Lighting Equipment Designing


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1 Introduction:

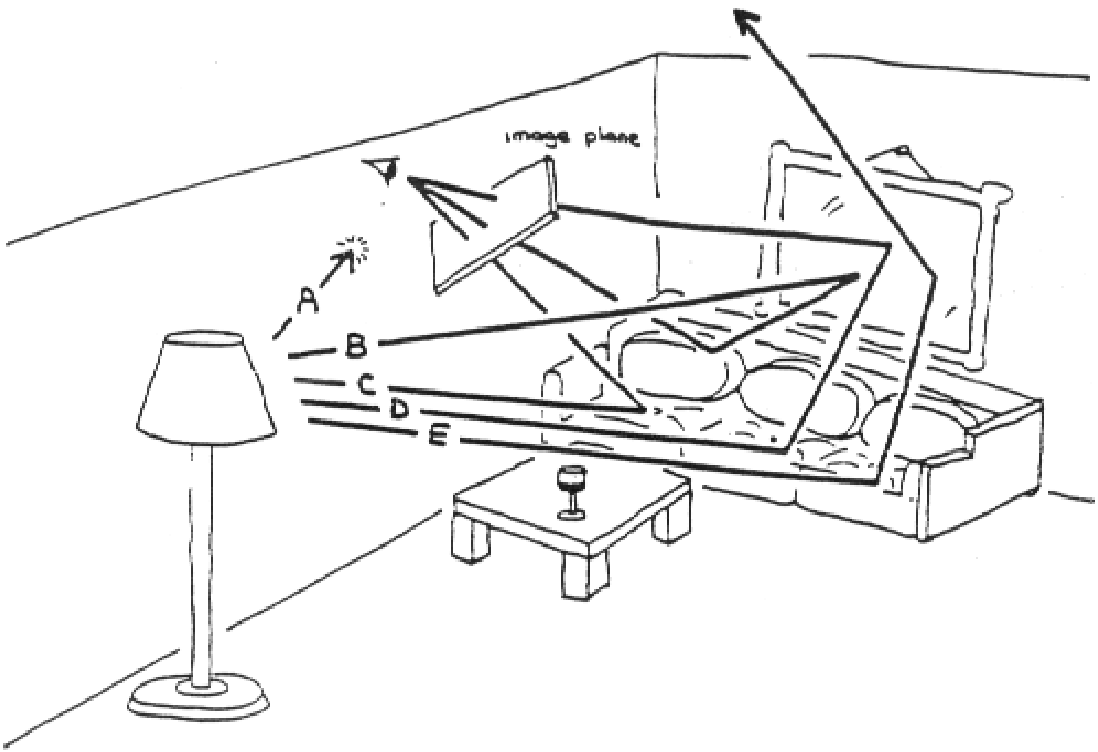
Light is a prime factor in the human life as all activities of human beings ultimately depend upon the light where there is no natural light, use of artificial light is made. Artificial lighting produced electrically on account of its cleanliness, ease of control, reliability, steady output as well as its low cost is playing an increasingly important part in modern everyday life. Optimization of light is becoming more important whatever the Application Street or medical, indoor, or architectural lighting one of the main requirements is to optimize the uniformity of the lite area taking into account the environment and minimizing blooming effects. A basic understanding of lighting fundamentals is essential for specifiers and decision-makers who are evaluating lighting upgrades. This document provides a brief overview of design parameters, technologies, and terminology used in the lighting industry. Good lighting has a lot of benefits where it decreases fatigue a protect health, eye, nervous system and reducing accidents, the science of illumination engineering is therefore becoming of major importance.

2 Indoor Lighting

2.1 Illumination

From Physics we can derive models, called "illumination ", of how light reflects from surfaces and produces what we perceive as color. In general, light leaves some light source, illumination is the result of the light on surfaces in which it falls thus the illumination makes the surface look more or less bright with a certain color, and this brightness and color which the eye sees and interprets as something useful or pleasant or otherwise.

(i.e. A lamp or the sun is reflected from many surfaces and then finally reflected to our eyes, or through an image plane of a camera).



