SOMETIMES THE SIMPLEST APPROACH
COULD BREACH THE DIVIDE BETWEEN
"TECHNOLOGY AND THE USER"
Lighting for Livelihood

Project brief

This project: "LED- Lighting for Livelihood" aims at providing practical and effective LED lighting which enhances the livelihood of different professions in rural areas, with the immediate target being underserved businesses like fruit and vegetable vendors, barber shops, chaat wala's, petty shops and other street hawkers. A further challenge would be to make the designs fairly generic and not too customized – so that volumes can drive down production costs.
Background

The Client: SELCO Solar Pvt. Ltd
Selco is primarily a social enterprise established in 1995, it provides sustainable energy solutions and services to under-served households and businesses.
It has been supplying solar lighting to rural and under-served customers for 15 years. Since solar energy is costly, every watt of power saved results in significant cost reduction of the system. Clearly, the lights that are used in the system have to be very energy efficient.

Current Scenario

The first generation of solar lighting used CFL lamps, and now the trend is towards LED. LED's are very power efficient, much better than CFL's, but on the flip side they do not provide omni-directional lighting the way a CFL or tungsten filament lamp does. So for a LED light fixture to serve its purpose, it has to be correctly designed to suit the particular application. In the rural home lighting market, LED's are fast gaining popularity as a good number of fixtures have been designed for this application. The picture alongside displays some of the CLF and LED light fixtures currently being used in rural homes.
The Need

The problem is when lighting is used as a business enabler or a livelihood generator in rural areas. No one is ready to use LED's in this segment, as they are perceived to be "too dim" or "not effective enough". The few LED fixtures existing are simply CFL fixtures replaced with LED's. The issue is not dimness, but design of the light that is causing this perception. Once the design is done right, LED's can be used and then solar energy can be harnessed to power the lights.

Why LED’s?

Much less toxic than CFLs, plus:
--Easy Installation Using Existing Socket
--LED Operating Life: 200,000+ hrs (20+ years)
--Solid-State, Fast Turn On, No Power Surge
--High Shock / Vibration Resistant Major Power Savings
--Voltages Available 12V DC,24V DC,110-130V AC,220-240V AC
--Major Reduction in Heat Generation
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Product Research

The research was done in two main areas- product and user research. Product research: which included getting to know LED’s as a developing technology, what’s new around the world, Indian market research, picking the right kind of LED’s for this purpose and gaining knowledge about the technical, physical and other aspects of them. The topics covered are briefly explained in the next few pages. Picture above shows (Lt -rt) warm white, natural white, day white and cool white shades a which are the currently available colour temperatures of white highpowered LED lighting.
About LED’s

An LED is a semiconductor which converts electricity to light. Early LED’s emitted low-intensity red light, but modern versions are available across the Visible spectrum, Ultraviolet and Infrared wavelengths, with very high brightness. The LED is based on the semiconductor diode. When a diode is forward biased (switched on), electrons are able to recombine with holes within the device, releasing energy in the form of photons. This effect is called electroluminescence colour of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. Important factors to look for while dealing with LED’s- colour temperature, colour rendering index, brightness, power and efficacy.

Advantages and Disadvantages

The advantages include: Long life –can exceed 100,000 hours. Robustness –no moving parts, no glass. Size –1-3mm. Energy efficiency –up to 90% less energy. Cost in long run. Non-toxicity – LEDs contain no mercury or lead and remain cool to the touch. No infrared or ultraviolet radiation. Versatility and durability – available in a variety of colors. In applications that are cycled between on and off frequently, like an outdoor solar light, LEDs are ideal since they won’t burn out quickly. LED bulbs are resistant to thermal and vibrational shocks and On off time –no power surge. Among the disadvantages; Expensive, Heat sensitive, Light Dispersement: An LED is designed to focus its light, so an incandescent or fluorescent may seem brighter since the light radiates in all directions, LEDs typically cast light in one direction at a narrow angle compared to incandescent or fluorescent, and they are still an emerging technology.
LED’s and the Indian Market

Market research

Research was conducted on SP road market, VVK Iyengar road, Avenue road, Prime lighting- Banaswadi, lighting shops on infantry road, Royal light- Magadi Road. LED’s are most commonly used only for highly directional or home lighting purposes among its other uses being: reading/study lights, emergency lights, chandeliers/wall scones, linear strip lighting (functions/decorations), recessed lighting/ceiling, porch/ outdoor/ landscaping lighting, stair and walkway lighting. High powered LED’s and fittings are hard to locate. When people ask for LED lighting, the manufactures just replace CFL fixtures with Led’s. There isn’t much demand for these as they have yet to gain popularity and prices have yet to come down.
Types of LED's

There are 3 main types of LEDs: miniature LEDs, alphanumeric LEDs, and lighting LEDs. LEDs are produced in an array of shapes and sizes. Other LED types: Multicolor LEDs, RGB LEDs, Flashing LEDs AND highpowered (HP) LED's.

Considerations while using LED's

Most LEDs have low reverse breakdown voltage ratings, so they will also be damaged by an applied reverse voltage of more than a few volts. Other considerations like colour potential difference, connecting LED's in series and making sure the driver and heat sink are suited are just some the key things to remember while testing LED's.

