"*

The Code of practice does not go as far as to state what these levels should be. Part of the purposes of this study is to try and determine what the appropriate, performance levels for South Africa are. These will be used as benchmarks to establish a guideline for Local Authorities as to what is acceptable in practice and hopefully to enable them to provide a better service to the communities they serve.

It would be greatly appreciated if you could take the time to complete the questionnaire and Email it to me at colin@pmce.co.za . The survey should take approximately 10 minutes to complete. All information supplied will be treated confidentially.

Note: To get the ☑ symbol press Alt 3
To get the ☐ symbol press Alt 2

Thank you for your time.

Colin Parfitt

1 Your Details

1.1 Name of City/Town in which you reside ____________________

Name of suburb/ township ____________________

Your Occupation ____________________

2 Your Area's Maintenance

2.1 Do you notice <u>any</u> of the following when walking or driving in your area?

a) The streetlight (or mast) outside your <u>house</u> is not working ☐

b) The streetlights (or masts) in your <u>area</u> are not working ☐

c) The lights are burning but the light levels are very low ☐

d) Very seldom take notice of the lighting ☐

2.2 If you notice that there is a light (or lights) out of order do you report this?

a) Yes, I report all faults to my councillor ☐

b) Yes, I contact the Local Authority directly and report all faults ☐

c) Yes but I only report the lights directly outside my house or in my street ☐

d) No, I do not know where to report them ☐

e) No someone else will report it ☐

2.3 Have you reported a fault (defective fitting/ section/ area) in the last 12 months?

Yes ☐

No ☐ (please go to question 2.4)

2.3.1 How would you describe the manner in which your complaint was handled?

a) Excellent – Efficient handling of my call and repairs carried out quicker than expected ☐

b) Good – Complaint effectively handled and repairs carried out within an acceptable time ☐

c) Average - ☐

d) Poor – Incompetent handling of call and took a long time to attend to the fault ☐

e) Extremely Poor – Had to call repeatedly, took excessively long to attend to the problem ☐

2.3.2 How long did it take the local authority to attend to your complaint? ('<' means less than)

☐ < 24hrs, ☐ < 48hrs, ☐ < 5 days, ☐ < 14 days, ☐ < 1mth, ☐ Longer,

☐ Had to follow up after ____ days before repairs were carried out

☐ Other (Please give details)____

____

____

2.4 With regard to Streetlight maintenance (SLM). How would you describe the maintenance in your area provided by your Local Authority – in general.

a) Excellent – most lights bum brightly and those that are out are repaired within a few days ☐
b) Good – most lights burn brightly and those that are out are repaired within a few weeks ☐
c) Fair – many lights burn and those that are out are repaired within 1 month ☐
d) Fair – most lights bum but they are not very bright ☐
e) Poor – many lights are out and are only repaired when someone complains ☐

2.5 Does your Local authority replace lamps when the lighting levels in the area have become poor?

a) Yes, it is noticeable when they are replaced ☐
b) Do not notice/ do not know ☐
c) No, they wait until the lamp fails ☐

2.6 What percentage of Streetlights, in your area, are working, on average?

a) 99% ☐ (only 1 streetlight out of every hundred streetlights is not working)
b) 95% ☐ (only 5 out in every hundred streetlights are not working)
c) 90% ☐ (1 streetlight out of every ten streetlights is not working)
d) 75% ☐ (1 streetlight out in every four streetlights is not working)
e) Other ________%

2.7 How would you rate the general appearance of the Streetlighting installation in your area? (Are all the poles and light fittings straight? Are there lots of broken fittings? are the cover plates all closed?)

a) Excellent ☐
b) Good ☐
c) Average ☐
d) Poor ☐
e) Very Poor ☐

3 Your Expectations

3.1 What in your opinion is an acceptable time for the Local Authority to attend to public complaints?

☐ < 24hrs ☐ < 48hrs ☐ < 5 days ☐ < 14 days ☐ < 1mth Other ______

3.2 What in your opinion is an acceptable percentage of streetlights being out at any given time?

a)	Less than 1%	☐ (1 out in every hundred fittings)
b)	Less than 5%	☐
c)	Less than 10%	☐ (1 out in every ten fittings)
d)	Less than 25%	☐ (1 out in every four fittings)
e)	Other	________%

Thank You

Annexure B

Expert Questionnaire

SURVEY ON PUBLIC LIGHTING MAINTENANCE

Introduction

This survey forms part of my MBA thesis, which is centred on the effectiveness of public lighting maintenance practices of Local authorities.

The purpose of this questionnaire is to obtain the opinion of knowledgeable people in the area of streetlighting maintenance. The emphasis of my study is on the maintenance of the existing networks and not on design issues.

SABS code of Practice ARP035 states the following:

" *To be able to render a service that complies with broad national and international standards (world class) and that consistently meets expectations of the local communities, service levels should be measurable and be monitored. .... The following are useful measures of performance:*

- *Percentage of lights burning at one time*
- *Response times*
- *Light levels*
- *Reporting facility*
- *Cost*"

Part of the purposes of this study is to try and determine what are the appropriate, percentages, times and levels for South Africa. These will be used as benchmarks to establish a guideline for LA's as to what is acceptable in practice.

It would be greatly appreciated if you could take the time to complete the questionnaire and forward it to colin@pmce.co.za. The survey should take approximately 15 minutes to complete. Please contact me on 083 680 9514 if you have any queries or require clarification.

The following short cut keys can be used to complete the form Electronically:

- Alt 3 for ☑
- Alt 2 for ☐

If you have trouble completing the form electronically please print it and fax the completed form to 011 4218124

All information supplied will be treated confidentially.

Thank you for your time.

Colin Parfitt

1 Your Details

1.1 Name of City/Town in which you reside ____________________

Your Name: (optional) ____________________

Contact Number: (optional) ____________________

Your Occupation ____________________

Main activity of your business ____________________

1.2 In general how would you rate the maintenance of streetlighting in South Africa

____

____

____

____

____

2 Your Area's Maintenance (around your home <u>or</u> office)

Please Note: I am looking for information on the maintenance of the existing infrastructure and not on the appropriateness of the lighting design.

2.1 With regard to Streetlight maintenance (SLM). In general How would you describe the maintenance in your area provided by your Local Authority (LA).

a) Excellent – very high level of system availability and good lighting levels ☐

b) Good – high level of system availability and good lighting levels ☐

c) Fair - low level of system availability but good lighting levels ☐

d) Fair – high level of availability but poor lighting levels ☐

e) Poor - low levels of availability and lighting levels ☐

2.2 Does your LA replace lamps whose lighting levels have dropped below an acceptable level ?

a) Yes, there is a noticeable area bulk replacement cycle ☐

b) Yes, but on an individual fitting (or small group) basis ☐

c) Can't say ☐

d) No, they wait until the lamp fails ☐

2.3 What percentage of streetlights in your area are out of service on average?

a) Less than 1% ☐ (1 out in every hundred fittings)

b) Less than 5% ☐ (1 out in every 20 fittings)

c) Less than 10% ☐ (1 out in every ten fittings)

d) Less than 25% ☐ (1 out in every four fittings)

e) Other _______%

3 Performance Levels

3.1 What in your opinion is an acceptable time for a Local Authority to attend to public Street lighting complaints?

☐ < 24hrs ☐ < 48hrs ☐ < 5 days ☐ < 14 days ☐ < 1mth Other ______

3.2 What in your opinion is an acceptable percentage of streetlights being out of service at any given time?

a) Less than 1% ☐ (1 out in every hundred fittings)

b) Less than 5% ☐ (1 out in every 20 fittings)

c) Less than 10% ☐ (1 out in every ten fittings)

d) Less than 25% ☐ (1 out in every four fittings)

e) Other _______%

3.3 At what total light output level do you feel **lamps** should be replaced where there is no detailed record of the design level, assuming that levels were recorded when the lamps were first installed? ***Assume that the diffuser and reflectors are as new***.

