STREET LIGHTING - SCOPE OF TECHNOLOGICAL ADVANCES AND ROAD USER SAFETY IMPROVEMENTS: A CASE STUDY OF SURAT

DHIRAJ M. SWAMI
B. E. Civil - I, Civil Engineering Department,
Sarvajanik College of Engineering & Technology, Surat – 395001
gooddhir@yahoo.co.in

ER. BHASKER V. BHATT
Assistant Professor, Civil Engineering Department,
Sarvajanik College of Engineering & Technology, Surat – 395001
bhasker.bhatt@scet.ac.in

ABSTRACT: All the fields of engineering and technology have developed significantly in attaining the sustainable and green aspect of technology conserving the natural state of planet Earth. The regime of civil engineering which is well-known for exploiting the maximum natural resources however, this exploitation is an integral part of overall development of any country and humankind as well. Road safety and street lighting is an integral part of traffic engineering. The importance and role of street lighting in traffic engineering is very well known however, the advancement of engineering and technology have least explored so far having practical success in this regards. Surat is one of the pivotal metropolitan cities of western India and has been one of the fastest developing cities of the country. In its journey of development, remarkably, the Surat Municipal Corporation (SMC) has principally achieved a zero debt burden status since almost a decade showing a positive cycle of development. Most of the capital expenditures are being shared by the revenues that are generated. Each year SMC is spending Crores of rupees towards O&M for thousands of streetlights. Saved money is money earned one and can be leveraged to yet another capital investment in a smarter way. The paper is based on analysis of the road crashes in Surat during morning and evening sunshine transition hours, additional illumination provided, level of lacking in service provision, extra expenses in absence of smarter streetlights, introduction of a concept of "intelligent street lighting" and saving aspects through a system of solar controlled illumination.

1. INTRODUCTION

1.1 Background

Does streetlight prevent road crashes and can be a source of savings for the power consumption of an urban local body? Making changes to environmental conditions and operational practices to discourage road crashes has become a well established part of the conventional prevention wisdom. Improved street lighting is entirely consistent with road crash prevention concepts; increased visibility should both reduce opportunity for road crash and increase the probability of an offender being caught. But, does it all really work? Present paper discusses an attempt to evaluate probable surplus and unwanted usage of energy consumption by street lighting in Surat city and reveals the road crashes at night with probable reason of absence of proper illumination on roads.

1.2 Description of the condition

As reported by National Criminal Records Bureau in India, Traffic Crashes majorly, road crashes is the major contributor of accidental deaths by Unnatural causes. 'Road Crashes' in the country have increased by 2.1% during 2010 compared to 2009. The casualties in Road Crashes in the country have increased by 5.5 during the period.

The statistics reveal the growing magnitude of 'Road Accidental Deaths'. During year 2010 with a total 4,30,654 'Road Crashes' were reported. These crashes caused 1,33,938 deaths that involved male fatality at 85.1%; people of age groups 15 to 44 yrs at 71.28% in which male toll to the tune of 61.56%. These age-groups are the economic contributors of the country.

Road traffic crashes should not be dismissed as the unfortunate culmination of chance, but are best considered as risk factors dependent upon epidemiological events. The risk of a driver having a crash in the dark is about 1.5 to 2 times higher than in daylight (Elvik et al, 2004). During 2010, maximum 'Road Crashes' as to 69,282 were reported during 18:00 to 21:00 (16.1%), followed by 46,176 (10.72%) during 21:00 pm to 24:00, and least number (29,129) of these crashes (6.8%) were reported during 00:00 to 3:00 in the night followed with 37,693 (8.75%) during 3:00 to 6:00 hrs. It was reported that the fatality occurred during night hours i.e. 18:00 to 6:00 Hrs was having a share of 42.33% to the total road traffic crashes. The problem is likely to become more severe as private car ownership continues to rise.

Surat in particular shares 3.2% of the total accidental death in mega cities of the country for the year 2010. During the year 2011, total road crashes in Surat was recorded as 1,223 out of which 41.46% were during 18:00 to 6:00 hours having 48.33% of total fatalities and 40.67% of total Major injuries. ***Figure 1*** indicates total number of road crashes recorded along with fatalities and major injuries observed during year 2011. The relevance of this information to that of the national figures and consideration of almost equal day and night statistics leads to a fact that there may be inadequate street lighting in urban centers of the country causing road crashes at night hours.

