Computer aided efficient lighting design practices in developing countries

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KEYWORDS

computer, software, information technology, lighting design, energy management, architects, interior designer, consultant, ProjectKalc, environmental protection agency, value light, GE, Eco Lumen, Tata Infotech Ltd

ABSTRACT

The paper deals with the analysis of the obstacles faced by designers & lighting professionals in achieving energy efficient designs. The paper takes inputs from the detailed market survey carried out by the authors for determining the extent of implementation of efficient lighting design practices in India. The paper attempts to analyze the impact of the emergence of various lighting design software solutions that look at both – the technical aspects as well as the energy consumption analysis of the designs.

BACKGROUND

Lighting design software have been available in developed countries for many years, but in most developing countries these software are used by the lighting manufacturers merely as a marketing tool for selling their lighting products. As a result, the aesthetic aspects of lighting designs were gaining greater focus as compared to the energy efficiency aspects. However, the recent interest in global energy conservation efforts has seen the development of various software solutions for the professionals to analyze the energy saving potential in lighting designs.

The energy-efficient lighting technologies available today can dramatically reduce energy consumption and prevent pollution while delivering comparable or better lighting. If energy-efficient lighting were used in India everywhere it were profitable, the electricity required for lighting would be cut by 50 percent, and aggregate national electricity demand would be reduced by more than 10 percent. At the same time, it was felt that most of the practicing architects & lighting designers in developing countries such as India do not provide enough priority to energy efficiency in their design related work. In order to assess the reality of this hypothesis that a detailed survey was carried out in the two major metros of India in early 2000.

SURVEY DETAILS

Objective of survey

The Objective of this survey was to determine the extent of implementation of efficient lighting design practices among professional building designers in India.

- To identify the methods and processes used by the building designers for lighting designs
- To determine the usage of existing lighting design software among the building designers
- To determine the awareness level among building designers for energy conservation using efficient design practices
- To analyze the reasons for non-compliance of scientific methods among those professionals who do not use them
- To estimate the perceived need for a lighting design tool having focus on energy efficient designing

Survey Methodology

Data Sources :

Secondary data sources were analyzed, but no publications or reports were available for providing the desired information in the Indian context. Hence secondary data sources were used for obtaining a list of the sampling universe and for an understanding of the technical aspects of lighting design.

The various secondary sources of data consulted include:

- The Directory of Architects (1998), by the Council of Architects, India
- The Yellow pages for Delhi and Mumbai, published by Tata Press
- The IESNA Handbook

The lack of information from secondary sources meant that primary sources would have to be contacted for compiling the required information.

Survey Type:

Given the technical nature of the information sought, it was decided to conduct personal interviews as the data collection methodology. This would allow more in-depth questioning and better understanding of the respondents work environment.

Sampling Methodology:

Sample Frame:

The total number of architects and interior designers in India was estimated at 44,000. Of these, 25,500 were architects registered with the Council of Architects, India and 18,500 were interior designers registered with the Indian Institute of Interior Design. The geographical distribution of the designers in India was rather skewed, with almost 35% of them practicing in the two major metros of Delhi & Mumbai.

The Directory of Architects indicated that more than 60% of the registered architects were in the age group of 25 to 40 years. 60% of the architects were self-employed while 20% were employed in private organizations and the remaining 20% in public enterprises.

Sampling Size

A sample size of 440 was considered appropriate for the survey so long as the cross section of the sample frame was represented in the sample.

Sampling Method

Given the fact that more than a third of the designers were populated in Delhi & Mumbai, and that the regional distribution of the remaining two-thirds was in numerous small sized packets, with no single other town accounting for more than 4% of the total designers, a decision was made to focus the surveys in these two metros.

The Sampling Method used was Stratified Quota Sampling with simple random selection. Quotas were created for each city in ratio of the professional designers populating the two cities. Stratified quotas were created for each city on the basis of the age profiles of the designers.

An initial list of 500 designers was selected by this method from the Sample Frame. The additional 60 designers were selected as a buffer for non-availability or no-response from some of the original list of 440. An additional list of 15 designers was selected from Mumbai for pilot testing the data collection format.

Data Collection Format

A detailed questionnaire was created. (An edited questionnaire providing overview of type of information collected is enclosed as Annexure I.) This questionnaire was classified into various segments. The first segment focused on obtaining demographic information about the designers for cross tabulation. The second segment was aimed at obtaining information about the methods of lighting design used by the designers. Subsequent sections focused on the awareness and usage of lighting design software, energy efficient lighting design practices and on the perceived need for a tool to aid in energy efficient lighting designing.