White, HP LED's

The ‘white’ of white LEDs comes from the narrow-band blue naturally emitted by GaN LEDs, plus a broad spectrum yellow generated by a phosphor coating on the die which absorbs a proportion of the blue and converts it to yellow. High power LED’s (HPLED) can be driven at currents from hundreds of mA to more than an ampere, compared with the tens of mA for other LEDs. Some can produce over a thousand lumens. Since overheating is destructive, the HPLEDs must be mounted on a heat sink to allow for heat dissipation. If the heat from a HPLED is not removed, the device will burn out in seconds. A single HPLED can often replace an incandescent bulb in a torch, or be set in an array to form a powerful LED lamp.
User Research

Spaces and People

User research took place in Ujire (small town near Dharmastala- Karanataka) and Bangalore so that I could get an idea of underserved businesses in both rural areas and urban scenarios. Many fruit vendors, vegetable vendors, chaat wallas, barber chops, petty shops and other street shops were looked at; the lighting in these spaces was observered and conversations about the lighting emerged. Along with that interviews were conducted and as a result a few case studies emerged which are discussed in the next few pages. Some case studies are already customers of Selco using solar powered CFL lighting at the moment.
Questions asked during Research

Other than observing the users; among many questions these were the important questions asked in order to get a clear idea of the lighting requirements in each place:
1. What amount of time are the lights used for each day?
2. How much do they spend on these lights?
3. How often do they need to replace these lights?
4. How much is their electricity bill per month?
5. What do they do when the electricity goes off? In cases of power cuts how much extra expenditure is required?
6. What are the essential spaces lights need to be enhanced in?
General characteristics of the lighting?
7. What kind of lighting do they prefer and why?
8. Can the lights be more than fixed elements?
9. Are they willing to pay more for something that will work out better for them in the long run? Are they able to understand the advantages to LED's?

More Information

Along with these questions, pictures of the shop/ space in the day and in the night, measurements of the space, spaces where light needed to be enhanced, purpose of the lighting, and lux readings in different areas of the shop during the night was recorded. This information could help while designing the light without having to visit the space.
Ujire

Case 1: Barber in Ujire

Name: Mr Suresh
Profession: barber
Location: Ujire market
Status: Open to new ideas and better lighting solutions for his shop.
  • He works six days a week, around 15 hours a day.
  • Shop timings: 7am-9pm, and if there are more customers he keeps it open till late.
  • During the day he uses 3-4 white 40Watt CFL tube lights (Rs 45)
  • And in the night he totally uses 13 tube lights (2 for the board outside and 11 inside his shop).
  • He approximately needs to change the lights once in 6-8 months, sometimes they even last for a year or more (depending on when the burn out).
  • For blackouts, He owns the generator which initially cost him Rs 26,000 and he fills kerosene (Rs 38 per
litre-black market) in it. He needs to use approximately 20 litres of kerosene per month (every Thursday the there is no electricity for whole day).

- The generator gives a guarantee for 1 year but works successfully for 3-5 years or more.
- He also owns an emergency light just he’s out of kerosene, but he cannot run his shop in that light. (the second img above are the small ceiling lights which dont really contribute to the lighting of shop)
- His electricity bill per month is between 400-600 Rupees or more depending on the usage.
- He earns about 1000 Rupees a day and manages, household, rent(shop and home), salary for his workers, articles and products for the shop, electricity bills and other expenses.
- His shop needs to be brightly lit, not only for his work but also to attract customers.

lx reading in his work area = 026, on his table= 028

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**Case 2: fruit vendor - Ujire**

Name: Abdul Rehman  
Profession: Fruit seller  
Location: Ujire market

- He opens at around 8am and closes down at 10:30 at night.
- He uses a 5Watt white CFL light which he needs to change one in 2 years on an average
- He also owns a 12W auto rickshaw battery to charge this light.
- His needs lighting that’s affordable and long lasting
- He wants his fruits to shine in the dark, in order to attract customers
- lx reading = 003
Case 3: Vegetable shop

Name: Praveen
Vegetable shop owner in Ujire market

- He uses three 40W CFL white lights, one at the entrance, one on his vegetables and one surrounding the area where he sits and the back storage.
- The lights last for over three years on an average
- His electricity bill is approximately 150-200 Rupees depending on the usage
- He uses the light from 7 in the evening to 10 at night depending on the business.
- In case of power cuts he owns an 8W small yellow CFL which he runs on the neighboring shops generator. (he pays them 30-35 rupees on the days he uses it) \text{lx reading} = 006-008
Case 4: Petty shop

Vasanthi Balakrishnan (petty shop owner)- Already a Selco customer.

- All his home electricity needs runs on solar panels, he charges a battery at home for his shop light and brings it to work every day.
- He uses an 8W CFL and for any reason if the CFL does not work he owns a gas lantern as a back up.
- He needs moderate lighting in every corner of his shop including his money box, storage area and in front of his shop where customers sit as well.
- He’s open from 7:30 in the morning to 9:30 at night and uses the light from around 6pm depending on the weather and the time of the year.
Bangalore

Case 1: Vegetable Market, shop1

Name: Saraswati
Vegetable shop owner
Malleshwaram vegetable market
She was the first vegetable shop owner to have solar powered lighting (after which more that 11 shops in the same market have taken to solar lighting). She took a bank loan for a set of two CFL lights, a battery and solar panel which cost Rs. 12,000)

- She has repaid her loan in two years and now she continues to use the set which she says has been working out perfectly for her.
- Before this she used kerosene lamps which cost her more that 45 Rupees daily.
- She requires lights from 6pm to 10pm.
- Because she has expanded her shop two lights aren’t bright enough, she has just purchased a new set from Selco.
- She prefers light that lights up not only her work space and her vegetables but also the pathway that leads up to the shop, so that customers will not have to walk in the dark.
- lx on the vegetables in the centre=005, at the edges=002 and on the pathway=001
Naggartamma - another vegetable shop owner in the same market

- She uses 4 lights totally - 1 set from Selco (2 lights, battery and solar panel) and two more lights which she charges with a battery through the battery hawker model.
- The hawker model - there are companies and NGO's that supply charged battery's in the evening and take them back in the morning i.e. Battery on rent at Rs 30 per use.
- She needs to use two extra lights because the two that come along with the panels aren't sufficient to light up her shop nicely.
Case 3: chaatwala

Prabhakar – chat and bhelpuri cart
- Stands near coles park.
- Uses a 2 kg gas cylinder which is Rs 130
  he uses the gas light only for two hours a day.
- Warm dim lighting, places himself under a
  street light
- He barely has light in his work space or
  otherwise. (he can still make the best bhel
  puri, hes mastered the art of doing so in the
  dark.)
- He requires a cheap and decent lighting
  system.