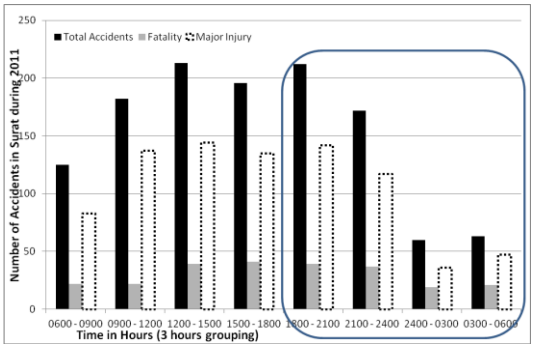

FIGURE 1: ROAD CRASHES AND FATALITIES IN CITY DURING 2011 (SOURCE: TRAFFIC POLICE, SURAT, 2012)

On the other hand, Surat city has been having roads with a total length of 1,885 km wherein following ***Table 1*** shows roads under various categories.

TABLE 1: ROAD LENGTHS WITHIN SMC

Road Surface	Length in km
Bituminous Top	1360
Cement Concrete	30
W. B. M.	290
Un-surfaced	205

(Source: Surat Municipal Corporation, 2012)

Altogether SMC has established a huge network of 87,569 streetlights under various categories till year 2011. Following ***Table 2*** gives information of about decadal category wise installation of streetlights carried out by SMC.

TABLE 2: CATEGORY-WISE INSTALLATION OF STREETLIGHTS IN SURAT

Year	28/40 W Halide & Sodium Lamp	70 W Halide & Sodium Lamp	150 W Halide & Sodium Lamp	250 W Halide & Sodium Lamp	125 W Lamp	400 W Halide & Sodium Lamp	Total
2001	23,395	1,113	5,989	4,781	629	512	36,419
2002	25,002	1,134	6,432	4,769	618	508	38,463
2003	29,561	1,782	7,054	5,014	581	508	44,500
2004	34,315	1,752	8,192	4,908	576	502	50,245
2005	36,013	1,811	8,940	5,355	638	474	53,231
2006	38,882	2,384	9,792	5,385	331	1,075	57,849
2007	43,906	2,521	10,316	6,339	588	1,092	64,762
2008	47,208	3,243	11,347	6,857	418	1,175	70,248
2009	54,344	3,560	12,421	6,836	512	1,522	79,195
2010	56,375	3,826	13,923	6,769	463	1,525	82,881
2011	59,584	4,142	14,615	6,870	333	2,025	87,569

(Source: Surat Municipal Corporation, 2012)

For the year 2010-11, SMC consumed almost 2.48 Crores of KWH at cost of INR 9.96 Crores for streetlight service in the city. This was accounting 17.17% of energy consumption and 13.75% of total expenditure towards energy consumed by SMC. The energy consumption sources apart from street light service are water supply service (52.51%), sewage disposal system (21.47%) and other services (8.85%) provided by SMC. The average energy rate for streetlight service observed at Rs. 4.004 per KWH.

TABLE 3: O & M EXPENDITURE ON STREETLIGHTS BY SMC

Year	O & M Expenditure (INR in Lacs)
2001-02	278.85
2002-03	197.58
2003-04	218.79
2004-05	265.76
2005-06	351.76
2006-07	407.31
2007-08	385.97
2008-09	517.85
2009-10	448.59
2010-11	447.91

(Source: SMC, 2012)

Table 3 describes total O & M expenditures carried out by SMC since 2001. Records from table state that average expenditure on streetlight services by SMC is INR 352.03 Lacs per year for the decade against obtaining a constant improvement on service coverage aspect.

Remarkably, ***Table 3*** suggests that expenditure for the year 2002-03 and 2003-04 are reduced against year 2001-02 though service coverage was increased. This in particular was obtained as SMC converted conventional FLL to Energy Efficient FLL (Jan-03) saving 15.37 Lacs KWH energy per annum. In the very same year, SMC also derived a policy to install new FLL with electronic ballast and hi-lumen lamp

(continuous) with a motive to conserve 11.91 Lacs KWH of energy per annum. Also, SMC initiated switching off streetlights during low traffic period (Jan-04) claiming saving 15.38 Lacs KWH energy per annum. Further reform was adopted in a way to install energy conservation feeder pillar based on central voltage reduction method (Sep-10) for 17 locations in the city saving 2.74 Lacs KWH of energy per annum.

1.3 Description of the intervention

Public lighting was first introduced in both London and New York in 1882, well before the rise of the motor car. The popularity of street lighting lay in the assistance it gave to the maintenance of social order and the reduction of crime. Scientific interest in injury prevention did not follow for another 70 years or so. During the 1950s and 1960s studies began to be conducted to assess the role that street lighting could play in improving the safety of the ever busier and more dangerous roads of motorized nations. The International Commission on Illumination (CIE) argued in 1960 that lighting reduced crashes on urban traffic routes (original report updated in 1992 (CIE 1992)), and work during the following decade suggested the magnitude of this reduction to be approximately 30%. Since then the provision of street lighting has generally been justified on the basis of cost savings expected from the increased service and safety levels (Macauley et al, 1989). It is perhaps unfortunate that the readiness with which this figure was accepted has dissuaded researchers from conducting as much research in the field as they might have otherwise done.