The questionnaire was divided into various workflows, based on the responses given the by respondent for each section. This made it even more imperative to have the questionnaire implemented by an interviewer rather than having a self-administered questionnaire. Accordingly, appropriate instructions were included in the questionnaire for the interviewers.

One iteration of improvement was implemented after the initial pilot test of the questionnaire. The major change in the questionnaire during this iteration was the inclusion of an annexure with the description and definition of technical terms used in the questionnaire.

Field Work

The entire fieldwork was to be completed over a period of 30 days. Hence, 20 interviewers were needed to cover all the respondents within the stipulated time. Based on the length of the questionnaire and the anticipated time required for obtaining appointments with the designers, an average of 3 respondents in 2 working days was expected.

The 20 interviewers were selected from 4 Post Graduate Management colleges in Delhi and Mumbai. All the applicants were first year students (for the two year courses), in Marketing Management, having covered a few hours of their courses on the basic understanding of primary surveys.

ANALYSIS

Data was collected from 447 designers during the field work. The data was compiled using various techniques including simple averages, weighted averages, standard deviation, correlation and regression. The need for more complex analysis methods had been earlier eliminated by the nature of study involved.

RESULTS

The results of the study conclusively showed that almost 90% of the architects and interior designers in India tend to use 'Experience' and 'Thumb Rules' for creation of lighting designs. 9.8% of the designers used scientific design practices for lighting design while only 0.2% of the respondents used any lighting design software. While the respondents did mention a growing concern among their clientele for energy conservation and reduction in electricity bills, only 1% had ever provided energy calculations to their clients.

Almost all the respondents (95%) mentioned the complexity of calculations (or lack of awareness about the scientific methods) as the major reason for non-compliance to scientific design practices. Other prominent reasons provided by the respondents included lack of awareness about modern energy efficient products (45%), lack of awareness about technical information about lighting products (40%).

Although as many as 80% of the respondents used computers in their offices, only 1% of them used these computers for scientific calculations. An overwhelming 70% of the respondents felt the need for a lighting design software that could also ensure energy efficiency in the designs at the same time as providing them with all the features required for creating professional lighting designs.

SURVEY SUMMARY

The survey, thus, clearly brought out the lacunae in the lighting design processes adopted by professional designers in India. What remained to be analyzed was the inherent obstacles to the process of efficient lighting designing that painted such a sorry picture for the designers in developing countries.

A detailed analysis of the factors involved in the designing of an efficient lighting system was therefore called for, in order to understand why these professionals were not able to devote enough time & effort in following these practices and to try and discover some workable solutions to the problem.

FACTORS INVOLVED IN LIGHTING DESIGN

The scope of lighting design can differ widely from installation to installation. Successful lighting design begins with an assessment of the occupants' lighting needs, which, in turn, depends on the tasks performed in the workspace. The lighting system should then be designed to provide the quantity and quality of light in accordance with those requirements. For visual comfort of the occupants it is essential that the lighting, task and surrounding area be evaluated together. Although lighting retrofits are generally limited to lighting equipment, a good design should evaluate and modify the work environments where appropriate.

Room dimensions and color of the room surfaces (walls and ceiling in particular) affect the light output obtained from a particular lighting system and thus the energy consumption of artificial interior lighting systems. As much as one-third of the energy used by a lighting system depends

Fig 1. Methods used by professionals for lighting designs

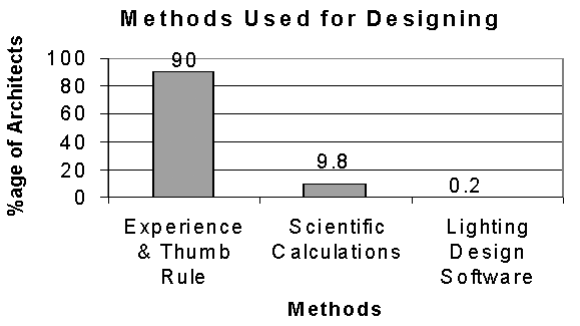
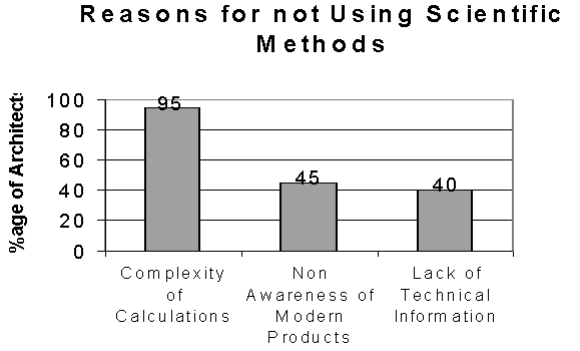


Fig 2. Reasons for not using scientific calculations



on the interior features such as ceiling height, windows and reflectance properties of the room surfaces and furnishings.