Case 4: chaatwala 2

Kishore Kumar–chatwala
- stands near cox town bridge
- uses a 60W CFL which costs him Rs 60 to
  change evry 2 years on an average.
- He uses the light from 6 pm to 10:30 pm
- He charges this light with a battery which is
  recharged at home or in a friends/neighbors
  house.
- The light is barely enough to for his own
  articles, his customers stand in the dark and eat
  around his cart.
Experiment I

AIM:
to get a clear idea of the LUMINOSITY, LUMINANCE UNIFORMITY, DEGREE OF LIGHT, and FUNCTIONALITY
to use HPLED's in combination with lenses, reflectors, other possible materials and observe the outcomes
to get an estimate on the distance and area these HPLED's can illuminate.
to notice the different kinds of white's produces (test the colour temperature)

Sourcing the parts

(left to right)
img1: rockforest LED driver (factory made driver which can support approximately five 1W LED's. (the
green connector on the right has been soldered separately).
img2: heat sink + one 1W HPLED. (the tiny hole on the top side of the LED is '+'.)
Connecting the basic circuit

**img1:** LED connected ready to be joint in circuit

**img2:** the rockforest driver works on 230-240V direct current. The output current that the LED’s need to work is merely 4V. The black thick wire is where direct current is supplied and on the left bottom of the driver LED can be connected in series/parallel.

Measure of light

**img alongside:** lux meter – The lux (symbol: lx) is the SI unit of illuminance and luminous emittance. It is used in photometry as a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface.

The lx can also be converted to lumens if required. But for a comparative study the value of lx can be taken. Below every test pic img: “lx=” will be the lx value as taken from 1.5 meters above the LED. The distance 1.5 meters remains constant for every picture in experiment I.
With lenses

Image alongside (L-R) Converging + Diverging lenses. The first part of the test was conducted with a plain 1W LED, the same LED with a converging lense and with a diverging lense. The difference between them is clearly demonstrated below.

plain 1 watt LED (no lense) $\text{l}x=001$

single 1 watt led with diverging lens ($\text{l}x=005$)

single 1W LED with converging lens ($\text{l}x=024$)
Home made reflectors + lenses

Image alongside: L-R
img1: dodecahedron structure with silvered surface inside (to be used as a reflector)
img2: pentagon prism (with mirrors on the inside)

single 1W LED inside closed mirrored pentagon (lx=000)

single 1W LED with closed mirrored pentagon + converging lens (lx=005)
Zigzag base + lenses

A structure with inclined surfaces was created on which LED's are placed in order to spread the light of 5 LED’s and make the area covered broader. After with separate converging and diverging lenses were used in combination on the structure.

Image 1-2-3: structure with three 1W LED’s (lx=002), structure with 3 1W LED's + converging lens (lx=001), structure with five 1W LED's (lx=002) + 5 diverging lens (lx=001)
Factory made reflectors + lenses

Image alongside L-R
img1: reflector a (big car head light reflector)
img2: reflector b (smaller cylindrical deep reflector - automobiles)
img3: reflector c (small dish reflector, again used in cars mostly)
(all the reflectors were sourced from a local gujri)

img1: reflector a + single 1 W LED (lx=001)
img2: reflector b + single 1 W LED (lx=003)
img3: reflector c + single 1 W LED (lx=002)
Image alongside: three LED’s placed in reflector “a” with diverging lenses being placed on each LED.

**img1:** reflector a + three 1W LED’s (lx=002)

**img2:** reflector a + three 1W LED’s + diverging lenses on all three LED’s (lx=002)
Redefining the project

Even with little or no money people of a lower income are open to long lasting sustainable solutions, and are able to understand that it does work out for the best in the long run. They are proud that they could be the “India’s first solar powered barber...” or “The first solar powered chaatwala...”

Findings through Research

- the surrounding light at tea/food carts
- the pathway lighting outside fruit/vegetable shops alongside streets/markets
- being a retail space the light is preferred very bright so that it can not only light up the shop but also attract customers
- the unwanted shadows at chaat shops
- Security issues of smaller shops
- the easy handling of fixed lights and gas lanterns
- cost issues
- constant power cuts
- directly looking into LED lights is blinding

The difference between rural and urban areas is that of income and the fact that in the city charging batteries from the grid itself barely costs them anything... so for a city the situation isn’t as dire in most cases.
There are three main aspects to Designing a luminaire: Meeting functional visual requirements, Achieving satisfying aesthetic results, and using lighting design technology intelligently. Many designs have reasonably obvious solutions determined by a combination of budget, energy code, and standards of the industry. Unless project requirements call for unique or specialized lighting it is often best to design using common luminaire types (some of which are mentioned under “standards of the industry- basics in lighting design book). Although when it comes to LED’s the fact they’re a fairly recent development justifies putting this project into a unique or specialized category. But it would be critical for me to keep in mind the target user and the fact that it needs to be mass manufactured and “affordable”. Hence the challenge will be to strike a balance between standards of the industry and unique ways of exploring LED’s.

The aim of this project will now be to minimize the reasons for LED’s being unaccepted in the retail space.