Light output is:

a) <90% ☐

b) <80% ☐

c) <70% ☐

d) <60% ☐

e) <50% ☐

3.4 When should the **entire luminaire** be replaced/ refurbished in terms of total light output when compared to a new fitting of the same type? ***Assume that a new lamp has been installed.***

Light output is: (with regard to a new fitting and lamp)

a) <90% ☐
b) <80% ☐
c) <70% ☐
d) <60% ☐
e) <50% ☐

3.5 What do you think is the most practical way of comparing the SLM cost between different Cities/ Towns/ Divisions? (Ignore running costs)

a) Number of consumers i.e. cost of SL per consumer ☐
b) Total area maintained in km^2 i.e. cost of SL per km^2 ☐
c) Total number of fittings maintained i.e. cost per fitting ☐
d) Per km of illuminated roadway i.e. cost per km of lighting ☐
e) Other (please state) ______________________________

4 Bulk Replacement (BR)

4.1 What is your opinion of a bulk lamp replacement strategy – (if managed properly)?

a) It is the most effective way to maintain both system availability and lighting levels ☐
b) Not all LA's practice this strategy there must be a reason for this. ☐
c) Difficult to manage with available resources ☐
d) Other ____

____

4.1.1 Which of the following do you think more appropriate in establishing the cycle time of a BR strategy?

a) Combination of Luminaire Maintenance factor and Lamp Survival factors provided by manufacturers ☐
b) Actual measured lighting levels ☐
c) Monitor number of complaints received from public ☐

Thank You

Annexure C

Public Officials Questionnaire

SURVEY ON PUBLIC LIGHTING MAINTENANCE

Introduction

It would be greatly appreciated if you could take the time to complete the attached survey that forms part of my MBA thesis, which I am doing, through the University of Natal (my student number is 201509456). My thesis is centred on public lighting maintenance practices utilised by Local authorities.

The survey should take between 15 and 25 minutes to complete. Should you require a summary of the results please provide a postal (or email) address in the space provided.

Please contact me on 083 680 9514 if you have any queries or require clarification.
It would be greatly appreciated if you could take the time to complete the questionnaire and forward it to colin@pmce.co.za **or** alternatively fax it to 011 421 8124.

If you have received the form electronically the following short cut keys can be used to complete the form

- Alt 3 for ☑
- Alt 2 for ☐

If you have trouble completing the form electronically please print it and fax it to the number above.

All information supplied will be treated confidentially.

Thank you for your time.

Colin Parfitt

1 Your Details

1.1 Name of City/Town ____________________

Your Name: (optional) ____________________

Contact Number : (optional) ____________________

2 Your Role

2.1 Please indicate briefly what your role is in the maintenance of streetlighting? (i.e. City/Town Elec eng, Divisional Manager, Maintenance Foreman etc)

____

2.2 Do you deal directly with the public when they phone in complaints?

Yes ☐

No ☐

2.3 Are you involved with establishing budgets for street light maintenance?

Yes ☐ (please go to question 2.3.1)

No ☐ (please go to question 3)

2.3.1 Which most aptly describes how your budget for SLM is determined?

a) Escalate previous years budget ☐

b) Analysis of personnel, equipment and material costs based on past usage and predicted costs ☐

c) Other (please provide details) ____________________

____

2.3.2 Does your department allow for or consider any of the following when compiling you SLM budget?

a) The total number of fittings installed on the network ☐

b) The total number of faults attended ☐

c) Build in "Fat" in case of unforeseen events ☐

d) Include for upgrading and replacement of old networks/fittings ☐

3 System Information

3.1 Do you know how many complaints/ phone-in-faults your department receives on a monthly basis?

Yes ☐

No ☐

3.2 Do you know the total number of fittings/faults that are attended each month – this includes the complaints and phone-in-faults from the public.

Yes ☐

No ☐

3.3 Do you know how many different types of faults were rectified over the past year? i.e. (the number of lamps replaced, the number of capacitors/ ballasts installed, cable or line faults etc)

Yes ☐

No ☐

If your answer to the above is NO please give your best estimate for questions 3.3.1 to 3.3.3

3.3.1 Please indicate the percentage of repairs carried out according to the following categories.

Under **Other** please include non-critical items such as ,cleaning diffuser, diffuser replacement, closing cover etc.

- Lamp Replacements ______%
- Capacitor Replacements ______%
- Ballast Replacements ______%
- Fitting Replacements ______%
- Cable/ Circuit Faults ______%
- Pole replacement/ repair ______%
- Other ______%
- Total 100 %

3.3.2 Of the above what percentage is as a result of the following?

- Accident damage ______%
- Vandalism ______%
- Normal Maintenance ______%
- Total 100 %

3.3.3 Are the number of different faults reconciled with the materials used on a monthly/ annual basis?

- Yes ☐
- No ☐

4 Your Organisations Maintenance Practices

4.1 With regard to Streetlight maintenance. How would you describe your departments maintenance strategy.

- a)Very proactive ☐
- b)More proactive than reactive ☐
- c)More reactive than proactive ☐
- d) Mostly reactive ☐

4.2 How would you best describe the maintenance strategy used by your department/ organisation? – If your organisation practices a combination of any of these please tick **all** the appropriate boxes.

		Cycle Time			
a)	React to complaints	☐			
b)	Bulk replacement strategy	☐ 18mth	☐ 24mth	☐ 30mth	☐ Longer
c)	Cyclical repair strategy	☐ <1mth	☐ <3mth	☐ <6mth	☐ Longer
d)	Regular Survey and repair strategy	☐ <1mth	☐ <3mth	☐ <6mth	☐ Longer

e) Other (please specify) ____

____

4.3 Please select **one** of the following, which most aptly describes your Streetlight maintenance operational structure.

- a) Complete outsourcing with independent external management agent ☐
- b) All repairs outsourced but with internal management and control ☐
- c) All repairs done using internal resources ☐
- d) Combination of internal and external resources used ☐

4.3.1 If your answer to question 4.3 was d) please indicate the type of work done and percentage work done by the external resources

- **a)** Bulk replacement _____%
- **b)** Normal daily maintenance _____%
- **c)** Management _____%

4.4 Are lamps whose lighting levels have depreciated below the applicable recommended level replaced?

a) Yes, we proactively follow this strategy ☐
b) Yes, by following a bulk replacement strategy ☐
c) Yes, only in areas where complaints are received from the public ☐
d) No, wait until lamp fails ☐

5 Performance Levels

5.1 What is the average time taken to attend phone-in-faults / complaints?

☐ < 24hrs, ☐ < 48hrs, ☐ < 5 days, ☐ < 14 days, ☐ < 1mth, ☐ Longer, ☐ don't know

5.1.1 What in your opinion is an acceptable time to attend to public complaints?

☐ < 24hrs ☐ < 48hrs ☐ < 5 days ☐ < 14 days ☐ < 1mth ☐ Longer

5.2 How effective (where effectiveness – refers to both cost effectiveness and system availability) do you feel your SLM strategy is?

a) Our SLM is very effective ☐
b) Our SLM is effective but can be improved ☐
c) Our SLM is ineffective ☐

5.3 On average what percentage of your streetlighting is out of service at any given time?

a) Less than 1% ☐
b) Less than 2.5% ☐
c) Less than 5% ☐
d) Less than 10% ☐
e) Less than 15% ☐
f) Less than 25% ☐
g) Other __________ %
h) Not sure ☐

5.3.1 What in your opinion is an acceptable percentage of streetlights being out of service at any given time?

a) Less than 1%☐
b) Less than 2.5% ☐
c) Less than 5%☐
d) Less than 10% ☐

e) Less than 15% ☐

f) Other________%

5.4 At what total light output level do you feel lamps should be replaced, (with reference to the 100hr output quoted by manufacturers)

a) <90% ☐

b) <80% ☐

c) <70% ☐

d) <60% ☐

e) <50% ☐

5.5 Please <u>rank in order of importance</u> from 1 to 5 the factors that <u>most-negatively</u> affect the implementation of your SLM strategy?