Although research continued throughout the 1970s the majority of work is now 30 years or more out of date. Much has changed on the world's roads since then: traffic volume has swelled universally, including in countries where automotive travel was previously rare. As such, the estimates derived from early work may not apply to modern roads and driver behavior. Furthermore, estimations for the effect of street lighting were never even investigated in many low and middle-income countries where there are more vulnerable road users who are less likely to be segregated from traffic. It is these countries that now carry the greatest burden from road traffic crashes.

In Surat, records in particular hour-wise road crashes are maintained by the Traffic Police Department however, there is no precise intervention available that might assist interrelating streetlight and road crashes. ***Table 4*** shows the number of crashes during probable sunrise and sunset hours for the year 2011 in city roads.

TABLE 4: ROAD CRASHES DURING SUNRISE AND SUNSET DURING 2011

Time (Hrs)	**Total Accident**	**Fatality**	**Major Injury**
06-07	35	9	20
07-08	48	8	37
17-18	81	13	54
18-19	75	12	47
Total	**239**	**42**	**158**
Total (2011)	1223	240	841
% to total	**20%**	**18%**	**19%**

(Source: Traffic Police, Surat, 2012)

It clearly indicates that the sunrise and sunset timings are having a considerable share of 20% to the total road crashes giving lead to investigate the relation among starting/stopping of the streetlight services and road crashes.

As such precise information is not available at present, the aspect shall be future scope of research and intervention. Here, further discussion is based on the optimization on usage of streetlights during sunrise-sunset hours.

2. ANALYSIS AND RESULTS

2.1 Methodology

With an objective to identify the possible cost optimization for the energy consumption by streetlights, following methodology was adopted:

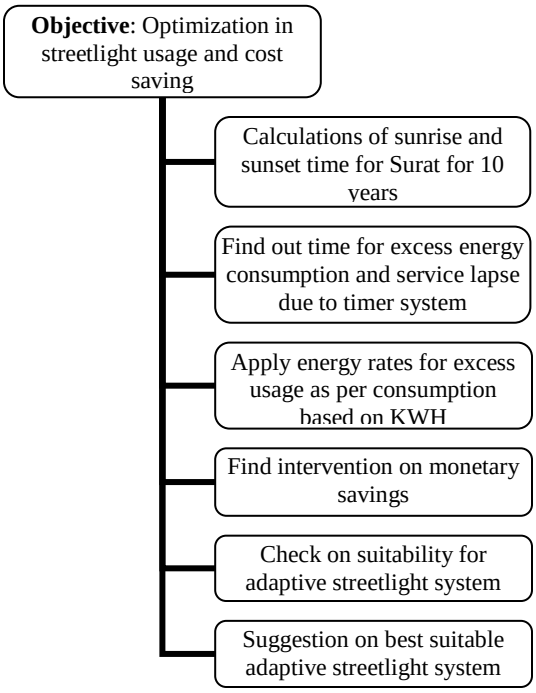

FIGURE 2: METHODOLOGY

Performing methodology as mentioned in ***Figure 2***, output regarding various aspects were obtained and are mentioned in subsequent subsections.

2.2 Outputs

The monetary aspect of a scientific study is very much required to make it practical and viable; and using sun calculations one can find the estimated improper financial resources utilization due to the lack of proper maintenance technology in street lighting. The Sun calculations also enables oneself to find the time for which the facility lacked and these calculations can be used to find the parameter of damage done and helps in evolving set of possible alternatives.

While performing the study, sunrise and sunset timings for Surat city were obtained for the duration 2001 to 2012 using software developed by *Almanac for Computers*, 1990 published by Nautical Almanac Office, United States Naval Observatory, Washington, DC 20392. The calculations were performed using best suitable logic and input data for Surat city.

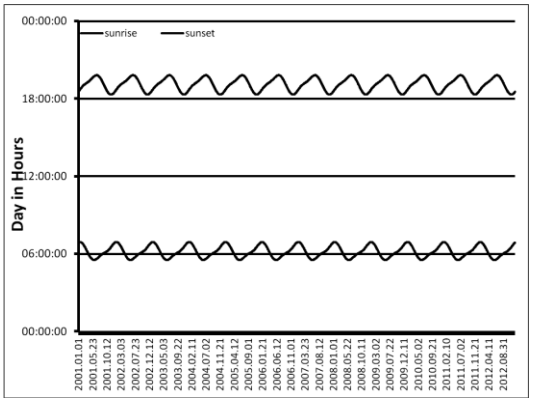

FIGURE 3 SUN TIME CALCULATIONS

Figure 3 shows the calculations performed to find out the variation of sunrise and sunset timings for a time period as stated earlier. The analysis shows that a particular pattern in observed with a little variation.