LED as a technology is developing every day, and to use a latest LED is unimaginably expensive and almost impossible due to the lack of availability and accessibility. Currently the LED fixtures available are CFL fittings replaced with LED. The most commonly available HP LEDS are the 1-3W LED’s, so the plan is to design fittings using these LED’s itself but to design it in such a way that it can compare to the CFL’s used in this sector and be suited to the specific purposes.

For now the lights designed will directly powered/ battery powered as the aim is to figure out the right kind of lighting for this space. Later when the lights will be solar powered it will only involve reduction in the size of batteries and the cost of system.

Image to the right: 12W existing street light fitting.
Considering the findings from the user research a general idea of what the final light luminaires should be is shown above
I will be concentrating on five main types:
Fixed lights
Pendant lights
Flat modular features
3D modular features
Flexible and Versatile lights
Design Approach

From the 'User research' case studies, I have taken the following three cases to illustrate the direction of work. As discussed in "redefining the project" a reverse approach will be taken—ie, designing only for the specific need and space.

Barber at Ujire

Fact: the barber needs light in almost every corner of the shop, not only for his work but it is important to keep his shop bright in order to attract customers.

According to experiment 1 (part 4) it was found that reflectors in combination with lenses work well for cases where light needs to be enhanced and thrown over a relatively larger space. Shown image alongside shows a possible scenario where in the essential space where the work takes place is securely lit and the others get lit in the process. In this case flat reflectors would work with a combination of task lighting. The difference between a curved reflector and flat reflector is illustrated in img 3 alongside. Curved reflectors are useful to contain and distribute the light where as flat ones can throw the light a lot more. An angular flat reflector could also help in this case.
Vegetable shop, Ujire Market

Fact: The vegetable shop owner has more specific requirements, he wants three areas to be sufficiently lit – the entrance/path shop, his vegetables most importantly and the area where he sits. He currently uses three lights for that purpose. Is it possible to reduce that to two/one and still satisfy his requirements using LED’s?

Possible Approach

The lighting plan above shows the possibility of his lights serving their purpose optimally. This could be possible with LED’s using simple solutions, like creating a mold for multiple LED units to fit in and bending the edges of the molds outwards as shown below so that the area covered increases drastically.

OR — The amount of light given out by each unit placed in a row would tend to overlap close to the LED units itself, just increasing the distance between the bulbs would ensure the overlap taking place further away from the LED units thus by the time it reaches the ground a larger surface area is covered (this would work well for an entry scenario)
Fact: Typical chaat carts either use a bulb or 1 gas cylinder which barely fulfills their needs. There are various areas that need lighting like: to make his cart itself noticeable, his work area where he mixes and stores, or the area where customers stand/sit around his cart.

Possible Approach

Possible lighting solutions for the chaatwala could be simple 2D or 3D modular units of which he may use one, two or more depending on his needs. The plan above shows a wide plane lit up, which would take care of the whole cart OR the front elevation above shows 3D modular units... some placed near his work space, some placed on top depending on his work needs. Another possible solution shown in the side elevation are flat modular structures which can also be used to light up the area for customers.
'LED’s could use flat reflective surfaces to enhance and increase brightness': this was the initial idea, after which, in the given model, instead of using a flat reflector, I decided use a bowl shaped bent reflector, where in the light would be reflected of the bent dome shape outer surface of the bowls. As shown above the light output could be sufficient for a larger area, the LED’s will not be directly visible and position of the LED’s on the base dish surface could add to the even spread. And instead of having three poles connecting the light and the reflector one single joining rod could be sufficient.
I decided to get bowl reflectors made in different shapes and sizes so that I could experiment with number of LED’s with respect to the size of the reflective surface.

Sourcing the right reflective surface: There were many ways to achieve the given shape with a silver mirrored surface, like bending the piece and then chrome plating it or casting the piece and then buffing and polishing it or coating it with abs electro plastic and the silvering the required surface.

The LED’s that are going to be used for this project have a 120 degree spread light angle. So if the LED’s are placed in the middle or at the edges of the bottom surface it would cause most of the light to escape to the ceiling and little to reflect down on the area required to be lit. Therefore the positioning of the LED’s was changed from the middle and edges to right at the base of the pole so that as much light can be reflected as possible. The adapter can fit in the hollow bowl area underneath the base of the LED’s. But being a prototype, this model runs on DC, hence just for the purpose of testing the lights the driver/PCB is on top of the reflector.
Process

I decided to use SS sheet metal, this sheet metal is the same reflective surface used in automobile light reflectors. Unfortunately this sheet metal can only be used while mass manufacturing because the only way to bend this metal is by making dyes and stamping. So for the prototype a thicker sheet metal was cut into circles and hit and bent and shown in the pictures alongside. Initially I thought of using a thin 1 mm sheet, but the minimum thickness to bend it in this inexpensive manner had to be more that 3mm thick.

Further progress

For the center rod joining the two surfaces, a hollow threaded pipe of 3\(\frac{3}{8}\) and 4" length can be used in the prototype (so that the wire from below will pass through the pipe and enable the light to hang) as shown below in the models. These pieces can now be wired and the LED's can be installed in them. For the bottom lid diffused white acrylic can be used. The pipe that I wanted to use was a 6mm pipe with 1mm wall thickness so that the wires can pass through easily. As the standard size available required 0.5 mm threading and this could cause the 1mm thick pipe to break when tightened a tap had to be bought in order to create a special 0.25mm threading.
Final Prototype

Image 1 and 2 alongside the pcb and driver housing, LED’s are placed as shown in the image on the right. Five 1W LED’s are used to demonstrate the concept. Images below show the final form of the light fixture.
As expected the light creates a circular shadow on the floor as well as the ceiling. The lx reading for the reflected light = 2-3lx at a distance of 1m, whereas the reading for the escaped direct light above was 6lx @ 1m. This shows that the reflected light is not as bright as the direct light, more than 50% of the light does not reach the desired area.