2.2 Quantity of Illumination

2.2.1 Light Output:

The most common measure of light output (or luminous flux) is the lumen. Light sources are labeled with an output rating in lumens. For example, a T12 40-watt fluorescent lamp may have a rating of 3050 lumens. Similarly, a light fixture's output can be expressed in lumens. As lamps and fixtures age and become dirty, their lumen output decreases (i.e., lumen depreciation occurs). Most lamp ratings are based on initial lumens (i.e. when the lamp is new). It can be explained in another way as a maintenance factor which is known by the ratio of illumination under normal working conditions to the illumination when the lamps are perfectly clean.

2.2.2 Light Level:

Light intensity measured on a plane at a specific location is called ***luminance***. Luminance is measured in ***foot-candles,*** which are workplace lumens per square foot. You can measure luminance using a light meter located on the work surface where tasks are performed. Using simple arithmetic and manufacturers' photometric data, you can predict luminance for a defined space. (Lox is the metric unit for luminance, measured in lumens per square meter. To convert foot-candles to lox, multiply foot-candles by 10.76.)

2.2.3 Brightness:

Another measurement of light is ***luminance***, sometimes called brightness. This measures light "leaving" a surface in a particular direction, and considers the luminance on the surface and the reflectance of the surface.

The human eye does not see luminance; it sees luminance. Therefore, the amount of light delivered into the space and the reflectance of the surfaces in the space affects your ability to see.

2.2.4 Quantity Measures:

- Luminous flux is defined as a total quantity of light energy emitted per second from a luminous body commonly called light output and is measured in lumens (lm) the conception of luminous flux helps us to specify the output and efficiency of a given light source.
- Luminance is called light level and is measured in foot-candles (fact).
- Luminance is defined as the luminance intensity per unit projected area of either a surface source of light or reflecting surface as is denoted by (L) where {L=I/A COS}.

2.2.5 Determining Target Light Levels:

When designing a new or upgraded lighting system, one must be careful to avoid over lighting a space. In the past, spaces were designed for as much as 200 foot-candles in places where 50 foot-candles may not only be adequate, but superior. This was partly due to the misconception that the lighter in a space, the higher the quality. Not only does over lighting waste energy, but it can also reduce lighting quality. Refer to Exhibit 2 for light levels recommended by the Illuminating Engineering Society of North America.

Within a listed range of luminance, three factors dictate the proper level: age of the occupant(s), speed and accuracy requirements, and background contrast. For example, to light a space that uses computers, the overhead light fixtures should provide up to 30 facts of ambient lighting. The task lights should provide the additional foot candles needed to achieve a total luminance of up to 50 facts for reading and writing. For luminance recommendations for specific visual tasks, refer to the IES Lighting Handbook, 1993, or to the IES Recommended Practice No. 24 (for VDT lighting).

The Illuminating Engineering Society of North America has developed a procedure for determining the appropriate average light level for a particular space. This procedure (used extensively by designers and engineers (recommends a target light level by considering the following:

- The task(s) being performed (contrast, size, etc.)
- the ages of the occupants
- the importance of speed and accuracy

Then, the appropriate type and quantity of lamps and light fixtures may be selected based on the following:

- fixture efficiency
- lamp lumen output
- the reflectance of surrounding surfaces the effects of light losses from lamp lumen depreciation and dirt accumulation
- room size and shape
- availability of natural light (daylight)

2.3 Quality of Illumination

Improvements in lighting quality can yield high dividends for US businesses. Gains in worker productivity may result by providing corrected light levels with reduced glare. Although the cost of energy for lighting is substantial, it is small compared with the cost of labor. Therefore, these gains in productivity may be even more valuable than the energy savings associated with new lighting technologies. In retail spaces, attractive and comfortable lighting designs can attract clientele and enhance sales.

Three quality issues are addressed in this section.

- glare
- uniformity of luminance
- Non-uniform illuminance causes several problems

2.3.1 Glare:

It is the brightness within the field of vision of such a character as to cause annoyance, discomfort, Interference with vision, or eye fatigue.

- **Lumen**:

It is the unit of luminous flux and is defined as the amount of luminous flux given out in a space represented

- **Luminous Intensity:**

It is the luminous flux emitted by the source per unit solid angle, measured in the direction in which the intensity is required. It is denoted by I and is measured in candela (cd) or lumens / steradian.