Various methods, such as lumen method, point-by-point method or ray tracing method can be used for lighting design. All lighting design software use one or more of these methods. Of these, lumen method is one of the most commonly used processes for lighting design.

For most of the designers what is more difficult is to keep track of the changes in the calculations through out the conceptualization & finalization of the project. Designers need to do these calculations repetitively with every change in the customer requirement. At the same time, most of the customers do no understand the intricacies of the design process and are unwilling to spend additional money for the time designer needs to spend in recalculating.

Discovering Solutions

Modern technology has provided designers with multiple options for overcoming the obstacles of energy efficient lighting designing. On the one hand, there are numerous lighting products available in the market that provide greater energy efficiency, on the other hand we have software that recommend the most appropriate lighting products to be used in the optimal quantities according to the application and usage. Following examples can illustrate the complications faced by the lighting professionals in finding optimum solutions & then implementing them.

It is a common practice in India to use incandescent bulbs in hotels & restaurants in large numbers due to their better color rendering property and the low initial investment. Although the energy saving benefits of the Compact Fluorescent Lamps (CFLs) is widely publicized by the manufacturers, lighting professionals find it difficult to convince the end user to invest in CFLs. Also there are numerous case studies available where maintenance personnel find it difficult to get the budget approvals for replacing the CFLs and as a result opting to use incandescent bulbs once the initial set of CFLs complete their useful life. The typical cost of incandescent bulb is Rs. 10. (20 cents) as compared to Rs. 300 – 500 ($6-10) for a good quality CFL. Thus end customer needs detailed lifecycle analysis from the consultant for doing the investment in CFLs.

In India most of the tube lights used for indoor illumination are 40-watt old tube-lights. Replacing them with more efficient tube-lights with tri-phosphor coatings offer a good opportunity for energy saving. The lighting efficiency of these new generation fluorescent tube-lights exceeds 90 lumens/watt as compared to 65-70 lumens/watt provided by the traditional fluorescent tube lights. Energy efficient fluorescent tube-lights cost around Rs. 40 – 50 (80 cents – 1 $) more as compared to the conventional tube-lights, at the same time the annual electricity cost of each tube-light can be in the range of Rs. 700 – 1000 ($ 14- 20), depending on the working hours. So more importance should be given to reduce the total number of tube lights by using more efficient lighting technology.

All fluorescent and HID (High Intensity Discharge) lamps require a ballast to provide the necessary starting voltage and regulate lamp current and power quality. Ballasts determine the lamp's light output, life and control capabilities. In India, the most common type of ballasts use is the magnetic ballasts, also known as electromagnetic ballasts. These ballasts have improved from the standard efficiency ballasts (10-13 watts loss for 36 watt tube light) to higher-efficiency low loss (5 watts loss) models. Replacing the existing conventional ballasts either by low loss ballasts or electronic ballast can reduce the ballast losses from 10-12 watts to 3-7 watts. Electronic ballasts have been developed for almost all fluorescent lighting applications to replace their conventional magnetic counterparts directly.

A lighting upgrade is an investment not only in reducing electricity consumption but also in improving the performance of the building for grater occupant satisfaction. A building's lighting directly affects the comfort, mood, productivity, health and safety of its occupants. Moreover, as the most visible building system, it also directly affects the aesthetics and image of the building and of the business conducted in that building. Successful lighting upgrades take into account the impact of energy efficiency choices on the building occupants and seek to merge efficiency with improved lighting quality and architectural aesthetics wherever possible.

Now let us review some of the leading lighting software dealing with the efficient lighting design practices.