To overcome the shadows, the light will be redesigned in such a way that an LED with a diverging lens will be facing the floor which may wash out the shadow. In order to make this work a similar piece can be placed inverted at the bottom. This unit could be made smaller and identical unit can be placed together mirrored to form one fixture.
Concept B: Street light

Wall mounted/ kept erect

Inspired by the street light a fixture that uses curved reflector as a tool to solve to problem of specific area based brightness. This light could be used wall mounted fixture or kept on a flat surface. Possible users: petty shop owners, small fruit carts, street vegetable vendors.
The idea was to have LED's behind the smaller inner housing so that the light would fall on the outer bigger reflector and be spread forward evenly in a smaller specific area. This way you don't directly look into the LED's even though the light faces you.
It was not possible to achieve these shapes in an ordinary utensil bending machine or by hand. Making strips and continuous welding was too impractical and expensive as well. The easiest and fastest was by creating a dye/pattern which would then be sand cast. The pattern could be created in thermacol, which is cheaper but risky. Therefore the best choice was to create a wooden pattern and then sand cast it for this purpose a positive and negative of the pattern was required. Picture alongside shows the two patterns in progress. For each pattern two pieces are needed, totally four wooden dyes would be created.
Shown above is the finished pattern. After which aluminum gravity sand casting had to be done to achieve the metal pieces. Aluminum was a cheaper and lighter option, also it is the best preferred material that houses heat sinks due to its heat absorbing properties. Alongside are the images of the cast Aluminum pieces which will now have to be buffed and polished. Because this method was followed this light fixture will be considerably heavy.
Further progress

6 LED’s were placed to test the light with the pcb and driver inside the smaller dome. The inside surface of the bigger dome is supposed to be highly reflective smooth surface. The inner surface of the casted piece inspite of being buffed and polished even by hand required a lot more work in order to gain the smooth surface required. Incase this piece would be mass manufactures a dye mild steel structure would work out best as shown. For the outer acrylic piece a step would need to be machined with a lock mechanism for easy assembly and detachment.

Finished prototype

For the sake of a quick prototype flat acrylic lid was attached with double sided foam tape as shown alingside. Other than the weight of the piece that can be taken care of during mass manufacturing the reflector can also be enhanced by plating the whole surface.
The lux readings: $I_x = 4.6$ at a distance of 1.5m, the light has a strange texture to it because the reflector has been hand polished unevenly. Overall, the light suffices barely two meters vertically ahead of it, beyond that it's a bare minimum reading.
Concept C: Flat angular reflector

Modular units + angular reflector

This concept combines the use of flat reflectors for larger areas and modular flat units. The models above demonstrate how each unit could fit into one another, so that the customer can buy these units depending on his/her need. Each unit is lit at the bottom, and on top (dual lighting). The most part of the light output on top is reflected by the flat angular reflector which should throw light further ahead and in all directions, specifically the parts that are not lit through the bottom direct light. Another important feature of this light is the fact that both the angle of the light fixture and the angular reflector could be adjustable. This would not only help in making the light more flexible but also for experimentation purposes.
Changes made: the base behind each LED will be a curved reflector as shown.
Both the flat reflector and the modular light structure will be wall mounted with a swivel mechanism so the angle can be adjusted accordingly.
Flat 3W or 2, 1W LED’s can be used in each unit on top and below.
Instead of 4 pipes to hold the two apart two pipes on either side of the structure are sufficient with a threaded rod running throughout the piece which will encompass the acrylic/glass cover as well. Surrounding the 4mm rod a thin pipe will ensure the distance between the two curved pieces to be constant.
Process

3mm thick aluminum pipe was slit with a 2 inch diameter arch, the inside surface was buffed and polished. 4, 6 inch pieces were cut and holes were drilled accordingly. Closed nuts are used for a perfect fit. The space between was decided according to the size of the driver, and battery (if needed). For the prototype a battery will not be required, instead wires will be taken through the mounted base of the light and connected to a battery.

Further progress

Model alongside is what the final casing can look like with the positive and negative jack plugs. The casing will be made with plastic/opaque acrylic. One side will be the jack and the other the negative of the jack so that the second unit will be lit once it is attached to the first. Possible jacks were discussed and the final one used will be the second black one shown above the model.
Testing part 1

\[ l_x = 8-10, \text{ 1m away} \]
\[ l_x = 4-6, \text{ 2m away} \]

Pictures alongside: these readings are just for one side of the light containing thin long 3W LED.

A temporary inclined set up was created with a scrap piece of the reflective material and the light structure to see if and how the reflector can enhance the light.

On the left are the pictures before and after the reflected light. Reflected light \( l_x = 5 \), more than 3m away.
Casing

Detailing, building the final body and wiring:
The prototype is made out of HAL (plastic) and a transparent acrylic lid.
Inside the body on the two ends as shown on the right a curved step was given so that the reflector could easily be slid into the box. (This meant avoiding the extra closed screw sticking out.)

Once the acrylic lid is placed two curved drilled brackets were constructed to be placed on either side of the reflector which holds the reflector and lid in place.

The driver is placed inside with foam double sided tape for now, and the negative and positive plugs and screwed on the respective sides.
The adjustable mechanism is a simple ball and socket with a tightening screw which ensures that the angle of the light can be changed, if needed.

The final body is attached to the ball mechanism cctv bracket fixture. As planned the second modular fixture can be plugged into the first. The second one is wired in such a way that the main to the battery is connected only through the first, so only when you plug the second one in a working first box will it light up.
All the LED’s \((3 \times 4 = 12 \text{W})\) work on a rechargeable sealed lead acid 12V battery which can be solar powered. Initial testing for the light has already been done in. The final testing and installation will take place once the angular reflector is made which will be above the light.
Shown above the adjustable base for the angular reflector (20” x 20”).