a) Budget Constraints ____

b) Insufficient maintenance personnel ____

c) Ineffective utilisation of resources ____

d) Insufficient management resources/ time ____

e) Lack of material availability ____

5.6 What do you think is the most practical way of comparing the SLM cost between different Cities/ Towns/ Divisions?

a) Number of consumers i.e. cost of SL per consumer ☐

b) Total area maintained in km^2 i.e. cost of SL per km^2 ☐

c) Total number of fittings maintained i.e. cost per fitting ☐

d) Per km of illuminated roadway i.e. cost per km of lighting ☐

e) Other (please state) ________________________________

5.7 Has your department compared the cost of it's maintenance with neighbouring Cities/ Towns/ Divisions?

a) No ☐

b) Yes, compares favourably with neighbours ☐

c) Yes, more expensive but better maintained ☐

d) Yes, but compares poorly with neighbours ☐

6 Bulk Replacement (BR)

6.1 Does your organisation practice a bulk replacement strategy?

a) Yes ☐ (please answer 6.1.1)

b) In some areas ☐ (please answer 6.1.1 and 6.1.2)

c) No ☐ (please answer 6.1.3)

6.1.1 If your answer to 6.1 above was a) or b) please select the <u>one</u> item which most aptly describes why your organisation chose to implement a BR strategy.

a) We have proven that BR is the most cost effective strategy ☐

b) We believe that it is more cost effective, but don't have proof ☐

c) Can easily be performed by an outside contractor and frees up internal resources to attend to other problems ☐

6.1.2 If your answer to 6.1 was b) please give brief details of the system implemented and reasons this route was adopted.

____

____

____

6.1.3 If your answer to question 6.1 was c) please indicate your organisations main reason for not implementing a BR strategy.

a) Don't believe it is more cost effective ☐

b) Requires considerably more management input ☐

c) Administratively more complex ☐

d) Believe it is more effective but don't have the resources to implement BR ☐

e) Budget constraints limit the starting of BR as it requires upfront expenditure ☐

f) Other ____________________________________

7 Outsourcing

Please refer to Question 4.3 and 4.3.1(If your answer to question 4.3 was c please answer questions 7.1 to 7.3 – If your answer to 4.3 was a, b or d please answer questions 7.4 onwards)

7.1 Please indicate the major reason(s) for keeping SLM internal.

a) Don't believe it is cost effective and increases administrative burden ☐

b) Would like to outsource but it is against council policy to outsource ☐

c) Cannot obtain trade union approval, as jobs will be lost ☐

d) Do not think that council work should be outsourced ☐

e) Previous attempts were a failure ☐

f) Have not found an outsourcing model that I am satisfied with ☐

g) Other (please state)______________________________________

7.2 Would you consider outsourcing SLM in the future and if so under what conditions?

____

7.3 If you were offered an outsourcing solution that guaranteed a maximum cost per fitting per month as well as guaranteed performance levels at a lower cost than your current budget would you consider outsourcing as a viable alternative?

a) Yes, only if the company had a proven track record ☐

b) No for the reasons given above ☐

7.4 Do you feel that since outsourcing, your network has been maintained

a) Better than previously ☐

b) At the same level as previously ☐

c) Worse than previously ☐

7.5 With regard to total costs since outsourcing which of the following is the most accurate.

a) Our total costs are less since outsourcing and service delivery has improved ☐

b) Our total costs are the same but service delivery has improved ☐

c) Our total costs are up but the improvement in service delivery can substantiate the increased cost☐

d) Our costs are down but so is the service delivery ☐

e) Our costs are up and the service delivery is worse than it was ☐

7.6 With regard to material usage since outsourcing.

a) Material usage is no longer monitored by us but only total cost ☐
b) Cannot say as no accurate records have been kept ☐
c) Material usage is substantially lower, and system availability is the same ☐
d) Material usage is the same as before ☐
e) Material usage is more than before but the system availability is greatly improved ☐
f) Material usage is substantially lower and system availability has improved significantly ☐

7.7 Would you consider outsourcing of SLM in future, which statement most accurately depicts your organisations attitude?

a) Yes, it is beneficial to us ☐
b) Yes, only because we no longer have the internal resources ☐
c) No, it is too difficult to administer, the contractor has a open cheque book ☐
d) No, results do not warrant outsourcing ☐

7.8 What is your opinion about the utilisation of an independent management agent to oversee and control the contractors' work and to ensure quality and service delivery?

a) Good idea as we lack the resources to control the contractor effectively, but depends on the real value added by the management agent ☐
b) Require additional information to make an informed decision ☐
c) Can't see the advantage, will only add to costs of outsourcing ☐
d) This method has proved itself to be more effective and is the best way to outsource SLM ☐

7.9 What in your opinion are the major problems associated with outsourcing? Please specify

____

____

8 Regional Electricity Distributors (RED's)

8.1 Does your department/ organisation consider Street lighting to be a core function of the electricity department?

☐ Yes

☐ No

8.2 How do you think that SLM will be performed when the RED's are finally implemented?

a) SLM Should remain a core function of the RED ☐

b) Will be maintained by the RED under a maintenance agreement with the Local authority ☐

c) Local Authority will establish a separate SL maintenance division (under roads dept) ☐

d) Local Authority will outsource the SL maintenance ☐

e) Other (please specify)____

9 Your Network details and Costs

Please provide the following information about your network, if you don't have accurate figures please make as accurate an estimate as possible and indicate how accurate you think this figure is (i.e. 95%)

	Estimate	Accuracy
9.1 How many fittings are maintained by your organisation?	______	_____%
9.2 How many fittings are under Bulk Replacement strategy?	______	_____%
9.3 Approximately how much of your SL network is supplied by an open overhead reticulation system	______%	

Completing the following is entirely up to you but would be greatly appreciated, as I need to compare the costs for maintenance of the different Municipalities. This information will not be distributed to any third party (except the university) without your written approval – this information can also assist you in evaluating your service delivery compared to other councils.

9.4 What is your total annual budget for SLM

Direct Personnel costs	R________
Vehicle costs	R________
Equipment costs	R________
Material costs	R________
Accidents damage	R________
Vandalism and theft	R________
Estimate hidden costs i.e. management costs not reflected above dealing with complaints etc	R________
Outsourced (contractors cost)	R________
Total Costs	R________

Thank you, for your co-operation it is highly appreciated. Should you require a summary of the findings please provide your postal or email address