- **Luminous Flux:**

It is defined as the total quantity of light energy emitted per second from a luminous body. It is denoted by symbol Φ and measured in lumens.

- **Lux or Meter Candle:**

It is defined as the luminous flux falling per meter square on the surface which is everywhere perpendicular to the rays of light from a source of one candle power and one meter away from it.

2.3.2 Uniformity of Illuminance on Tasks:

The uniformity of illuminance is a quality issue that addresses how evenly light spreads over a task area. Although a room's average illuminance may be appropriate, two factors may compromise uniformity.

- improper fixture placement based on the luminaire's spacing criteria (ratio of maxim recommended fixture spacing distance to mounting height above task height)
- Fixtures that are retrofit with reflectors that narrow the light distribution.

2.3.3 Non-uniform illuminance causes several problems:

- inadequate light levels in some areas
- visual discomfort when tasks require frequent shifting of view from underlit to overlift areas
- bright spots and patches of light on floors and walls that cause distraction and generate a low-quality appearance

2.4 HOW TO CALCULATE LUMEN?

2.4.1 Luminaires in Regular Arrays:

$$E = \frac{N.n.\Phi.UF.MF}{A_f}$$

Were

E = average Illuminance (lx)
N = no. of luminaires
n = no. of lamps in each luminaire
F = flux from one bare lamp
UF = utilization factor
MF = maintenance factor, allowing for effects of dirt and depreciation
A_f = area of working plane or floor

- **Utilization Factor:**

The Utilization Factor (UF) is the proportion of light flux emitted by the lamps which reaches the working plane. Luminaire manufacturers issues tables of utilization factors for various combinations of Room Index and surface reflectance's.

The Room Index for a rectangular room l x w where h_m is the height of luminaries above the working plane, is given by;

$$RI = \frac{lw}{h_m(l+w)}$$

- **Maintenance Factor:**

The maintenance Factor (MF) is the ratio of illumination under normal working conditions to the illumination when the things are perfectly clean

M.F= (Illumination under normal working condition/illumination when everything is perfectly clean).

Some factors affect maintenance factor such as:

- Dust and dirt inside luminaries' surfaces.
- Aging of light bulbs emitting less light.
- Cleaning of room surfaces, e.g. ceiling.

Without detailed knowledge of maintenance plan,

one sets MF = 0.8 ~ 0.9

- **Depreciation Factor:**

This is merely the reverse of the maintenance factor and defined as the ratio of initial meter-candles to the ultimate maintained meter-candles on the working plane. Its value is more than unity.

- **Spacing to Mounting Height ratio (SHR):**

It is the ratio of horizontal distance between adjacent lamps and height of their mountings.

$$SHR = \frac{\text{distance between adjacent fittings (centre - to - centre)}}{\text{height of fittings above working plane}}$$

The best ratio is between 0.8 and 1.2 (0.8<SHR<1.2).

- **Ceiling ratio:**

The recommendation for general lighting with a predominantly downward distribution is for the ratio of average illuminance on the ceiling to the average illuminance on the horizontal working plane to be within the range 0.3 to 0.9.

In general, the ceiling cavity reflectance should be as high as possible, at least 0.6.

For indirect lighting, the average luminance of all surfaces forming the ceiling cavity should be no more than 500 cd/m2 however small areas of luminance up to 1500 cd/m2 will generally be acceptable, provided sharp changes from low to high luminance are avoided.

- **Walls:**

Higher reflectance of wall and partition surfaces will increase the perception of lightness in the interior. Walls with windows are a particular case. The walls surrounding a window should have a reflectance not less than 0.6 in order to reduce contrast.

The ratio of the average illuminance on the walls to the average illuminance on the horizontal working plane is related to the average vertical plane illuminance throughout the space. This has been shown to give good correlation with visual satisfaction for office lighting. The recommendation is for the ratio of the average illuminance on any wall or major partition surfaces to the average illuminance on the horizontal working plane to be within the range 0.5 to 0.8.

In general, the effective reflectance of the principal walls should be between 0.3 and 0.7.

- **Floor and working plane:**

The reflectance of the floor cavity plays an important part in the visual appearance of a room. With most lighting installations a proportion of the light on the ceiling will have been reflected off the floor. Low-reflectance benches and desktops should be avoided since these surfaces have a major effect on effective floor cavity reflectance.