Picture 3 and 4 is the white mounting base made for light+reflector.

And the pictures on the right are the place and area it was placed while doing the final testing for the light.
The first image is the area without light. The second is one with the regular lighting in that area. And the third is the light test for concept C. The picture on the left: The car gives an idea of the amount of light that's thrown ahead and to what distance. The right hand bottom edge of the picture shows that the light travels even beyond that.
Concept D: Dome reflector lamp

Dome reflector + converging lens

The first image on the right is that of an LED with converging lens, and the second is with a diverging lens. Considering a reflector placed where the thick grey line is, in the picture, clearly a converging lens would succeed in hitting a larger and heavier content of light on the reflector than the diverging lens. This concept is based on just that. Tests showed that when a converging lens is placed on an led and it is directed towards a reflector a much larger surface area was covered. Without any lens the side and bottom area around the reflector were let up but with a converging lens even the cieling was lit up.
Progress

Converging lenses come in various degrees (8, 20, 45, 60...). And depending on the degree and quality of the lens it is possible to get a higher amount of area the light would cover. The smaller the angle and the better the quality the sharper and more defined the light.. The plan is to reflect this converged light off a curved surface as shown in the model. This light can be used as hanging lantern in any shop, it may ensure a higher area being sufficiently lit up for a medium sized kade (small shop), especially the area in front of/ leading towards the shop/ chaatwaala.

Sourcing parts

In the images alongside are already available three LED, lens, heat sink and adapter. for the sake of the prototype instead of used separate LED’s and lenses as shown in the model, i will be using these; i'll need a 3 inch long housing. The lens shown below are available in different makes and degrees.
Process

In the prototype scrap 2mm ms pipe is used for the top (3 inches) and base (3’’) housing, and for the dome shaped reflector a deep spoon. The overall diameter of the piece is 3’. The total height will be 9-10’ depending on the size of acrylic/glass pipe (center).

Further progress

The top bottom and lens tray dishes are cut out and polished on one side each and the dome is cut. as you can see in the picture below the dome needs to be grinded to fit the required dia and a hole will be made for the lens on a one of the discs with a step so that the lenses fit in housing.
Finishing

Both the lower and upper parts of the light buffed and polished. In order to fix the plate containing the lenses small screws were drilled at the edges of the upper part so that a plate could be tightened.

The heat sink, LED’s and lenses are wired and fixed to the plate which is then placed and tightened in the housing space.

The required thickness and length of the acrylic pipe needed could not be purchased (only an available piece of 3mm thick, minimum 2 feet acrylic was bought) due to the limited quantity required. A 6’ piece was cut for the prototype.
The light does not work best when kept at ground level or close to the ceiling. It is meant to be hung/placed a few feet above the base level. It was designed keeping in mind the area right outside chaat walas/tea shops / petty shops which needs to be fairly lit.
The pictures above show how the light is directed down and reflected light redirected towards the side and top.
lux values at a distance of 1m=1 lx
and 0.5m=3 lx
Concept E: Strap on

Curved base + portable

The idea behind this concept was to increase the area that a 3W led fitting currently covers. Ideal for chaat wals, vegetable vendors or any other street vendor. The bend in the surface changes the angle of the first and last LED’s hence ensuring that it covers more area. More over this could be a fitting where the battery is inside the light so that it is completely portable and can be strapped on and used if needed as shown above in the concept figure.
The fixture would have four essential parts, the body, in which the battery, driver and wires sit, the 3mm thick aluminum base (acts as heat sink) on which the three LED’s will be placed, a acrylic lid and a back cover which would also hold straps/belts. These could be adjustable straps, so that the light can be fixed anywhere, around any thickness or material. While constructing the model, certain changes will be made to accommodate faster and cheaper ways to assemble the light. The light can run on 2 4V batteries, a maximum and minimum size of the batteries were taken into consideration before going ahead with the prototype.
The LED's are kept in place using a special sticker which is meant for this purpose, once the sticker heats up it is said to become a strong adhesive. 0.25 mm holes were drilled on either side before the LED's were placed so that the wires could go through the holes. The main body was again constructed with plastic and the battery housing was divided into two sections so that the batteries would remain in place. The back cover was given a centrally aligned partition that maintains the battery stations.

The front acrylic cover was very difficult to achieve because of its shape, heating and bending the acrylic sheet 3mm / 1mm to this shape was causing it to crack or split. Even if one side bends perfectly the other is nearly impossible to achieve. A shape closest to the shape I wanted is used although even that has plenty of imperfections. The acrylic lid will continue to be worked on. An extension of the lid was created along with holes and a screw which is the fixing point for the lid.
Final Prototype

For the aluminum piece to sit a step was given in the shape of the piece itself, which exactly holds the bend tightly. Two adjustable velcro straps are provided so that the light can be easily mounted and used anywhere. The painting and buttons for this product will still be worked on.
The Lid

As discussed the front acrylic still needed to be done without cracks and bends. First a wooden pattern was created so that blister packaging could be done, unfortunately in blister packaging method only 0.5mm thickness was possible. No transparent acrylic sheet is available in this thickness. A copy was made as a sample in black opaque abs plastic.

Transparent abs plastic was too thin to act like a protective cover, even for the prototype. The black cover was cut in the same shape as the initial heated and bent acrylic to see if the if the fit is perfect, so that using the same mould other processes can be explored.