Based on the timer set for operating the streetlights in Surat city, time for the extra illumination and lack of facilities were obtained. This are as shown in ***Table 5*** below.

TABLE 5: EXTRA ILLUMINATION AND LACK OF FACILITY

Year	Street lights	Extra illumination	Lack of facility
2001	36419	444:02:08	106:57:05
2002	38463	444:01:47	106:56:56
2003	44500	444:01:24	106:56:11
2004	50245	444:33:13	107:48:11
2005	53231	444:00:52	106:56:00
2006	57849	444:00:32	106:55:50
2007	64762	444:00:27	106:55:38
2008	70248	444:32:22	107:55:27
2009	79195	443:59:41	106:55:08
2010	82881	443:59:18	106:54:50
2011	87569	443:58:59	106:54:31
2012	89099	444:31:45	107:54:29
Total		**5329:42:28**	**1286:00:16**

Summing up this way, it is evolved that total extra illumination was consuming energy for 5329.42 hours wherein the service was not available for 1286 hours during 2001 to 2012.

Further, based on rating available for energy consumption, total of this extra illumination was converted to actual KWH energy consumption for actual number of streetlights assuming that all these streetlights are working for the whole year. ***Table 6*** enumerates energy consumption under each categories.

TABLE 6: CATEGORY WISE ENERGY CONSUMPTION BY STREETLIGHTS

Year	40 KWH	70 KWH	150 KWH	250 KWH	125 KWH	Total KWH
2001	415570.06	34598.27	398939.27	530786.62	34915.79	1414810.01
2002	444115.53	35251.07	428448.38	529454.38	34305.18	1471574.54
2003	525097.96	55394.54	469881.05	556654.28	32251.31	1639279.13
2004	609544.21	54461.97	545685.50	544886.16	31973.76	1786551.60
2005	639706.12	56296.02	595511.28	594512.10	35415.38	1921440.90
2006	690668.74	74108.07	652264.70	597842.70	18373.81	2033258.03
2007	779911.06	78366.80	687169.39	703755.78	32639.88	2281842.91
2008	838565.15	100810.60	755846.36	761264.14	23203.18	2479689.43
2009	965323.34	110664.74	827387.65	758932.72	28421.12	2690729.57
2010	1001400.40	118933.51	927438.88	751494.38	25701.13	2824968.29
2011	1058402.51	128756.56	973534.38	762707.40	18484.83	2941885.67
2012*	1077924.27	129658.04	989854.32	773143.28	19428.50	2990008.40

** Note: Estimated for entire year*

Further it was informed that the subsidized rate of energy consumed by SMC was charged by two agencies were at an average of INR 3.15 per KWH during 2001-2009, INR 3.25 per KWH for year 2012 and INR 3.15 per KWH then after. Analysis on energy bill spent on additional energy consumption (in absence of sunlight adaptive streetlight) has resulted in an expenditure of INR 71.47 Lacs per year. ***Table 7*** elaborates year-wise energy bill for additional energy consumption. If SMC through any of reforms agenda, could utilize technology and implement using adaptive streetlight, possibly INR 857.58 Lacs would be saved in past 12 years.

TABLE 7: ADDITIONAL ENERGY BILL FOR EXTRA ILLUMINATION

Year	Additional energy bill (INR in Lacs)
2001	44.57
2002	46.35
2003	51.64
2004	56.28
2005	60.53
2006	64.05
2007	71.88
2008	78.11
2009	84.76
2010	91.81
2011	102.97
2012*	104.65
Total	**857.58**
Average	**71.47 (per year)**

** Note: Estimated for entire year*

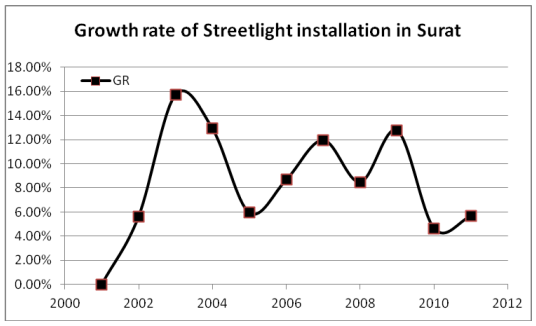

FIGURE 4: STREETLIGHT INSTALLATION PATTERN

Based on ***Table 2*** and ***Figure 4***, it is revealed that depending upon availability of funds and suitability, SMC has increased overall streetlights on an average rate of 8.39% each year during period 2001-2011.