below____

____

____

Annexure D

Responses to Public Questionnaire

Question																	
Response #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1 Your Details																	
1.1 Name of City/Town in which you reside	Pretoria	Jhb	Centurion	Jhb	Centurion	Jhb	Jhb	Benoni	Benoni	Jhb	Jhb	Pretoria	Jhb	Jhb	Pretoria	Dublin	W
1.2 Name of suburb/ township	Waterkloof	Blairgowne	Highveld	Bryanston	Swartkops	Dainfern	Parktown no	Crystal park	Daveyton	Lenasia	Bryanston	Brooklyn	Midrand	Sunninghill	Faerie Glen	Lucan	
1.3 Your Occupation	Attorney	Typist	Attorney	Attorney	Secretary	Attorney	Manager	Electrician	Klerk	Elec tech	Co Director	Training ma	Unemployed	Project Fina	Reservation	Quantity Su	G
Coded Response 1	Pretoria	Jhb	Centurion	Jhb	Centurion	Jhb	Jhb	Benoni	Benoni	Jhb	Jhb	Pretoria	Jhb	Jhb	Pretoria	Dublin	W
2 Your Area's Maintenance																	
2.1 Do you notice any of the following when walking or driving in your area? Q1																	
a) The streetlight (or mast) outside your house is not working		1		1	1			1	1	1	1	1			1	1	
b) The streetlights (or masts) in your area are not working			1				1				1				1		
c) The lights are burning but the light levels are very low				1		1				1							
d) Very seldom take notice of the lighting	1						1						1	1			
Coded Reponse 2.1	4	1	2	1	1	3	2	1	1	1	1	1	4	4	1	1	
2.2 If you notice that there is a light (or lights) out of order do you report this? Q2																	
a) Yes, I report all faults to my councillor									1	1							
b) Yes, I contact the Local Authority directly and report all faults								1									
c) Yes but I only report the lights directly outside my house or in my street				1													
d) No, I do not know where to report them			1			1	1						1		1		
e) No someone else will report it	1	1			1		1				1	1	1	1		1	
2.2	5	5	4	3	5	4	4	2	1	1	5	5	4	5	4	5	
Yes to 2.1 a and No to 2.2	0	1	0	0	1	0	0	0	0	0	1	1	0	0	1	1	
Yes to 2 1 d and No to 2.2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	
Yes to 2 1 c and No to 2.2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Yes to 2.1 a or b or c and No to 2.3	0	1	1	0	1	1	1	0	0	0	1	1	0	0	1	1	
2.3 Have you reported a fault (defective fitting/ section/ area) in the last 12 months? Q3																	
a) Yes								1	1	1							
b) No	1	1	1	1	1	1	1				1	1	1	1	1	1	
2.3	2	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	
Yes to 2.3 and No to 2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Yes to 2.2 and Yes to 2.3	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	
2.1 d and Yes to 2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2.1a and 2.3 a	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	
2.3.1 How would you describe the manner in which your complaint was handled? Not Included																	
a) Excellent – Efficient handing of my call and repairs carried out quicker than expected									1								
b) Good – Complaint effectively handled and repairs carried out within an acceptable time																	
c) Average -																	
d) Poor – Incompetent handing of call and took a long time to attend to the fault										1							
e) Extremely Poor – Had to call repeatedly, took excessively long to attend to the problem								1									
2.3.1	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	4	FALSE	3	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	
2.3.2 How long did it take the local authority to attend to your complaint? ('<' means less than) Not Included																	
☐ a) < 24hrs,								1	1								
☐ b) < 48hrs,																	
☐ c) < 5 days,										1							
☐ d) < 14 days,																	
☐ e) < 1mth,																	
☐ f) Longer,																	
☐ g) Had to follow up after ____ days before repairs were carried out																	
☐ h) Other (Please give details)																	
2.3.2	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	1	1	3	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	

Question																
Response #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2.4 With regard to Streetlight maintenance (SLM). How would you describe the maintenance in your area provided by your Local Authority – in general. Q4																
a) Excellent – most lights burn brightly and those that are out are repaired within a few d	1				1				1				1			1
b) Good – most lights burn brightly and those that are out are repaired within a few weeks		1	1				1	1			1	1		1		
c) Fair – many lights burn and those that are out are repaired within 1 month				1		1									1	
d) Fair – most lights burn but they are not very bright																
e) Poor – many lights are out and are only repaired when someone complains										1						
2.4	1	2	2	3	1	3	2	2	1	5	2	2	1	2	3	1
2.5 Does your Local authority replace lamps when the lighting levels in the area have become poor? - Not Included																
a) Yes, it is noticeable when they are replaced					1			1	1							
b) Do not notice/ do not know	1					1	1			1	1	1	1	1	1	1
c) No, they wait until the lamp fails		1	1	1												
2.5	2	3	3	3	1	2	2	1	1	2	2	2	2	2	2	2
2.6 What percentage of Streetlights, in your area, are working, on average? - Q5																
a) 99%	1		1		1			1	1				1			1
b) 95%						1	1					1				
c) 90%		1		1							1			1	1	
d) 75%										1						
e) Other																
2.6	1	3	1	3	1	2	2	1	1	4	3	2	1	3	3	1
2.7 How would you rate the general appearance of the Streetlighting installation in your area? (Are all the poles and light fittings straight? Are there lots of broken fittings? are the cover plates all closed?) - Not Included																
a) Excellent								1	1	1			1			1
b) Good	1		1		1											
c) Average		1		1		1					1	1		1	1	
d) Poor																
e) Very Poor																
2.7	2	3	2	3	2	3	FALSE	1	1	1	3	3	1	3	3	1
3 Your Expectations																
3.1 What in your opinion is an acceptable time for the Local Authority to attend to public complaints? - Q6																
a) < 24hrs	1			1	1			1	1	1	1	1				
b) < 48hrs		1	1				1						1	1	1	1
c) < 5 days						1										
d) < 14 days																
e) < 1mth																
f) Other																
3.1	1	2	2	1	1	3	2	1	1	1	1	1	2	2	2	2
3.2 What in your opinion is an acceptable percentage of streetlights being out at any given time? - Q7																
a) Less than 1%	1		1	1				1	1	1	1	1				
b) Less than 5%		1			1	1	1						1	1	1	1
c) Less than 10%																
d) Less than 25%																
e) Other																
3.2	1	2	1	1	2	2	2	1	1	1	1	1	2	2	2	2

Question											
Response #	18	19	20	21	22	23	24	25	26	27	28
1 Your Details											
1.1 Name of City/Town in which you reside	Centurion	Centurion	Pretoria	Pretoria	Jhb	Pretoria	Windhoek	Jhb	Jhb	Cape Town	Auckland
1.2 Name of suburb/ township	Eldoraigne	Eldoraigne	Groenkloof	Menlo Park	Kibler Park	Montana	Klein Windh	Midrand	Weltevreder	Durbanville	Kohimarama
1.3 Your Occupation	Manager	Product beh	Retired Fina	Reservations consultant		National Ma	Lawyer	Food Techn	Information	Programme	Partner in bu
Coded Response 1	Centurion	Centurion	Pretoria	Pretoria	Jhb	Pretoria	Windhoek	Jhb	Jhb	Cape Town	Auckland
2 Your Area's Maintenance											
2.1 Do you notice any of the following when walking or driving in your area? Q1											
a) The streetlight (or mast) outside your house is not working	1	1	1		1	1		1	1	1	1
b) The streetlights (or masts) in your area are not working							1		1		
c) The lights are burning but the light levels are very low			1			1			1		
d) Very seldom take notice of the lighting				1							
Coded Reponse 2.1	1	1	1	4	1	1	2	1	1	1	1
2.2 If you notice that there is a light (or lights) out of order do you report this? Q2											
a) Yes, I report all faults to my councillor			1								
b) Yes, I contact the Local Authority directly and report all faults	1					1					
c) Yes but I only report the lights directly outside my house or in my street	1				1	1			1		
d) No, I do not know where to report them		1		1			1	1			
e) No someone else will report it				1			1			1	
2.2	2	4	1	4	3	2	4	4	3	5	FALSE
Yes to 2.1 a and No to 2.2	0	1	0	0	0	0	0	1	0	1	0
Yes to 2.1 d and No to 2.2	0	0	0	0	0	0	1	0	0	0	0
Yes to 2.1 c and No to 2.2	0	0	0	0	0	0	0	0	0	0	0
Yes to 2.1 a or b or c and No to 2.3	0	1	0	0	0	0	1	1	0	1	0
2.3 Have you reported a fault (defective fitting/ section/ area) in the last 12 months? Q3											
a) Yes	1		1			1				1	
b) No		1		1	1		1	1	1		1
2.3	1	2	1	2	2	1	2	2	2	1	2
Yes to 2.3 and No to 2.2	0	0	0	0	0	0	0	0	0	1	0
Yes to 2.2 and Yes to 2.3	1	0	1	0	0	1	0	0	0	0	0
2.1 d and Yes to 2.3	0	0	0	0	0	0	0	0	0	0	0
2.1a and 2.3 a	1	0	1	0	0	1	0	0	0	1	0
2.3.1 How would you describe the manner in which your complaint was handled? Not Included											
a) Excellent – Efficient handling of my call and repairs carried out quicker than expected											
b) Good – Complaint effectively handled and repairs carried out within an acceptable time	1										
c) Average -											
d) Poor – Incompetent handling of call and took a long time to attend to the fault						1					
e) Extremely Poor – Had to call repeatedly, took excessively long to attend to the problem			1							1	
2.3.1	1	FALSE	4	FALSE	FALSE	3	FALSE	FALSE	FALSE	4	FALSE
2.3.2 How long did it take the local authority to attend to your complaint? ('<' means less than) Not Included											
☐ a) < 24hrs,											
☐ b) < 48hrs,	1										
☐ c) < 5 days,											
☐ d) < 14 days,						1				1	
☐ e) < 1mth,											
☐ f) Longer,			1								
☐ g) Had to follow up after ____ days before repairs were carried out						1				1	
☐ h) Other (Please give details)											
2.3.2	2	FALSE	6	FALSE	FALSE	4	FALSE	FALSE	FALSE	4	FALSE