For acrylic to be moulded a negative wooden pattern was also required. Once this was made transparent 1.5mm thick (the minimum thickness available in transparent acrylic sheet) acrylic sheet was moulded and then cut to fit the shape.
Finished Prototype
image 1 above displays the adjustable strap and for image two the lux readings are as follows:
lx values: at 0.5m =3-4 lx
    at 1m =0-1 lx
Concept F: The Pyramid

3D modular structure
A 3d single illuminated pyramidal unit that fits into more of the same units to form different shapes. For users who have multiple lighting needs like chaatwala. The idea was to have a 3d modular solution that would work as a single unit or as a group of units put together. The pyramidal concept shown in the model above needed to be worked on in order to get the best use of LED’s possible.
The idea initially was to have a bent reflector at the base of the pyramid and an LED on the top black tip of the pyramid which would act as the housing (model on top) for the driver/battery. Since there was some experimentation with bent reflectors in concept D, this concept was interchanged, so that the base of the LED could be curved and the bottom could be a flat or a textured reflector as shown on the right.
Progress

For the LED base 3mm thick aluminum was used and for the base reflector 0.5mm thick SS automobile reflector material cut into a perfect square was used. The body was constructed out of HAP plastic and acrylic. Two of these pieces were constructed, one with a curved LED base and one with a flat square LED base so that the difference can be realized. The flat one can use between 1 to 4 1W LED’s and the curved base needs minimum of two LED’s on either side so that the shape can be used to its advantage.

Assembly

For now, a driver which can work on direct electricity is used in the housing, along with a frame for the base. The frame has two holes on either sides, and the housing tip of the pyramid was given two niches which allow removal and assembly through the screws that can fit the pieces together as shown alongside.
The prototype has two main components, the housing and the reflector. Model pictures are of the curved base model.
The light was intended to suffice a chat or any food cart, due to the levels when the pyramid/pyramids are kept on a glass surface/ hung in the air, the light would not only reach the sides but the bottom and top area would also be illuminated to a certain level. In the pictures above the flat base light pyramid is being tested. Lux reading 1m away = 2-3 lx.
Concept G: 4 in one

Small independant reflectors

On the right is a comparison between 1W plain LED and 1W LED with a small automobile fog reflector. And below that is an image from ‘design approach’ which illustrates increasing the distance between LED’s so that the overlap does not waste any of the light output. This concept combines both these ideas. It basically has four fog reflectors and four 1W LED’s, each LED has its own reflector. In the process of giving each LED its own reflector the spacing between the LED’s becomes more. It would be an added benefit if each LED and its reflector could have a different angle according to the users needs.
The blue model above shows the concept where 4 LED's have separate reflectors and the angle of the LED+reflector can be changed if required. For the sake of a quick prototype to test out the concept I’ve kept the housing (for driver) as two simple boxes and the reflectors directly mounted on these. At the base of each box is an adjustable small ball and socket bracket, so that the angle of a set can be changed together.
Further Progress

Shown alongside are the car fog light reflectors and the 3mm thick heat sink that needs to be present behind the LED. Four of the reflectors were bought from a Gujri and Four pieces of heat sinks were cut out of a 3mm thick.

After which the box was built out of wood. This was done simple by cutting and nailing each side of it, one side of the box was left open to install the driver and fix the bracket.

The reflectors are mounted on the wooden box with a plastic fitted thread inside the box and negative thread on the base of the reflector.
Final Prototype

The box is painted with 3 coats of white and the driver is placed in the housing. The box is sealed with small 1mm screws. Pictures show the different views.
image 1 is the light output of two units (LED+Reflector) Lx=4 on the bright spot and 2-3 lx on the rest of the lit up space at a distance 1.5m
image 2 is the light output of two units (LED+Reflector) Lx=4 on the bright spot and 3+ lx over a larger area on the rest of the lit up space at a distance 1.5m
More testing with diffusers

Further testing was carried out with different kinds of diffusers. Frosted glass, slightly textured glass, soft box material (used in photography) were the ones that seemed most promising. All were placed one by one on 2W part of the “4 in one” concept and tested. See images below.

light fixture without any diffuser
light fixture with white photographic diffuser
light fixture with slightly textured glass
light fixture frosted glass
Concept H: oval-e-d

Flat oval reflector + 3 LED's

The yellow arrows show the direction light would go in and the area it might cover. (this is just showing a few to explain the idea, an actual 60 degree LED will spread much more than this). The grey arrows show the reflected light and when the light hits the top reflector. The maroon are arrows show what will happen if there is a reflector at the back as well. The idea is to have LED's at the base throwing light on top and an oval flat reflector at the top which is angled so that the throws the light back to the bottom, ahead and the sides.
Parts

For the top reflector an oval piece of 0.5mm thick automobile SS reflective material was lazer cut and buffed and polished. For the bottom a readily available converging lens with a rotatable base and round frame was chosen. This included the heat sink, driver and lens as shown alongside.

Detailing

For the prototype a circular plastic frame was made which goes around the metal frame. Right at the bottom of the light two stoppers were given so that the driver would not move sideways. An H shaped frame which has potrusions that fit exactly into the rectangular groove of the metal base was made so that the light would remain upright in its place and the driver in the bottom would be prevented from moving up. This light also runs on direct current for the sake of testing. A 3mm hole was drilled at the base behind the light so that the wires could be brought out.
image above shows the press fit mechanism and the way to remove and assemble the light. The body is made out of plastic which is spray painted with duco paints. To the left: views of the prototype.
Through this prototype we know that the reflected light = to the direct light = 6 lx 2.5 m away. So now further experimentation will be done by making the long straight curve also a reflective surface. 3 different kinds of reflective surfaces will be tested out which can be compared.
More testing with reflectors

Further testing was carried out with stainless steel reflector and matte white reflector. A piece was cut and bent to fit the length of the cavity in the light fitting. Both were placed and options to enhance the light were tested. See images below.
DISH PENDANT LIGHT