In general, it is undesirable for the average floor reflectance to exceed 0.40 or fall below 0.20. The reflectance of the area surrounding the task should not be less than one-third of the task itself. In the case of office tasks involving white paper, this will require desktops to have a reflectance of at least 0.30.

2.4.2 Laws of Illumination

2.4.2.1 Inverse square law:

If a source of light that emits light equally in all directions be placed at the center of a hollow sphere the light will fall uniformly on the inner surface of the sphere each square mm of the surface will receive the same amount of light if the sphere be replaced by one of the larger radiuses, the same total amount of light is spread over a larger area proportional to the square of the radius.

E1 = I * w / A1 LUMEN / UNIT AREA

Where **A**1 = w (R1^2)

E1 = I / (R1^2)

Similarly, illumination on the surface area (A2)

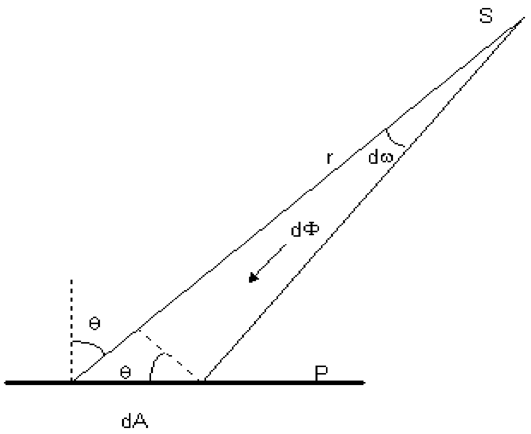
E2 = I / (R2^2)

2.4.2.2 Lambert cosine law:

At any point on a surface is proportional to the cosine of the angle between the normal at that point and the direction of luminous flux. We consider a point source, S, illuminating a plane surface, P. We know the luminance on a small area *ad*, illuminated by a luminous flux $d\Phi$

Where $d\omega$ is the angle subtended by the element *ad* at the source.

The luminance produced at a point source at a distance *r* from a plane is obtained by first eliminating $d\Phi$ from the above two equations



E = I*(dw/da)

AND dw = da COS θ/ r^2

Substituting for dw gives

E (I COS θ) / (R^2)

This expresses both the inverse square and cosine laws of illumination from a point source.

2.5 Types of lamps

2.5.1 Incandescent lamps:

Incandescent lamps or bulbs are the least energy-efficient type of lighting. They are inexpensive to buy, but their running costs are high. Incandescent lamps are most suitable for areas where lighting is used infrequently and for short periods, such as laundries and toilets. Standard incandescent bulbs last about a thousand hours and must be regularly replaced.

- **Theory of Operation:**

  When electric current passes through the resistance of the filament wire, power ($I^2 R$) is used to heat the filament and produce a glowing.

Incandescent Lamps

Fixtures of Incandescent Lamp

2.5.2 Fluorescent lamps:

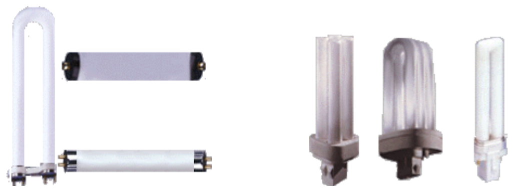
Fluorescent lamps are the most energy-efficient form of lighting for households and use only about a quarter of the energy used by incandescent bulbs to provide the same light level. They are more expensive to buy but are much cheaper to run and can last up to ten thousand hours. Most fluorescent lamps do not switch on immediately. This is a design feature to lengthen the life of the tube.

Fluorescent lamps are ideal for areas where lighting is required for long periods of time, such as the living room, kitchen, and for security lighting.

There are two main types of fluorescent lamps:

- Tubular.
- Compact type.

Tubular lamps, also known as fluorescent tubes, are available in a straight or circular style. They are cheaper to buy than compact fluorescent lamps (CFLs), but unlike CFLs require special fittings. Tubes are ideal for kitchens, garages and workshops.