PROJECTKALC

ProjectKalc assists Green Lights partners in selecting aggressive upgrades that meet the profitability and lighting quality criteria established in the Green Lights Memorandum of Understanding (MOU). Green Lights is a voluntary, non-regulatory program sponsored by the U.S. Environmental Protection Agency (EPA). Its purpose is to encourage major U.S. corporations to install energy-efficient lighting technologies wherever they are profitable and maintain or improve lighting quality. The program is specifically developed for the users in United states & thus requires some inputs & uses terminology, which might be alien to designers in other parts of the world.

ProjectKalc's basic capabilities can be used to define an existing fixture type and analyze the impact of a potential upgrade fixture and control application. ProjectKalc calculates project costs, energy and demand reduction, energy cost savings, internal rate of return (IRR), life cycle cost (LCC), and net present value (NPV).

User can define a project, which includes data about the building as well as rooms. User needs to enter various inputs such as room dimensions, color of wall, ceiling. Based on the user defined inputs the software then calculates lighting parameters such as room cavity ratio, reflectance etc. ProjectKalc comes with a basic database of standard fixtures which user can include in the project. It also allows users to add custom fixtures by entering performance information for fixtures not contained in the reference databases.

ProjectKalc also allows user to define new upgrades by entering a name for the upgrade in the Upgrade box. This upgrade name is used as an identifier for this upgrade. User can compare the upgrade for finding out the economic feasibility and the energy consumption comparison of the project.

ProjectKalc produces a number of reports ranging from summary level data to complete project reports. The Executive Summary report includes general, energy, financial, and pollution prevented information for a project. The Location Summary report includes information on the fixtures and controls included in each upgrade for a project, and the rooms where the equipment is found. User can also print the Fixture Survey Form, the Room Survey Form, and the Detailed Room Survey Form used for surveying projects and rooms.

VALUE LIGHT

GE has developed Value Light, an economic analysis software program capable of instantaneously calculating total operating expenses, savings over base installations, simple payback and many other components of a complete economic analysis. Value Light 1.3 considers the economics of lighting systems and allows you to compare alternative lighting schemes from an overall operating cost perspective. Value Light does not concern itself with light levels or design considerations and does not perform the lighting design calculations. It allows user to create projects containing a base installation, which may be compared with up to nine alternative installations.

Fig 3 ProjectKalc project information screen

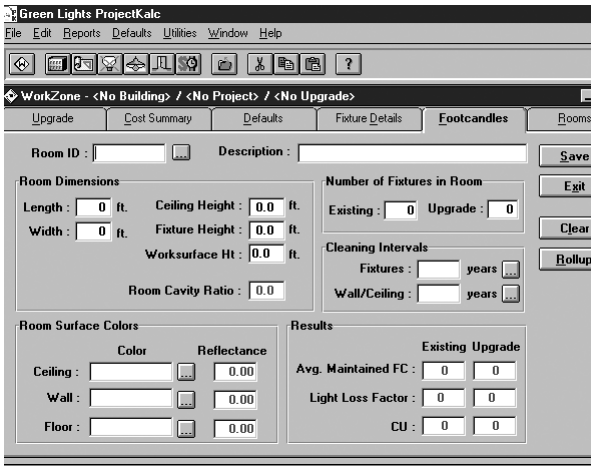
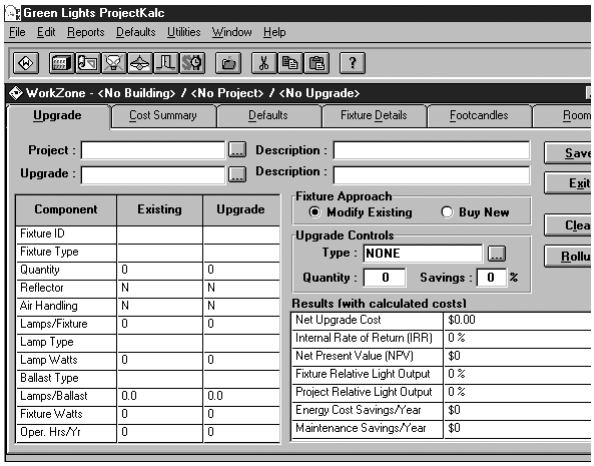


Fig 4 Upgrade results screen



Value Light includes a GE lamp database, permitting complete project and system analyses, that are instantaneously calculated. The analyses include a broad range of feedback, from yearly lamp maintenance cost to total operating expenses. Once the user has specified the Project Information, user can specify the base and alternative installations by selecting a lamp form the database, and a ballast configuration and ballast if required. The user needs to specify many costs associated with the installation such as lamp, ballast, retrofit, rebate and disposal costs. The user is then ready to view the System Analysis Results and select an optimum alternative installation.