Dish reflector pendant light, 5x1W LEDs. Light is reflected off the top reflector, 120 degrees LEDs light escapes to the side and top as well.
DC 230V
Street inspired light wall mounted/stand alone fixture, 5x2W LEDs. LEDs places behind the small dome, light is reflected in the bigger dome.
Aluminium body, Acrylic lid.
230V DC.
FLED MODULAR WALL MOUNT

Modular units that fit into each other, each unit: 3W+3W (dual lighting, top and bottom). Flat angular reflector. The angles of both the unit and reflector can be changed. The light below the unit covers the immediate area and the light above the unit is reflected on the flat surface and spreads in many other areas beyond. Bent base reflector provides an even spread. Body: plastic + acrylic, stainless steel reflector + wooden frame, adjustable brackets. Runs on 7V Lithium battery.
DOMO | HANGING FIXTURE

Dome reflector at the bottom, 3x1W LEDs, with diverging lenses on top. Direct light falls down and reflected light is directed upwards and on the sides. DC 230V
STRAP-ON | 3W FIXTURE

Rechargeable, portable fixture, 3x1W LEDs. The bend of the base beneath the LEDs drastically increases the area covered by the direct light.

Body: plastic, automotive paints, lid: acrylic, velcro straps.
2x4V rechargeable batteries
PYRAMID | 3D MODULAR UNIT

3D modular unit which can be fixed into one another or a single one can be used as pendant light. 2x1W LEDs / 4x1W LEDs.
Flat base is stainless steel reflector. Light is reflected upwards without it being diminished.
Body: plastic + aluminium, stainless steel reflector.
Runs on DC 230V
4 IN ONE | CEILING FIXTURE

Four automobile fog light reflectors, 4x1W LEDs. The angle of two LEDs can be changed independently. Spacing between the LEDs and each LED having its own reflector contributes to the brightness and area. DC 230V.
Oval-e-d light fixture with 3x1W LEDs. Light is projected from the base of the fixture to the oval reflective surface at the top of the fixture, reflecting light up to 140 degrees. LEDs have 20 degrees converging lens and a rotatable metal casing. Body: plastic + automotive paint, stainless steel reflector. Runs on DC 230V.
Implementation

User Testing

User testing was conducted in Ujjire as well as Bangalore. The cases of users targeted in the user research were tracked down once again and the lights are tested in their shops. A few new users have also been introduced in the testing, user research was redone and lights were implemented for these users. Once tested, along with pictures a comprehensive feedback was taken. In the next few pages some of these tests are shown, a few quotes and observations are also mentioned.
Iron-man with 3W - concept FLED

Fruit cart with 3W - concept C
dual light, concept C.
For this watermelon street shop the needs plenty of light in both the cutting and selling area and in the display area on the fruit. Hence this light suited him well.
Surface area covered by the FLED as compared to 1, 40W CFL is almost the same.

Color temperature of the LED’s used will have to change to cool white; currently it is warm white just for this prototype therefore we see a great difference in the brightness.

Although he agreed that the cost-effect relationship is the best when it comes to LED’s a considerable increase in the number and brightness of LED’s is required.

He says he can only tell the difference if more n number of FLED’s could be installed for the testing.

“You will have to have one light like this for each seat”

image 1: barber shop with 2, 40W CFL tubes switched on.

image 2: barber shop with "FLED"; 6W + some reflected light.

image 3: alongside, barber working under FLED.
He spent 3000 rupees for his 11W CFL and the large battery that he needs in order for it to run up to 3-4 hours.

- He travels with his battery back home, in order to charge it and brings it back every day.

- What "strap-on" offers him is a 3W light which runs on one or two 4V batteries which will last him the same time.

- Strap on covers every corner of his cart and also illuminates the front and the back areas just as the CFL did.

- He first insisted that the CFL was brighter but then once he was explained how the cost and size and weight and life of the strap on would be better in the long run he quickly agreed that LED was a much more convenient and better option for him.
As an emergency light it covers almost his entire shop, compared to the little area covered by his 8W CFL.

- He uses one 25W CFL, and two 15W CFL on a normal basis.
- He was ready to replace CLF with LED's provided all his three fittings would be replaced which meant comparing 55W to 15W (3 "DISH" lights).
- He was positive about the cost and he said the brightness was absolutely fine for his shop.
Fruit vendor with 11W CFL lamp

Fruit vendor with "4 in one" concept.

"YES, it is brighter than my light for sure."

- He uses an 11W CFL lamp hanging at the top of his display.
- His display has different levels that light needs to reach, like most fruit shops.
- The adjustable angle of the LED lights can help fruit vendors.
- Because of the reflectors his fruits shine even more brightly with the LED than with the CFL.
- What 4 in one does is take the light and focus is where is matter's the most.
- He too agreed with the cost-effect relationship being better with LED's.
“The cost is most important for me, if it works out well for me, there is no reason why I wouldn’t take it.”

From the four images alongside, the two images on the left are with the ‘4 in one concept’, and the two images on the right is the scenario otherwise.

- On some days he can manage to borrow a battery get it charged and use the regular 40W white CFL tubelight.
- On most days he has to manage with a candle.
- He is open to the idea of having a solution which can solve his problem.
- He is happy with the brightness and area the LED light covers.
- If the LED works out better than the 40W CFL and the battery and then he could wouldn’t have to make do with a candle.
• Comparing this picture to the one taken during user research on page 13, the
difference is clear.
• It is possible to compare a high wattage CFL with a 2-3W LED when it comes to
lighting these kind of spaces.
• This is supposed to be a modular unit, so the vendor can purchase it according
to his requirement.
• Because of the flat reflector the light is more even and falls exactly where
required.
• Kishore Kumar agrees that an LED light fixture, can be not only cheaper but also
better.
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