Question											
Response #	18	19	20	21	22	23	24	25	26	27	28
2.4 With regard to Streetlight maintenance (SLM). How would you describe the maintenance in your area provided by your Local Authority – in general. Q4											
a) Excellent – most lights burn brightly and those that are out are repaired within a few d		1					1			1	1
b) Good – most lights burn brightly and those that are out are repaired within a few week	1				1						
c) Fair – many lights burn and those that are out are repaired within 1 month						1			1		
d) Fair – most lights burn but they are not very bright				1				1			
e) Poor – many lights are out and are only repaired when someone complains			1								
2.4	2	1	5	4	2	3	1	4	3	1	1
2.5 Does your Local authority replace lamps when the lighting levels in the area have become poor? - Not Included											
a) Yes, it is noticeable when they are replaced		1	1				1	1			1
b) Do not notice/ do not know	1			1	1					1	
c) No, they wait until the lamp fails						1			1		
2.5	2	1	1	2	2	3	1	1	3	2	1
2.6 What percentage of Streetlights, in your area, are working, on average? - Q5											
a) 99%	1	1			1		1			1	1
b) 95%						1			1		
c) 90%											
d) 75%			1	1				1			
e) Other											
2.6	1	1	4	4	1	2	1	4	2	1	1
2.7 How would you rate the general appearance of the Streetlighting installation in your area? (Are all the poles and light fittings straight? Are there lots of broken fittings? are the cover plates all closed?) - Not Included											
a) Excellent		1								1	1
b) Good	1			1	1		1	1			
c) Average			1			1			1		
d) Poor											
e) Very Poor											
2.7	2	1	3	2	2	3	2	2	3	1	1
3 Your Expectations											
3.1 What in your opinion is an acceptable time for the Local Authority to attend to public complaints? - Q6											
☐ a) < 24hrs	1	1	1		1	1	1			1	1
☐ b) < 48hrs				1					1		
c) < 5 days								1			
☐ d) < 14 days											
☐ e) < 1mth											
f) Other ______											
3.1	1	1	1	2	1	1	1	3	2	1	1
3.2 What in your opinion is an acceptable percentage of streetlights being out at any given time? - Q7											
a) Less than 1%	1	1	1		1	1	1			1	1
b) Less than 5%				1					1		
c) Less than 10%								1			
d) Less than 25%											
e) Other											
3.2	1	1	1	2	1	1	1	3	2	1	1

Question																
Response #	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
1 Your Details																
1.1 Name of City/Town in which you reside	Pretoria	Pretoria	Durban	Pretoria	London	Pretoria	Pretoria	Pretoria	Cape Town	Windhoek	Jhb	Cape Town	Durban	Pretoria	Brakpan	Brakpan
1.2 Name of suburb/ township	Groenkloof	Queenswoo	Durban Nor	Doornpoort	Battersea	Menlo Park	Rietondale	Elardus Par	Somerset W	Olympus	Sunninghil	Claremont	Umhlanga	Lynwood	Rand Collie	Rand Collien
1.3 Your Occupation	Economist	Mineral Spe	Travel cons	Retired Kler	Travel Cons	Projecr eval	Manager	Constructio	HR Manage	Director En	Engineer	Manager	Plant Breed	Advocate	Chef	Engineer
Coded Response 1	Pretoria	Pretoria	Durban	Pretoria	London	Pretoria	Pretoria	Pretoria	Cape Town	Windhoek	Jhb	Cape Town	Durban	Pretoria	Brakpan	Brakpan
2 Your Area's Maintenance																
2.1 Do you notice any of the following when walking or driving in your area? Q1																
a) The streetlight (or mast) outside your house is not working	1	1					1		1			1				
b) The streetlights (or masts) in your area are not working	1	1					1		1	1	1			1	1	1
c) The lights are burning but the light levels are very low	1					1					1			1		1
d) Very seldom take notice of the lighting			1	1	1			1					1			
Coded Reponse 2.1	1	1	4	4	4	3	1	4	1	2	2	1	4	2	2	2
2.2 If you notice that there is a light (or lights) out of order do you report this? Q2																
a) Yes, I report all faults to my councillor																
b) Yes, I contact the Local Authority directly and report all faults	1														1	
c) Yes but I only report the lights directly outside my house or in my street							1									1
d) No, I do not know where to report them		1				1					1			1		
e) No someone else will report it			1	1	1	1		1	1	1	1	1	1			
2.2	2	4	5	5	5	4	3	5	5	5	4	5	5	4	2	3
Yes to 2.1 a and No to 2.2	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Yes to 2.1 d and No to 2.2	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
Yes to 2.1 c and No to 2.2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Yes to 2.1 a or b or c and No to 2.3	0	1	0	0	0	1	0	0	1	1	1	1	0	1	0	0
2.3 Have you reported a fault (defective fitting/ section/ area) in the last 12 months? Q3																
a) Yes	1						1									1
b) No		1	1	1	1	1		1	1	1	1	1	1	1	1	
2.3	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	1
Yes to 2.3 and No to 2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yes to 2.2 and Yes to 2.3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
2.1 d and Yes to 2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1a and 2.3 a	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2.3.1 How would you describe the manner in which your complaint was handled? Not Included																
a) Excellent – Efficient handling of my call and repairs carried out quicker than expected																
b) Good – Complaint effectively handled and repairs carried out within an acceptable time																
c) Average -																
d) Poor – Incompetent handling of call and took a long time to attend to the fault	1						1									
e) Extremely Poor – Had to call repeatedly, took excessively long to attend to the problem																1
2.3.1	3	FALSE	FALSE	FALSE	FALSE	FALSE	3	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	4
2.3.2 How long did it take the local authority to attend to your complaint? ('<' means less than) Not Included																
☐ a) < 24hrs,																
☐ b) < 48hrs,																
☐ c) < 5 days,																
☐ d) < 14 days,	1															
☐ e) < 1mth,							1									
☐ f) Longer,																1
☐ g) Had to follow up after ____ days before repairs were carried out	1						1									1
☐ h) Other (Please give details)																
2.3.2	4	FALSE	FALSE	FALSE	FALSE	FALSE	5	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	6

Question Response #	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
2.4 With regard to Streetlight maintenance (SLM). How would you describe the maintenance in your area provided by your Local Authority – in general. Q4																
a) Excellent – most lights burn brightly and those that are out are repaired within a few d										1						
b) Good – most lights burn brightly and those that are out are repaired within a few week			1		1			1					1			
c) Fair – many lights burn and those that are out are repaired within 1 month	1						1		1							
d) Fair – most lights burn but they are not very bright		1		1		1					1	1		1	1	
e) Poor – many lights are out and are only repaired when someone complains																1
2.4	3	4	2	4	2	4	3	2	3	1	4	4	2	4	4	5
2.5 Does your Local authority replace lamps when the lighting levels in the area have become poor? - Not Included																
a) Yes, it is noticeable when they are replaced		1								1					1	
b) Do not notice/ do not know			1	1	1			1	1		1	1	1	1		
c) No, they wait until the lamp fails	1					1	1									1
2.5	3	1	2	2	2	3	3	2	2	1	2	2	2	2	1	3
2.6 What percentage of Streetlights, in your area, are working, on average? - Q5																
a) 99%					1					1	1					
b) 95%	1		1			1	1	1	1			1	1			
c) 90%				1										1	1	1
d) 75%		1														
e) Other																
2.6	2	4	2	3	1	2	2	2	2	1	1	2	2	3	3	3
2.7 How would you rate the general appearance of the Streetlighting installation in your area? (Are all the poles and light fittings straight? Are there lots of broken fittings? are the cover plates all closed?) - Not Included																
a) Excellent																
b) Good	1	1	1		1	1			1	1		1	1			
c) Average				1			1	1			1			1	1	1
d) Poor																
e) Very Poor																
2.7	2	2	2	3	2	2	3	3	2	2	3	2	2	3	3	3
3 Your Expectations																
3.1 What in your opinion is an acceptable time for the Local Authority to attend to public complaints? - Q6																
☐ a) < 24hrs	1				1		1			1						
☐ b) < 48hrs			1	1		1			1			1	1		1	1
c) < 5 days		1						1			1			1		
☐ d) < 14 days																
☐ e) < 1mth																
f) Other ______																
3.1	1	3	2	2	1	2	1	3	2	1	3	2	2	3	2	2
3.2 What in your opinion is an acceptable percentage of streetlights being out at any given time? - Q7																
a) Less than 1%	1				1		1		1	1		1				
b) Less than 5%			1	1		1		1			1		1			1
c) Less than 10%		1												1	1	
d) Less than 25%																
e) Other																
3.2	1	3	2	2	1	2	1	2	1	1	2	1	2	3	3	2