The program takes lamps (and ballasts) in a fixture and allows you to replace them with different lamps and ballasts. The program compares alternatives and chooses one. It calculates many factors including maintenance costs, energy savings and air-conditioning savings. The results contain of information about general items like total operating cost and simple payback period, and detailed items such as the yearly cost for relamping and ballast disposal cost. These may be displayed in several formats with Summary, Tabular and Graphical available in System Analysis Results, and Summary and Tabular available in Project Analysis Results.

Fig 5 Value Light Project Information screen

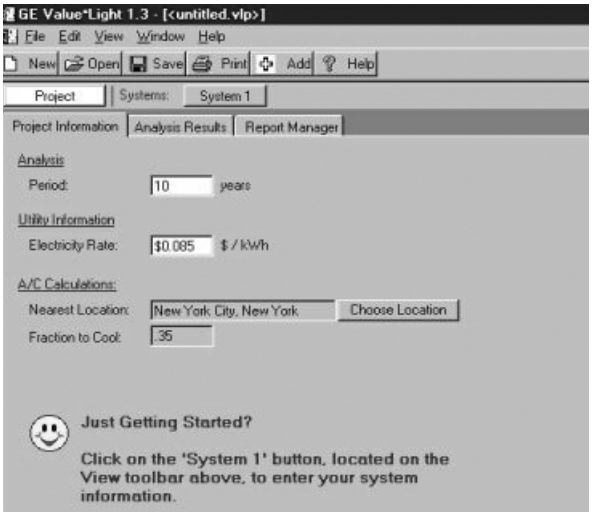
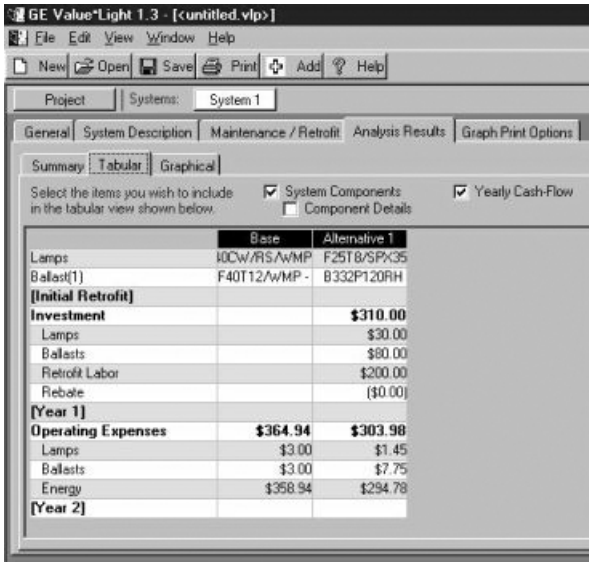


Fig 6 Value Light system definition screen



ECO LUMEN

Eco Lumen™ is a decision support tool developed by Tata Infotech Limited to aid facility designers in the process of creating scientific lighting designs. The use of Eco Lumen™ can reduce the time required to create the lighting design of a facility by as much as 80% when compared to the traditional approach. An extremely user friendly interface guides the designer through the various aspects of lighting design, including the room specifications, selection of appropriate light fixtures and the optimization of the energy consumption. Designs created using Eco Lumen™ have a potential to save as much as 30% of the lighting related electricity bills for any facility.

Eco Lumen provides designers easy access to the technical details of the individual components such as lamps and

