Paper presented at the CIBSE National Lighting Conference
Lancaster, UK, April 1998

A STUDY OF INDIRECT ENERGY COST DUE TO REDUCED URBAN LIGHTING MAINTENANCE

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Urban lighting is a service to the citizen that must evolve according to the population growth and needs, changes in the electrical energy tariff rate, and new lighting technological developments. Moreover, during operation lighting facilities are depreciated. This requires a permanent care in order to prevent any reduction in the quality of the service.
Adequate lighting management permits considering all the involved aspects. It is also the best tool to achieve a rational energy consumption considering simultaneously the lighting systems efficiency.
An important part of lighting management is maintenance, an area where it is necessary to achieve a balance between cost and benefits. The paper will analyse some aspects of this problem, providing results from a preliminary study where energy charges from the lack of maintenance in urban lighting installations were evaluated at different areas of Barcelona.

1. INTRODUCTION

Urban lighting installations provide a service that is frequently not appreciated until lack is experimented. The opposite, a diminishing lumen output with time (depreciation), is hardly ever perceived. Consequently, lighting facilities require attention during operation in order to: guarantee a correct performance, reduce deterioration and adapt according to urban and technological evolution. Care must begin in the design stage and continue during all its useful life.

The current situation of lighting management and maintenance, when is accomplished, is mainly based on empirical criteria or acquired habits. Experience shows that a high percentage of lighting systems could be found presenting from mild deficiencies up to severe failure because of a lack in optimisation and planning of management and maintenance.

At the present time a project is being carried out at the Universitat Politecnica de Catalunya, in order to study and analyse the management and maintenance lighting problems of under a general cost / benefits approach. In a first stage evaluations of actual costs from the lack of maintenance in urban lighting systems are necessary to establish the weight of the different aspects involve and also as arguments to motivate right applications and the exploration of possible improvements in the practices of procedures.

2. APPROACH

While analysing the cost/benefit relationship that a urban lighting installation produces it is useful to identify the most relevant aspects, their relative importance and the method of evaluating them.

2.1 COSTS

In a synthetic description, costs can be grouped into installation and management costs. Management costs can be divided in energy consumption costs, maintenance costs that will depend on the adopted policy, (spot, bulk, etc.) and administration costs (supervision, control etc.). Lack of an adequate maintenance policy, has a direct influence on costs because it reduces the maintenance operations cost, etc. Moreover it generates other indirect cost, usually overlooked, related to reducing the lighting system lifetime because the same investment must be amortised in a shorter period. Reducing lifetime from 20 to 12 years, with a financial interest of the 8%, makes an increase in the annual amortisation equivalent to 30%.

The natural gradual reduction of the lighting systems output, added to a reduction of the maintenance, has the consequence of increasing in energy consumption, wasting money, and reducing lifetime in components. This phenomenon, usually underestimated, can be the result of:

- lighting system operation out of the necessary schedules
- reactive power comsumption, due to lack of maintenance in the capacitors.
- improper tariff contract with the energy supplying company.
- poor energy supplying quality mainly caused by voltage supply variation.
- sporadic losses difficult to evaluate.

In order to evaluate the weight of each aspect mentioned above, different real cases were analysed.

2.1.1 CASE STUDY

From different areas of Barcelona a data survey of the urban lighting service was fulfilled during the period ranging from 1991 to 1996 and now studied in the light of analysing the increase in costs produced by lack of maintenance in order to establish limits and trends of the most relevant factors involved.

By ***operation of the lighting system out of schedule***: the increase in energy consumption can reach 25 to 30% [1] (table 1). The main cause of these high percentages was lack of maintenance associated with the use of photo-cell controls that require greater care. This conclusions are reinforced by comparison with other results arising from situations [2] in which a good maintenance policy was carried out and in where two sort of switch controls were available. The photo-cell control produced an average operation time ($To_{average}$) in excess of +11.4 min. which represents 1.6% of the energy consumption increase, while lighting systems fitted with programmable astronomical clocks[†] produced a $To_{average}$ = +2,6 min., with a energy consumption increase of 0,4%.