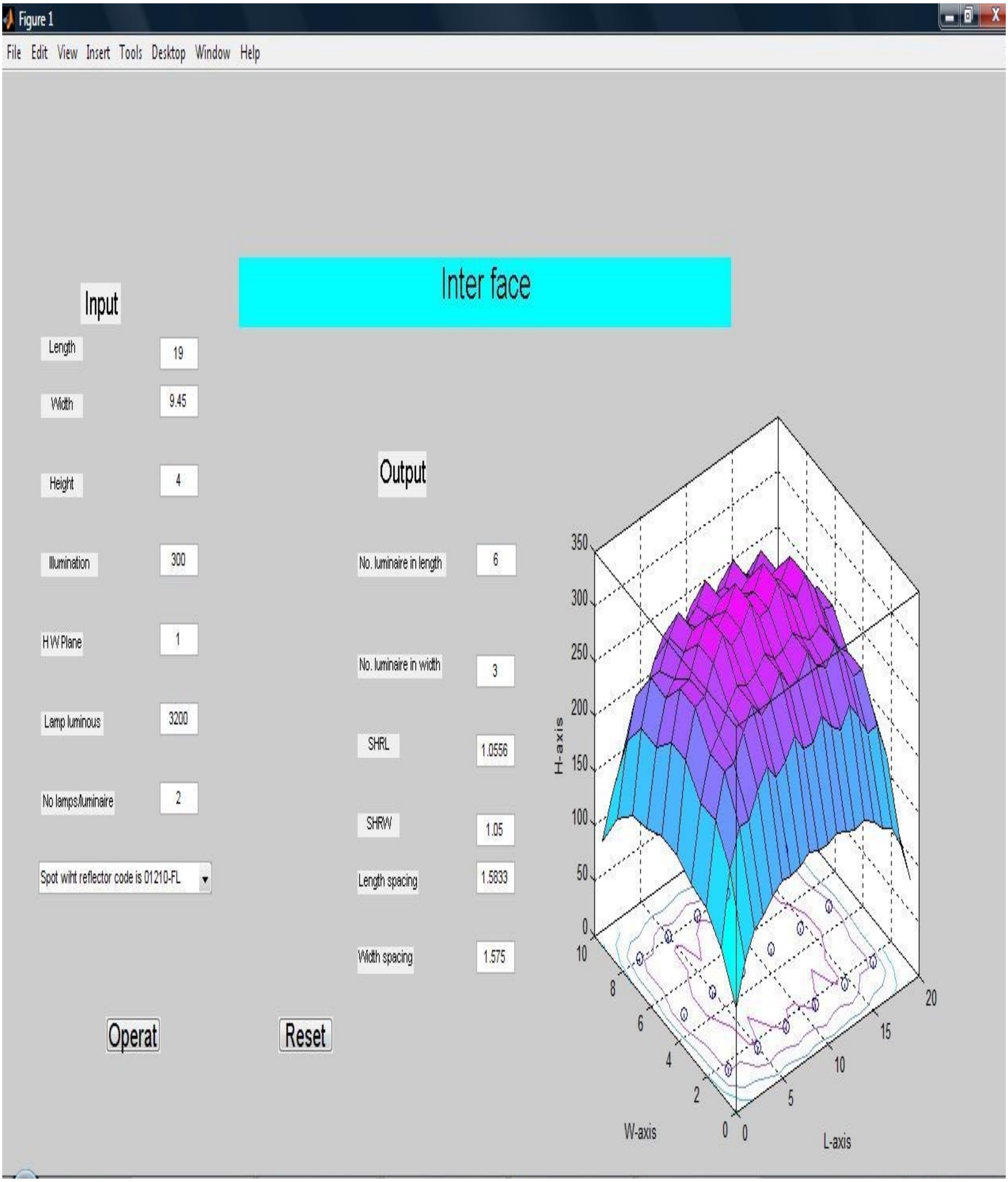
Different Types of Fluorescent Lamps

Fixtures of fluorescent Lamp

2.5.3 High-pressure sodium lamp:

A high-intensity discharge (HID) lamp whose light is produced by radiation from sodium vapor (and mercury)