Annexure E

Annual Equivalent Annuity Calculations for Fitting Replacement

Annual Equivalent Annuity Calculatations for Fitting Age

Cycle Time Years		15	16	17	18	19	20	21	22	23	24	25	30	35
AE		R 61.53	R 60.11	R 58.99	R 58.14	R 57.52	R 57.11	R 56.88	R 56.84	R 56.95	R 57.23	R 57.65	R 61.91	R 69.86
Annuity Factor		10.3797	10.8378	11.2741	11.6896	12.0853	12.4622	12.8212	13.1630	13.4886	13.7986	14.0939	15.3725	16.3742
PV		R 638.67	R 651.45	R 665.08	R 679.62	R 695.13	R 711.68	R 729.33	R 748.15	R 768.23	R 789.65	R 812.49	R 951.70	R 1,143.92
Purchase price of new fitting		500	500	500	500	500	500	500	500	500	500	500	500	500
PV of Maintenance		R 138.67	R 151.45	R 165.08	R 179.62	R 195.13	R 211.68	R 229.33	R 248.15	R 268.23	R 289.65	R 312.49	R 451.70	R 643.92
Year	AF @ 5%													
0	1.0000	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00	R 0.00
1	0.9524	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86	R 2.86
2	0.9070	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44	R 5.44
3	0.8638	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77	R 7.77
4	0.8227	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
5	0.7835	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
6	0.7462	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
7	0.7107	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
8	0.6768	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
9	0.6446	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
10	0.6139	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
11	0.5847	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
12	0.5568	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87	R 9.87
13	0.5303	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53	R 10.53
14	0.5051	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23	R 11.23
15	0.4810	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98	R 11.98
16	0.4581		R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78	R 12.78
17	0.4363			R 13.63	R 13.63	R 13.63	R 13.63	R 13.63	R 13.63	R 13.63	R 13.63	R 13.63	R 13.63	R 13.63
18	0.4155				R 14.54	R 14.54	R 14.54	R 14.54	R 14.54	R 14.54	R 14.54	R 14.54	R 14.54	R 14.54
19	0.3957					R 15.51	R 15.51	R 15.51	R 15.51	R 15.51	R 15.51	R 15.51	R 15.51	R 15.51
20	0.3769						R 16.54	R 16.54	R 16.54	R 16.54	R 16.54	R 16.54	R 16.54	R 16.54
21	0.3589							R 17.65	R 17.65	R 17.65	R 17.65	R 17.65	R 17.65	R 17.65
22	0.3418								R 18.82	R 18.82	R 18.82	R 18.82	R 18.82	R 18.82
23	0.3256									R 20.08	R 20.08	R 20.08	R 20.08	R 20.08
24	0.3101										R 21.42	R 21.42	R 21.42	R 21.42
25	0.2953											R 22.85	R 22.85	R 22.85
26	0.2812												R 24.37	R 24.37
27	0.2678												R 25.99	R 25.99
28	0.2551												R 27.73	R 27.73
29	0.2429												R 29.57	R 29.57
30	0.2314												R 31.55	R 31.55
31	0.2204													R 33.65
32	0.2099													R 35.89
33	0.1999													R 38.28
34	0.1904													R 40.84
35	0.1813													R 43.56

Annexure F

Life Cycle Costs and Replacement Cycle for Energy Efficient Lamps

Life Cycle Costs MV vs. HPS

Assumptions
Energy costs of 16c/kWh
Burning hours per annum 4000
Replacement cycle 16000 hours
Fittings Compared

125 W Mercury Vapour – output 6500 lumen
70 W HPS – output 6300 lumen

Lamp Costs R15 for MV and R47.50 for HPS

Time (Years)	Total Cost	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
125 W Mercury Vapour																						
Capital Cost of Installed Fitting	R 445.00	R 445.00																				
Energy Costs (140W x 4000hrs x 16c/kWh)	R 1,792.00		R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60
Lamp Costs	R 75.00					R 15.00				R 15.00				R 15.00				R 15.00				R 15.00
Undiscounted Total Costs	R 2,312.00	R 445.00	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60
Present Value @ 5% 'Real' discount rate	R 1,604.98																					
70 W HPS																						
Capital Cost of Installed Fitting	R 470.50	R 470.50																				
Energy Costs (84W x 4000hrs x 16c/kWh)	R 1,075.20		R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76	R 53.76
Lamp Costs	R 237.50					R 47.50				R 47.50				R 47.50				R 47.50				R 47.50
Undiscounted Total Costs	R 1,783.20	R 470.50	R 53.76	R 53.76	R 53.76	R 101.26	R 53.76	R 53.76	R 53.76	R 101.26	R 53.76	R 53.76	R 53.76	R 101.26	R 53.76	R 53.76	R 53.76	R 101.26	R 53.76	R 53.76	R 53.76	R 101.26
Present Value @ 5% 'Real' discount rate	R 1,277.81																					

Time (Years)	Total Cost	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
80 W Mercury Vapour																						
Capital Cost of Installed Fitting	R 445.00	R 445.00																				
Energy Costs (89W x 4000hrs x 16c/kWh)	R 1,139.20		R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96	R 56.96
Lamp Costs	R 75.00					R 15.00				R 15.00				R 15.00				R 15.00				R 15.00
Undiscounted Total Costs	R 1,659.20	R 445.00	R 56.96	R 56.96	R 56.96	R 71.96	R 56.96	R 56.96	R 56.96	R 71.96	R 56.96	R 56.96	R 56.96	R 71.96	R 56.96	R 56.96	R 56.96	R 71.96	R 56.96	R 56.96	R 56.96	R 71.96
Present Value @ 5% 'Real' discount rate	R 1,198.22																					
50 W HPS																						
Capital Cost of Installed Fitting	R 470.50	R 470.50																				
Energy Costs (58W x 4000hrs x 16c/kWh)	R 742.40		R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12	R 37.12
Lamp Costs	R 237.50					R 47.50				R 47.50				R 47.50				R 47.50				R 47.50
Undiscounted Total Costs	R 1,450.40	R 470.50	R 37.12	R 37.12	R 37.12	R 84.62	R 37.12	R 37.12	R 37.12	R 84.62	R 37.12	R 37.12	R 37.12	R 84.62	R 37.12	R 37.12	R 37.12	R 84.62	R 37.12	R 37.12	R 37.12	R 84.62
Present Value @ 5% 'Real' discount rate	R 1,070.44																					