Reactive power comsumption. This factor has in Spain a charge in tariff if the power factor cosφ is < 0.9, otherwise, a discount is applied, its percentage being calculated by means of:

$$Kr(\%)_i = \frac{17}{\cos^2 \varphi_i} - 21 \quad (1)$$

where $Kr(\%)_i$: percentage value to apply to the basic billing of the customer (i), as a discount if it is negative, or as a charge if its positive (capacity loads have charge).

[†] Electronic control switch with an internal clock. This device can be programmed to control the lamp burning hours following the annual seasonal changes for any latitude and longitude.

As within a town hall district several points with energy meters for public lighting can be installed, a $Kr\%_{average}$ can be estimated through the expression:

$$Kr\%_{average} = \frac{\sum_{i=1}^{n}(Kr(\%)_i \times KW_i)}{\sum_{i=1}^{n} KW_i} \qquad (2)$$

KW_i is the lighting power installed in each point (i) where the energy is metered.

Figures 1 and 2 show Kr (%) values. They are data [2,3] collected from two town halls where the maintenance policies are different. A $Kr\%_{average}$ =10% is obtained for fig.1 due to lack of maintenance in the capacitors compensation, while in fig.2, with an efficient maintenance management, $Kr\%_{average}$ = 0.4%.

The ***energy tariff policy*** in Spain [3], allows different possible forms of contracts. In order to determine them, economic studies have to be done because some depend on the load demand, geographical situation, contracted power, etc. A change in the contracting tariff on a town hall, placed in a very unfavourable situation, can mean a 10 % saving [4].

Energy quality supply, specially voltage supply variations, affects lamps characteristics producing alterations in lifetime and lamp power output. The monitored voltage analysed in a town hall [5] with supply voltage problems in the different lighting networks, are shown in figure 3. Variations ranging from
- 4% to +16% were recorded, and originated by load reduction in the network during night.

When using high pressure sodium lamps, the increase in lamp power (P_L) by lamp voltage (U_L), refered to nominal values (P_N ,U_N) can be estimated by means of [6]:

$$\frac{P_L}{P_N} = 2{,}6833 \times \left(\frac{U_L}{U_N}\right) - 168{,}22 \qquad (3)$$

A 22% lamp power increase was expected if all the lamps were running on, a value that can be smaller due to lamp lifetime reduction.

Spanish legislation [7] prescribes that the tolerances for customer voltage level supply should usually not go beyond ±7%. A tariff reduction up to 50% could be applied in case of repeated deficiencies. However this becomes an additional cost due increase in lamp power when the town hall does not control and meter the voltage supply. Furthermore the relamping due premature lamp failure and lifetime reduction in control gear generates a new cost source.

The above situation can be compared with data of a town hall [3], where the management and voltage supply control is considered as acceptable. For this case, the distribution of maximum voltage deviations referred to nominal voltage during night presented in figure 4. The median is +4% and only 8% of the observed values were greater than the +7% prescribed. With a +4% in voltage supply, lamp power will increase in 10%. However, it should be recalled that networks are designed to have a 3% voltage drop at the customer intake point; what in fact compensates the voltage increase, reducing the final lamp power increase to 5 %.

2.2 BENEFITS

The main benefits from urban lighting are to provide the proper conditions for:

- road safety
- citizen safety
- visual comfort
- ambience and amenity

It is difficult to quantify and evaluate these aspects since they have complex cause effects, therefore, they are hard to correlate with the quality of management and maintenance. For this reason, at the time being it is preferred to look for an operative indicator based on service conditions, that is related to:

- lighting level, uniformity and glare, referred to standard values
- service interruption time
- qualitative factor corrections according to aesthetics etc.

This methodology already explored [8] conceptually is to be applied in this project.

3. CONCLUSIONS

Results from a preliminary study where energy charges from lack of maintenance in urban lighting installations were evaluated at different areas of Barcelona. Table 2 summarises the analysed aspects. Costs could fluctuate from ~ 6 % with a good management and maintenance to 72% or even more with the lack of management and maintenance. It is assumed that these aspects influence the costs / benefit ratio arising from urban lighting management.