2.6 MATLAB Calculation for some areas:



Hall room

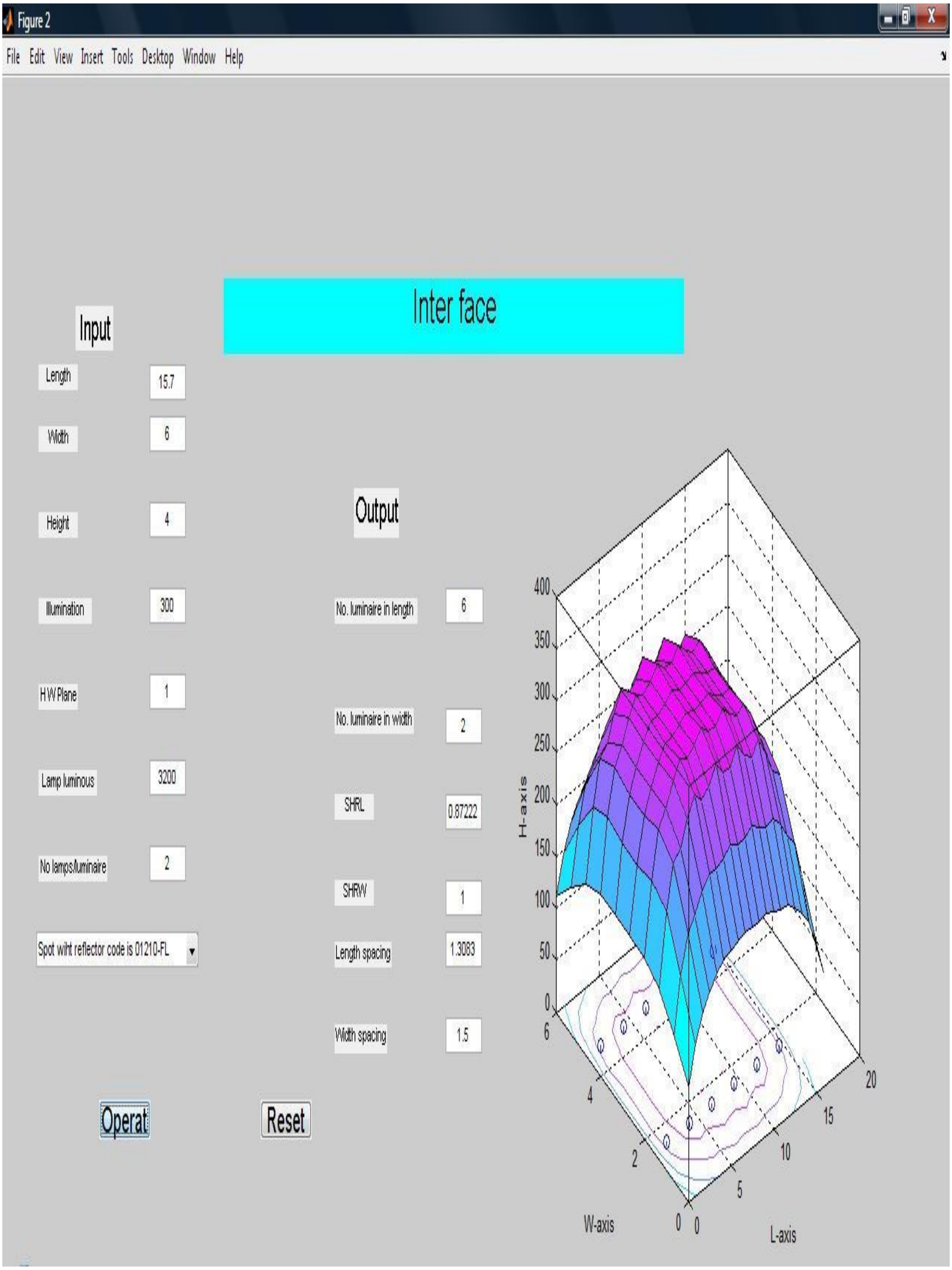


Figure 2
File Edit View Insert Tools Desktop Window Help
Inter face
Input
Length
15.7
Width
6
Height
4
Illumination
300
H W Plane
1
Lamp luminous
3200
No lamps/luminaire
2
Spot wiht reflector code is 01210-FL
Output
No. luminaire in length
6
No. luminaire in width
2
SHRL
0.87222
SHRW
1
Length spacing
1.3083
Width spacing
1.5
Operat
Reset
H-axis
W-axis
L-axis