Time (Years)	Total Cost	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
250 W Mercury Vapour																						
Capital Cost of Installed Fitting	R 690.00	R 690.00																				
Energy Costs (278W x 4000hrs x 16c/kWh)	R 3,558.40		R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92	R 177.92
Lamp Costs	R 125.00					R 25.00				R 25.00				R 25.00				R 25.00				R 25.00
Undiscounted Total Costs	R 4,373.40	R 690.00	R 177.92	R 177.92	R 177.92	R 202.92	R 177.92	R 177.92	R 177.92	R 202.92	R 177.92	R 177.92	R 177.92	R 202.92	R 177.92	R 177.92	R 177.92	R 202.92	R 177.92	R 177.92	R 177.92	R 202.92
Present Value @ 5% 'Real' discount rate	R 2,979.56																					
150 W HPS																						
Capital Cost of Installed Fitting	R 690.00	R 690.00																				
Energy Costs (160W x 4000hrs x 16c/kWh)	R 2,048.00		R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40	R 102.40
Lamp Costs	R 350.00					R 70.00				R 70.00				R 70.00				R 70.00				R 70.00
Undiscounted Total Costs	R 3,088.00	R 690.00	R 102.40	R 102.40	R 102.40	R 172.40	R 102.40	R 102.40	R 102.40	R 172.40	R 102.40	R 102.40	R 102.40	R 172.40	R 102.40	R 102.40	R 102.40	R 172.40	R 102.40	R 102.40	R 102.40	R 172.40
Present Value @ 5% 'Real' discount rate	R 2,168.53																					

Replacement Cycles - For conversion to Energy Efficient Luminaire

Time (Years)	Total Cost	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1 year (21 Year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 89.60		R 89.60																				
Lamp Costs	R 0.00																						
Replacement after 1 years	R 1,277.81		R 1,277.81																				
Undiscounted Total Costs	R 1,367.41	R 0.00	R 1,367.41																				
Present Value @ 5% 'Real' discount rate	R 1,302.29																						
Cycle length 21 years - Annuity Factor	12.8212																						
AEA	101.5739																						
2 years (22 Year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 179.20		R 89.60	R 89.60																			
Lamp Costs	R 0.00																						
Replacement after 2 years				R 1,277.81																			
Undiscounted Total Costs	R 1,457.01	R 0.00	R 89.60	R 1,367.41																			
Present Value @ 5% 'Real' discount rate	R 1,325.61																						
22 years	13.1630026																						
AEA	R 100.71																						
3 Years (23 year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 268.80		R 89.60	R 89.60	R 89.60																		
Lamp Costs	R 0.00																						
Replacement after 3 years					R 1,277.81																		
Undiscounted Total Costs	R 1,546.61	R 0.00	R 89.60	R 89.60	R 1,367.41																		
Present Value @ 5% 'Real' discount rate	R 1,347.82																						
23 years	13.4885739																						
AEA	R 99.92																						
5 years (25 year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 448.00		R 89.60	R 89.60	R 89.60	R 89.60	R 89.60																
Lamp Costs	R 15.00					R 15.00																	
Replacement after 4 years							R 1,277.81																
Undiscounted Total Costs	R 1,740.81	R 0.00	R 89.60	R 89.60	R 89.60	R 104.60	R 1,367.41																
Present Value @ 5% 'Real' discount rate	R 1,401.46																						
25 year af	13.7986418																						
AEA	R 101.56																						
10 Years (30 Year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 896.00		R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60											
Lamp Costs	R 30.00					R 15.00				R 15.00													
Replacement after 10 years												R 1,277.81											
Undiscounted Total Costs	R 2,203.81	R 0.00	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 1,367.41											
Present Value @ 5% 'Real' discount rate	R 1,498.82																						
30 year af	15.372451																						
AEA	R 97.50																						
15 Years (35 Year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 1,344.00		R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60						
Lamp Costs	R 45.00					R 15.00				R 15.00				R 15.00									
Replacement after 15 years																	R 1,277.81						
Undiscounted Total Costs	R 2,666.81	R 0.00	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 1,367.41						
Present Value @ 5% 'Real' discount rate	R 1,575.51																						
35 year af	16.3741943																						
AEA	R 96.22																						
20 Years (40 year Cycle)																							
Capital Cost of Installed Fitting	R 0.00																						
Energy Costs (140W x 4000hrs x 16c/kWh)	R 1,792.00		R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	R 89.60	
Lamp Costs	R 75.00					R 15.00				R 15.00				R 15.00				R 15.00				R 15.00	
Replacement after 20 years																							[illegible]
Undiscounted Total Costs	R 1,867.00	R 0.00	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	R 89.60	R 89.60	R 89.60	R 104.60	[illegible]
Present Value @ 5% 'Real' discount rate	R 1,618.64																						
40 year af	17.1590864																						
AEA	R 94.33																						

Annexure G

Bulk versus Spot Replacement Cost Comparison

Bulk vs Spot Replacment Cost Comparison

Spot

Total Number of fittings 20000

	Months	***1***	***2 to 12***	***13 to 24***	***25 to 36***	***37 to 48***	***49 to 60***
Faults	5000	417	417				
Labour Cost		R 60.00	R 60.00				
Lamp Cost		R 55.00	R 55.00				
Total Cost		R 47,916.67	R 47,916.67				
NPV @ 5% real	R 562,057.41						
af							
AEA	R 562,057.41						

3 Year Bulk Replacement Cycle

Replacements	28154	20000	33	83	617		
Labour Costs		R 25.00	R 60.00	R 60.00	R 60.00		
Lamp Cost		R 55.00	R 55.00	R 55.00	R 55.00		
		R 1,600,000.00	R 3,833.33	R 9,583.33	R 70,955.00		
PV	R 2,439,974.15						
af	2.7232						
AEA	R 895,995.21						

4 Year Bulk Replacement Cycle

Replacements	29450	20000	17	33	133	617	
Labour Costs		R 25.00	R 60.00	R 60.00	R 60.00	R 60.00	
Lamp Cost		R 55.00	R 55.00	R 55.00	R 55.00	R 55.00	
		R 1,600,000.00	R 1,916.67	R 3,833.33	R 15,333.33	R 70,916.67	
PV	R 2,532,044.39						
a.f	3.546						
AEA	R 714,056.51						

5 Year Bulk Replacement Cycle

Replacements	36850	20000	17	33	133	617	617
Labour Costs		R 25.00	R 25.00	R 25.00	R 25.00	R 25.00	R 25.00
Lamp Cost		R 55.00	R 55.00	R 55.00	R 55.00	R 55.00	R 55.00
		R 1,600,000.00	R 1,333.33	R 2,666.67	R 10,666.67	R 49,333.33	R 49,333.33
PV	R 2,724,329.33						
a.f	4.3295						
AEA	R 629,248.03						

Annexure H

Chi-Square Calculations for Hypothesis Testing

Q4 - Perception of SLM

Chi-Square Test Null Hypothesis = Public and Experts have the same Perception of Service

Observed Frequencies			
	Column variable		
Row variable	Public	Experts	Total
Good + Excelent	24	3	27
Fair + Poor	20	10	30
Total	44	13	57

Calculations

fo-fe	
3.157895	-3.15789
-3.15789	3.157895

Expected Frequencies			
	Column variable		
Row variable	Public	Experts	Total
Good + Excelent	20.84211	6.157895	27
Fair + Poor	23.15789	6.842105	30
Total	44	13	57

(fo-fe)^2/fe	
0.478469	1.619433
0.430622	1.45749

Data	
Level of Significance	0.05
Number of Rows	2
Number of Columns	2
Degrees of Freedom	1

Results	
Critical Value	3.841459
Chi-Square Test Statisti	3.986014
p -Value	0.045879
Reject the null hypothesis	

Expected frequency assumption is met.