Cost increase due to	**Management**	
	good	**poor**
Operation out of schedule	0.4%	30 %
Reactive energy consumption	0.4%	10 %
Energy tariff contract	0 %	10 %
Energy supply quality	5 %	22 %
Total	**5.8%**	**72%**

Table 2: Increase of energy charges under reduced urban lighting maintenance

Nowadays attempts are being undertaken to establish a methodology to obtain, control and simulate the costs/benefit ratio from urban lighting and it is expected to use this methodology as a tool to argue and stimulate the adoption of policies of correct lighting management.

4. ACKNOWLEDGEMENTS

The authors wish to thank Saro O., Albert V., Villarraso V., and Gallego J. for the data supplied in the achievement of the paper.

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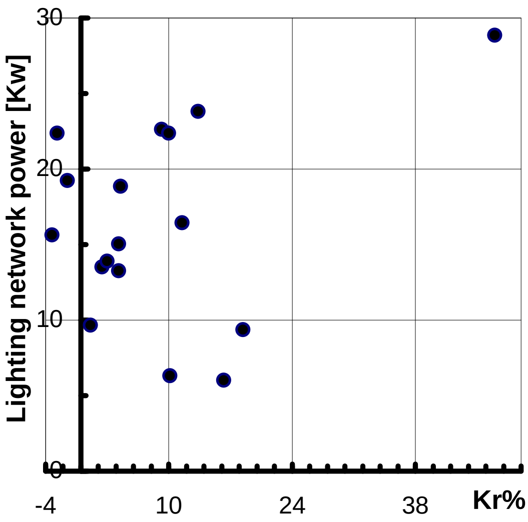

Figure 1: Kr% with poor maintenance for each lighting network in a town hall [2] as a function of the install power.

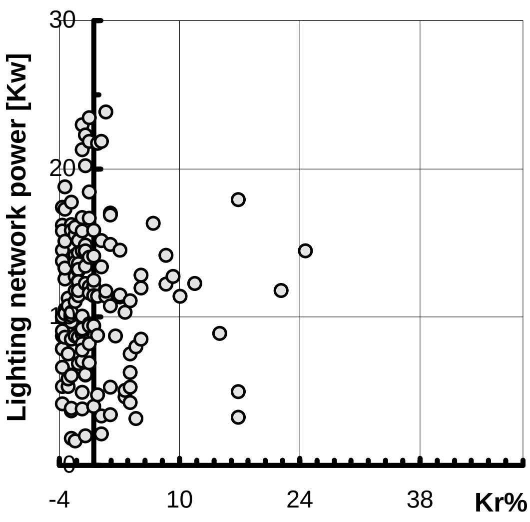

Figure 2: Kr% with good maintenance for each lighting network in a town hall [3] as a function of the install power.