With prevailing financial situation, expansion and growth momentum being handled by SMC, it can be said that SMC shall still continue to make capital investment in the sector in particular with almost the same pace. Hence there is potential scope of additional energy consumption through extra illumination, which depicts a need for adaptive and intelligent streetlight operation system rather than existing clock timer based system.

3. SCOPE ALTERNATIVE TO TIMERS

It is being first ever conceptually introduced in India to install each of streetlight with a device which is being operated on the luminosity of natural sunlight (detected by a photovoltaic cell) and having GSM technology based sim card for pre-programmed communication regarding status of its operational conditions, each of streetlight can be converted into an intelligent one. The photovoltaic cell can, through circuit, control the on-off process and the supply of energy for electric lighting unit. On the other hand, the sim card can be programmed to send message directly to a received with a unique identity if the energy supply is interrupted. Average cost of such a device is estimated to be around INR 2,000 each using prevailing technology and relevant logistics. If all streetlights installed till 2012 be equipped with such a device, it will required additional initial capital investment of INR 1781.98 Lacs however on the other hand, it will start saving of energy at least worth INR 104.63 Lacs each year making its capital cost recovered.

For evaluation on fiscal feasibility of such part considering total capital investment and 4% maintenance cost for fifteen year expected device life duration, a total fund requirement for such equipment installation is anticipated at INR 3,209.25 Lacs. However, with anticipated amount of savings each year, it can save INR 4,093.86 Lacs in total leveraging net savings from energy bills at INR 884.61 Lacs towards yet efficient utilization of public money.

Capital investment payback period is anticipated as around 12 years. Hence, such a device is capable of not only to recover its capital investment as well as saves considerable amount from future energy bills also. In addition, it can lead to reduced manpower requirement deputed for routine checkups, thus saving further revenue from establishment. On the other hand, it will reduce road crashes at larger extent. At present no analysis is possible for evaluating the economic interventions from nonoccurrence of crashes during morning and evening transition times.

4. CONCLUSION

The need to reduce power consumption has brought on significant research and product development in the world of roadway lighting. The term "Intelligent Lighting" can be used to define the concept of illumination based on sunlight and reporting for need of attending for maintenance. Adoption of such a system can be helpful in pulling down the rate of accident at critical sunshine transition hours as well as turn up all the public service devices into direct savings assets leveraging funds for further effective utilization for SMC. This SMC can take additional responsibility for the environment, improve service level and traffic safety, save energy and maintenance costs and make a good example in the country also.

5. REFERENCES

- Almanac for Computers, 1990 published by Nautical Almanac Office, United States Naval Observatory, Washington, DC 20392
- Accidental Deaths and Suicides in India (2010), National Crime Records Bureau, Ministry of Home Affairs, India (http://ncrb. gov.in)
- Atkins S, Husain S and Storey A, (1991) The influence of Street Lighting on Crime and Fear of Crime ISBN 0 86252 668.
- Beyer FR, Ker K, Street lighting for preventing road traffic injuries (review), the Cochrane collaboration, John Wiley & Sons, 2009
- Bhatt B. V. (2007). Evolution of Mechanism for Road Safety Audit of Urban Roads: A Case study of Surat, Dissertation, Post Graduate Course in Town and Regional Planning, Civil Engineering Department SVNIT, Surat.
- Black Sea Regional Energy Centre (June 2008), Intelligent road and street lighting in Europe (E-street), grant agreement: EIE/05/157/SI2.419662, Bulgaria
- Don McLean-DMD & Associates Ltd (Sep-Oct 2006), Adaptive Roadway Lighting, IMSA Journal
- Laha Shatabdi, A Study on energy efficient and solar PV street lighting system, Solar ppt
- Per Ole Wanvik, Adaptive Street lighting in Drammen, Norwegian Public Roads Administration (per.wanvik@vegvesen.no and www.datek.no)
- Surat City Development Plan (2008-2013), Surat Municipal Corporation (SMC) and Surat Urban Development Authority (SUDA), Surat.
- Surat Municipal Corporation Website, street light department and energy conservation cell pages, 2012. (http://www. suratmunicipal.gov.in/content/ energyeff/consumption.shtml)
- World Health Organization (April, 2011), Causes of Death 2008: data sources and methods
- World health statistics 2008 (http://www.who.int/whosis/who stat/2008/en/index.html