Fig 7 Eco Lumen lighting layout screen

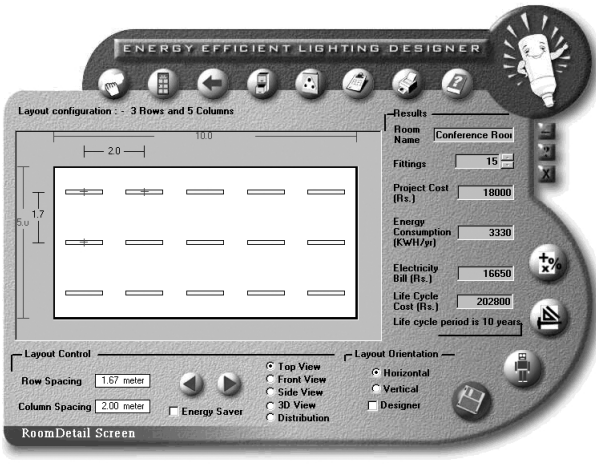
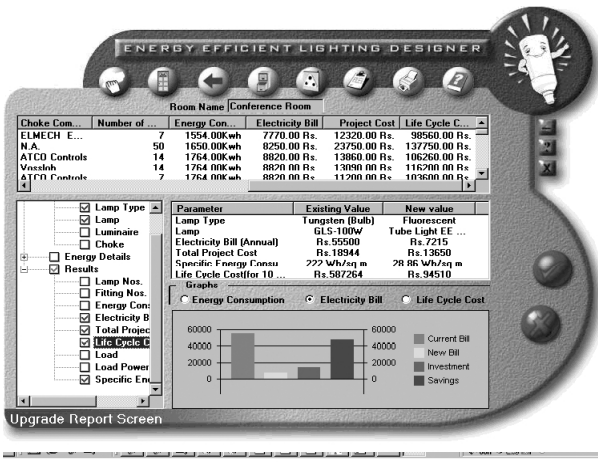


Fig 8 Eco Lumen Upgrade Comparison screen



fittings, as well as to the standards used in the calculations such as the illumination levels (based on the IS 3646 Standard) Designers can also add new lighting products to the database, either by specifying the technical parameters of the product or by importing the photometric files.

Eco Lumen™ takes the concept of implementing Energy Efficiency in facilities, beyond merely the designing of new facilities. It allows the designer to upgrade existing facilities to greater efficiency at minimum replacement costs. This feature gives designers the flexibility to compare various options for a room and then allows them to select the appropriate design after considering the investment as well as recurring costs. The software also includes features for calculating life cycle costs and payback period for different upgrade options.

Eco Lumen™ is also equipped with additional utilities such as the Energy Calculator and the Unit Converter to assist professionals with the complexities of their routine calculations.

CONCLUSION

To come up with energy efficient designs the designers need to consider various design parameters and understand the new developments in the technology. The study carried out by the authors suggested that most of the professionals are aware of the general trends in efficient lighting technologies available, at the same time this awareness doesn't reflect in their designs due to lack the time & efforts required in doing the analysis required. This is exactly the area where IT can help the lighting designers. What is required is, understanding the specific needs, further enhancement of the current software solutions available, & promoting their usage in the younger generation & students associated with building design.

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TERMS & TERMINOLOGY

Professional Building Designers : Architects & Interior Designers

Lighting Design Process : The methodology adopted for creating lighting designs for any indoor facility

Scientific methods of lighting design: Lumen Method, Zonal Cavity Method, Point-by-point method, Ray Tracing Method, Monte Carlo integration method or any other method involving the calculation of light available on a surface, plane or cavity of a facility

Energy Efficient Lighting Design Practices : The process of creating lighting designs for any facility with a focus on optimizing the energy bills for the facility.

SUMMARY OF THE FEATURES

Features	ProjectKalc 3.0	Value Light 1.3	Eco Lumen 3.0
System Requirements			
Hard Disk Space	10 MB	NA	20 MB +
RAM	12 MB	NA	16 MB +
Processor	486 or higher	NA	Intel Pentium or equivalent
Operating System	Windows 3.1 / 95 / NT	Windows 9x	Windows 9x / NT /2000
Display Settings	VGA monitor	NA	800 * 600 res.
Lighting Features			
Recommends Illumination levels as per standards	No	No	Yes
Provides database of lighting products	Yes	Yes	Yes
Allows user to enhance the database of lighting products	Yes	Yes	Yes
Allows user to import photometric data files	No	No	Yes
Recommends optimum number of fittings as per room usage and products used	Yes	No	Yes
Provides Lighting layout options to designer	No	No	Yes
Provides light distribution diagram	No	No	Yes
Energy Management Features			
Compares 2 or more lighting equipment for energy efficiency	Yes	Yes	Yes
Recommends the most energy efficient equipment from database	No	No	Yes
Provides energy calculations	Yes	Yes	Yes
Provides economic analysis	Yes	Yes	Yes
Calculates maintenance & relamping labor cost	Yes	Yes	No
Allows for multiple illumination level switching	No	No	Yes
General			
User Interface	Standard	Standard	Attractive
Help & User Documentation	Yes	Yes	Yes
Reports	Yes	Yes	Yes
Graphical results	No	Yes	Yes
Additional tools	No	No	Yes
Price	Freeware	Freeware	Ver 2.0 – Freeware Ver 3.0 – Rs. 9000/- (180$)