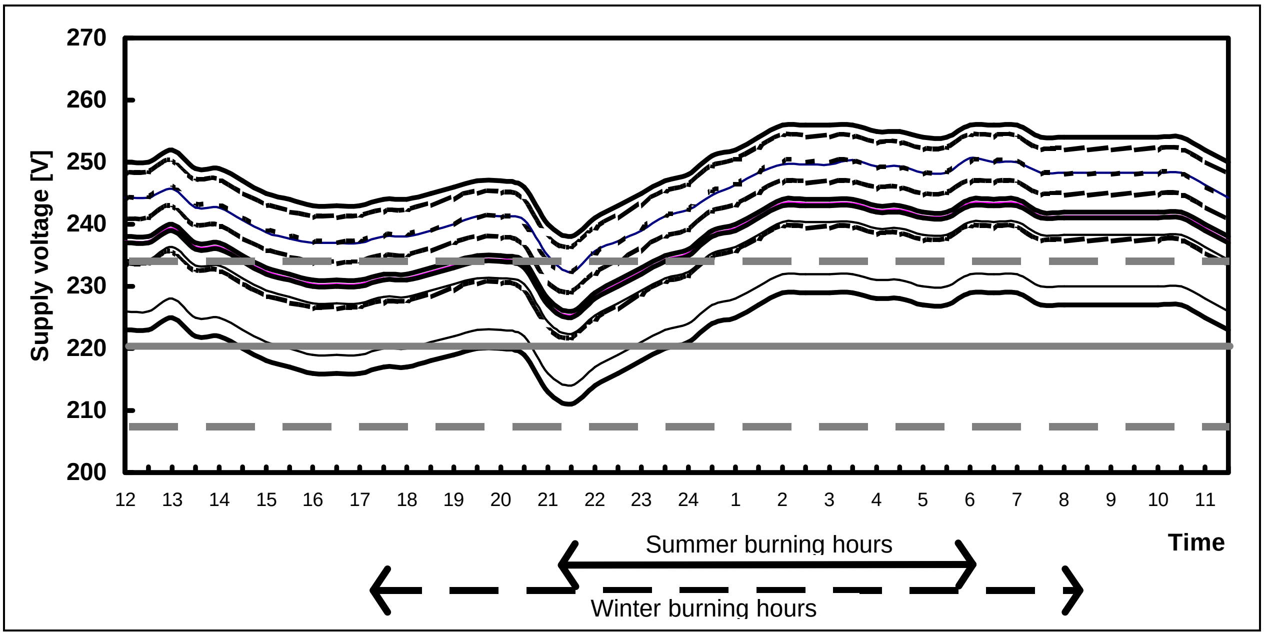

Figure 3: Variation of lighting network voltage [6] over a 24 h period.
In bracket lines ±7% of 220V supply voltage is indicated.

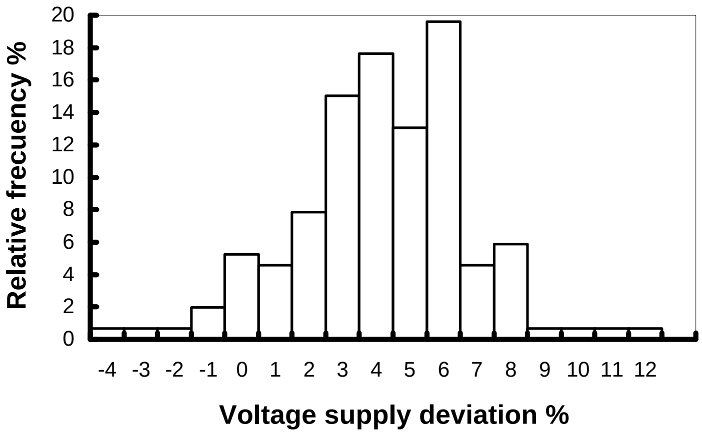

Figure 4: Distribution of maximum voltage deviations [3], refered to the nominal value during the night. Frequency is refered to total observations

Table 1: Example of operation of the lighting system out of schedule

Town hall: R..., Nº Light points: **811,** period: 291 days [1]							
Point	**Lighting power [Kw]**	**Theoretic energy [Mw.h]**	**Energy billing [Mw.h]**	**Running time [hs]**	**Out running time [hs]**	**Exceeded time [hs]**	**Wasted energy [Mw.h]**
A	9.67	33.44	15.61	1614	1842		
C	22.37	77.33	148.90	6655		3119	71.58
D	13.50	46.66	61.08	4525		1069	14.43
E	13.87	47.95	22.52	1623	1833		
F	15.05	52.01	24.48	1626	1830		
H	6.32	21.86	8.69	1373	2083		
J	16.42	56.76	73.50	4475		1019	16.74
K	15.62	54.00	52.51	3360	96		
L	23.82	82.34	123.98	5204		1748	41.64
Total	*136.64*	*472.35*	*531.27*				*144.39*
%		**100.00**					**30.56**

Town hall: SPR, Nº Light points: **1157,** period: 305 days [1]							
A1	13.25	43.54	24.70	1864	1422		
A2	6.00	19.72	13.60	2267	1019		
A3	9.37	30.81	44.78	4776		1490	13.97
B	22.87	75.15	50.16	2193	1093		
C	17.78	58.43	62.37	3508		222	
D2	22.62	74.35	133.28	5891		2605	58.93
Total	*267.12*	*302.00*	*328.89*				72.90
%		**100.00**					**24.14**