Q5 - Percentage SL working

Chi-Square Test Null Hypothesis = Public and Experts have the same Perception of Service

Observed Frequencies					
	Column variable				
Row variable	**>99%**	**>95%**	**>90%**	**>75%**	**Total**
Public	17	13	9	5	**44**
Experts + Officials	1	4	6	2	**13**
Total	**18**	**17**	**15**	**7**	**57**

Expected Frequencies					
	Column variable				
Row variable	>99%	>95%	>90%	>75%	Total
Public	13.89474	13.12281	11.57895	5.403509	44
Experts + Officials	4.105263	3.877193	3.421053	1.596491	13
Total	18	17	15	7	57

Calculations

fo-fe			
3.105263	-0.12281	-2.57895	-0.40351
-3.10526	0.122807	2.578947	0.403509

(fo-fe)^2/fe			
0.693979	0.001149	0.574402	0.030132
2.348853	0.00389	1.94413	0.101986

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	4
Degrees of Freedom	3

Results	
Critical Value	**7.814728**
Chi-Square Test Statistic	**5.698521**
***p*-Value**	**0.127235**
Do not reject the null hypothesis	

Expected frequency assumption is met.

Q6 - Acceptable Response time

Chi-Square Test Null Hypothesis = Public and Experts have the **same Expectation**

Observed Frequencies				
	Column variable			
Row variable	**<24 hrs**	**<48 hrs**	**<5 days**	**Total**
Public	21	17	6	**44**
Experts + Officials	4	5	12	**21**
Total	**25**	**22**	**18**	**65**

Calculations

fo-fe		
4.076923	2.107692	-6.18462
-4.07692	-2.10769	6.184615

Expected Frequencies				
	Column variable			
Row variable	<24 hrs	<48 hrs	<5 days	Total
Public	16.92308	14.89231	12.18462	44
Experts + Officials	8.076923	7.107692	5.815385	21
Total	25	22	18	65

(fo-fe)^2/fe		
0.982168	0.298299	3.139161
2.057875	0.625008	6.577289

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	3
Degrees of Freedom	2

Results	
Critical Value	**5.991465**
Chi-Square Test Statistic	**13.6798**
***p*-Value**	**0.00107**
Reject the null hypothesis	

Expected frequency assumption is met.

Q7 - Acceptable Percentage of SL working

Chi-Square Test Null Hypothesis = Public and Experts have the same **Expectation**

Observed Frequencies				
	Column variable			
Row variable	**<1%**	**<5%**	**<10%**	**Total**
Public	23	17	4	**44**
Experts + Officials	6	10	5	**21**
Total	**29**	**27**	**9**	**65**

Calculations

fo-fe		
3.369231	-1.27692	-2.09231
-3.36923	1.276923	2.092308

Expected Frequencies				
	Column variable			
Row variable	<1%	<5%	<10%	Total
Public	19.63077	18.27692	6.092308	44
Experts + Officials	9.369231	8.723077	2.907692	21
Total	29	27	9	65

(fo-fe)^2/fe		
0.578261	0.089213	0.71857
1.211595	0.186922	1.505576

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	3
Degrees of Freedom	2

Results	
Critical Value	**5.991465**
Chi-Square Test Statistic	**4.290137**
***p*-Value**	**0.11706**
Do not reject the null hypothesis	

Expected frequency assumption is met.

Perception of Service vs Expectation of Service

Chi-Square Test Null Hypothesis = Perception of Service is the Same as **Expectations of Service**

Observed Frequencies					
	Column variable				
Row variable	**>99%**	**>95%**	**>90%**	**>75%**	**Total**
Perception	19	22	17	7	**65**
Expectation	29	27	9	0	**65**
Total	**48**	**49**	**26**	**7**	**130**

Expected Frequencies					
	Column variable				
Row variable	>99%	>95%	>90%	>75%	Total
Perception	24	24.5	13	3.5	65
Expectation	24	24.5	13	3.5	65
Total	48	49	26	7	130

Calculations

fo-fe			
-5	-2.5	4	3.5
5	2.5	-4	-3.5

(fo-fe)^2/fe			
1.041667	0.255102	1.230769	3.5
1.041667	0.255102	1.230769	3.5

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	4
Degrees of Freedom	3

Results	
Critical Value	**7.814728**
Chi-Square Test Statistic	**12.05508**
***p*-Value**	**0.007197**
Reject the null hypothesis	

Expected frequency assumption is met.

Chi-Square Test

Null Hypothesis = There is no difference in the number of expected faults on an OH network Compared to a Underground Netwrok

All Fittings

Observed Frequencies			
	Column variable		
Row variable	**Network**	**Faults**	**Total**
Underground	2920	2869	**5789**
Overhead	7289	7340	**14629**
Total	**10209**	**10209**	**20418**

Calculations

fo-fe	
25.5	-25.5
-25.5	25.5

Expected Frequencies			
	Column variable		
Row variable	Network	Faults	Total
Underground	2894.5	2894.5	5789
Overhead	7314.5	7314.5	14629
Total	10209	10209	20418

(fo-fe)^2/fe	
0.22465	0.22465
0.088899	0.088899

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	2
Degrees of Freedom	1

Results	
Critical Value	**3.841459**
Chi-Square Test Statistic	**0.627098**
***p*-Value**	**0.428422**
Do not reject the null hypothesis	

Expected frequency assumption is met.

Null Hypothesis = There is no difference in the number of expected faults on an OH network Compared to a Underground Netwrok

Chi-Square Test

125 W MV Fitting

Observed Frequencies			
	Column variable		
Row variable	**Network**	**Faults**	**Total**
Underground	**1958**	**1947**	**3905**
Overhead	**55**	**64**	**119**
Total	**2013**	**2011**	**4024**

Calculations

fo-fe	
4.529573	-4.52957
-4.52957	4.529573

Expected Frequencies			
	Column variable		
Row variable	Network	Faults	Total
Underground	1953.47	1951.53	3905
Overhead	59.52957	59.47043	119
Total	2013	2011	4024

(fo-fe)^2/fe	
0.010503	0.010513
0.344653	0.344995

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	2
Degrees of Freedom	1

Results	
Critical Value	**3.841459**
Chi-Square Test Statistic	**0.710664**
***p*-Value**	**0.399223**
Do not reject the null hypothesis	

Expected frequency assumption is met.

Null Hypothesis = There is no difference in the number of expected faults on an OH network Compared to a Underground Netwrok

Chi-Square Test

70W HPS

Observed Frequencies			
	Column variable		
Row variable	**Network**	**Faults**	**Total**
Underground	1644	1595	**3239**
Overhead	572	620	**1192**
Total	**2216**	**2215**	**4431**

Calculations

fo-fe	
24.13451	-24.1345
-24.1345	24.13451

Expected Frequencies			
	Column variable		
Row variable	Network	Faults	Total
Underground	1619.865	1619.135	3239
Overhead	596.1345	595.8655	1192
Total	2216	2215	4431

(fo-fe)^2/fe	
0.359582	0.359744
0.977086	0.977527

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	2
Degrees of Freedom	1

Results	
Critical Value	**3.841459**
Chi-Square Test Statistic	**2.673939**
***p*-Value**	**0.102003**
Do not reject the null hypothesis	

Expected frequency assumption is met.

Q5 vs Physical Survey Percentage SL working

Chi-Square Test Null Hypothesis = Public and Experts Perception of Service is the same as the Actual status

Observed Frequencies					
	Column variable				
Row variable	**>99%**	**>95%**	**>90%**	**>75%**	**Total**
Public and Experts	18	17	15	7	**57**
Physical Survey	3	3	7	8	**21**
Total	**21**	**20**	**22**	**15**	**78**

Calculations

fo-fe			
2.653846	2.384615	-1.07692	-3.96154
-2.65385	-2.38462	1.076923	3.961538

Expected Frequencies					
	Column variable				
Row variable	>99%	>95%	>90%	>75%	Total
Public and Experts	15.34615	14.61538	16.07692	10.96154	57
Physical Survey	5.653846	5.384615	5.923077	4.038462	21
Total	21	20	22	15	78

(fo-fe)^2/fe			
0.458936	0.389069	0.072138	1.431714
1.245683	1.056044	0.195804	3.886081

Data	
Level of Significance	**0.05**
Number of Rows	2
Number of Columns	4
Degrees of Freedom	3

Results	
Critical Value	**7.814728**
Chi-Square Test Statistic	**8.735469**
***p*-Value**	**0.033023**
Reject the null hypothesis	

Expected frequency assumption is met.