Annexure 1

Sample Questionnaire

Name :_____

Title :_____

Company :_____

Address :_____

Telephone :_____**Fax**_____

E-mail :_____

1. How would you classify your business ?

- ❑ Architect
- ❑ Interior Decorator
- ❑ Electrical Consultant
- ❑ Electrical Manufacturers
- ❑ Other Building Professional _____
- ❑ Facility Manager
- ❑ Lighting Designer
- ❑ Professor in Building Design
- ❑ Others _____

2. What is the size of your organisation, in terms of :

> Annual revenue : _____

> Number of Technical Professionals : _____

3. What are the factors that you consider while calculating the Lighting specifications for a room?

- ❑ Area of room
- ❑ Colour of wall, ceiling.
- ❑ Type of lighting fixtures
- ❑ Type of light source
- ❑ AC/Non AC/open office
- ❑ BIS lighting standards
- ❑ Working Hours
- ❑ Energy Tariff
- ❑ Others_____

4. What is the average time required for providing a detailed analysis for a lighting design ? _____

5. Considering the multiplicity of the factors involved do you compromise on the scientific calculations due to lack of time or due to the repetitiveness of the work ?

- ❑ Yes
- ❑ No

6. Which method do you use for performing calculations :-

- ❑ Lumen method
- ❑ Zonal Cavity method
- ❑ Point by point method
- ❑ By experience, without doing calculations
- ❑ By use of thumb rules
- ❑ Others_____

7. Do you feel the need for software that can take care of the lighting design?

- ❑ Yes
- ❑ No
- ❑ Can't Say

8. What features do you think should a lighting design software contain, and how important are each of these features on a scale of 0-10, 0 being least important and 10 being most important ?

Feature	Rating	Feature	Rating
❑ Cost Estimation	_____	❑ Upgrade Feasibility of various options	_____
❑ Energy Consumption Analysis	_____	❑ Task Lighting Approach	_____
❑ Report Generation	_____	❑ Daylight calculations	_____
❑ Light Distribution Layouts	_____	❑ Integration with Control Strategies	_____
❑ 3-Dimensional room views	_____	❑ Industrial Lighting	_____
❑ Analysis for effect of Obstructions	_____	❑ Outdoor Lighting Design	_____
❑ Lighting quality analysis	_____	❑ Others_____	_____
❑ Photometric Data File Compatibility	_____	❑ Others_____	_____

Annexure 1 (continued)

9. **Please provide some information about the various software products that you use for design of trade-related aspects in terms of the name of the product, the use that you put it to and how useful it is to you.** Please rate the usefulness on a scale of 0-10, where 10 means that the product meets all your requirements and 0 indicates a product that has no utility for you. Similarly a rating of 5 will indicate that it meets half your requirements from such a product.

No.	Name of the Software Product	Use of the Product	Rating on a scale of 0-10
1			
2			

10. Kindly mention what you consider to be the useful features of the software product(s) that you use.

11. Kindly mention what you consider to be the weak points in the software product(s) that you use. What are the areas of improvement ?

12. Which factors do you consider or intend to consider while purchasing a software ? Please also rate the importance of each of these features on a scale of 0-10, 0 being least important and 10 being most important ?

Factor	Rating	Factor	Rating
❑ Price in general	_____	❑ Technical specifications	_____
❑ Company's reputation	_____	❑ Training programs	_____
❑ Company's range of product line	_____	❑ Support/ help line	_____
❑ Marketing strategy	_____	❑ Overall quality of service	_____
❑ Utility of the package	_____	❑ Others _____	_____

13. How much are you willing to spend on a lighting design software package as compared to conventional & manual calculations and which can improve the productivity & reliability of your lighting designs ?

❑ Above Rs.50,000	❑ Rs.25,000 – Rs. 20,000	❑ Rs. 10,000 – Rs. 5,000
❑ Rs.50,000 – Rs. 40,000	❑ Rs. 20,000 – Rs. 15,000	❑ Below Rs.5,000
❑ Rs.40,000 –Rs. 25,000	❑ Rs.15,000 – Rs. 10,000	

14. What are the other aspects of your work, where such a design software product will be useful ?