Looby

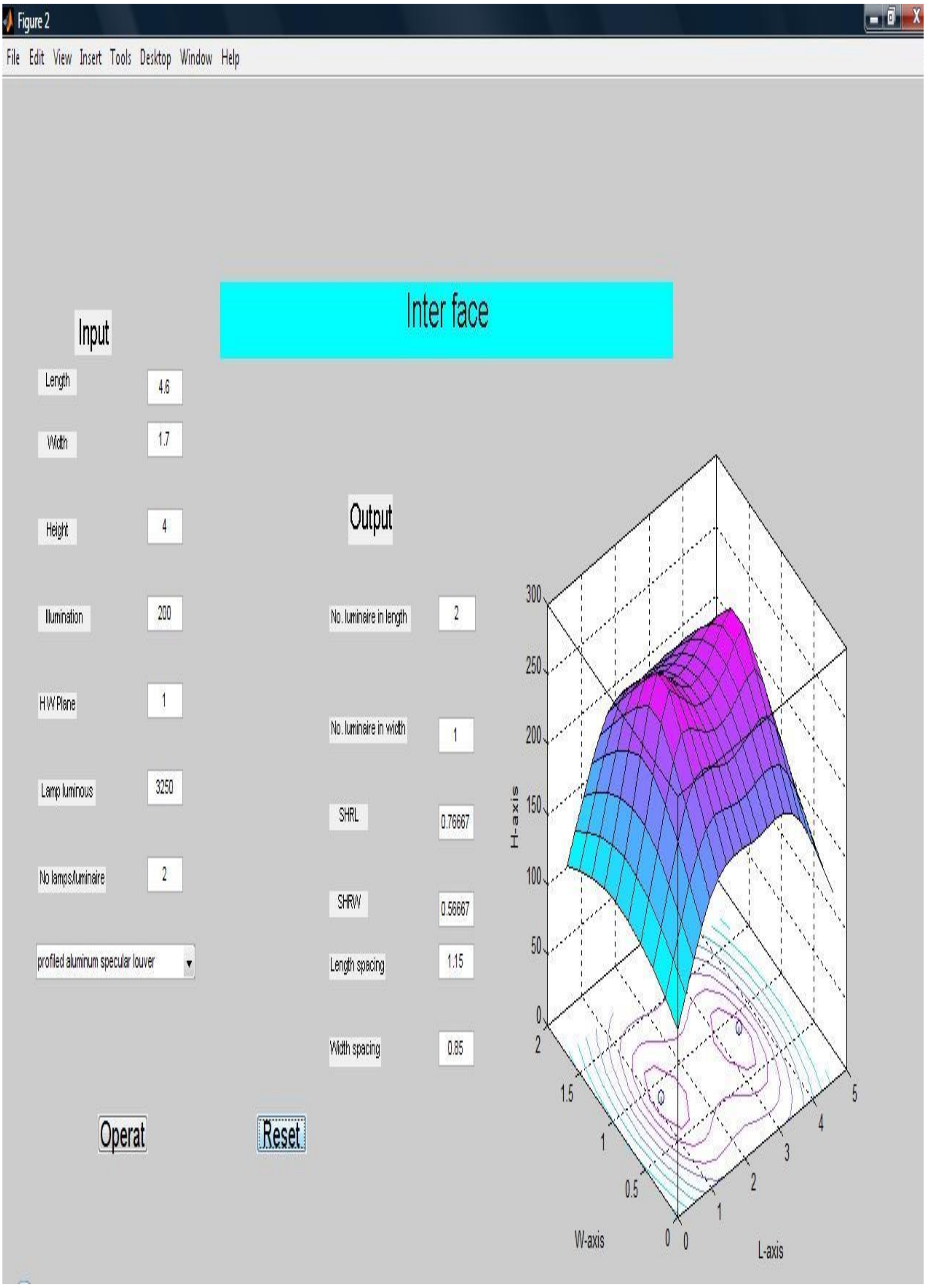
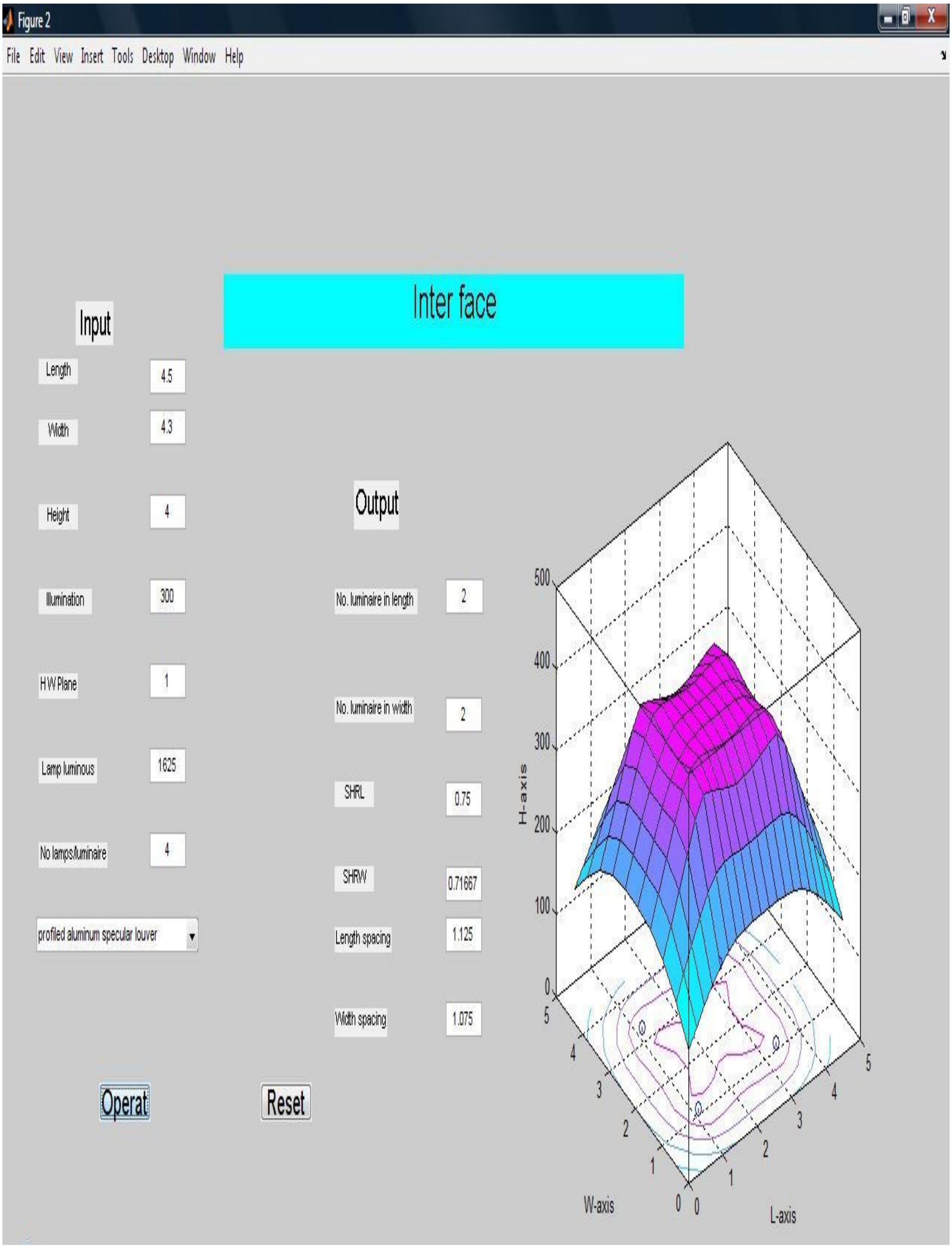


Figure 2
File Edit View Insert Tools Desktop Window Help
Inter face
Input
Length
4.6
Width
1.7
Height
4
Illumination
200
H.W Plane
1
Lamp luminous
3250
No lamps/luminaire
2
profiled aluminum specular louver
Output
No. luminaire in length
2
No. luminaire in width
1
SHRL
0.76667
SHRW
0.56667
Length spacing
1.15
Width spacing
0.85
Operat
Reset
H-axis
W-axis
L-axis

Storage



General cashier

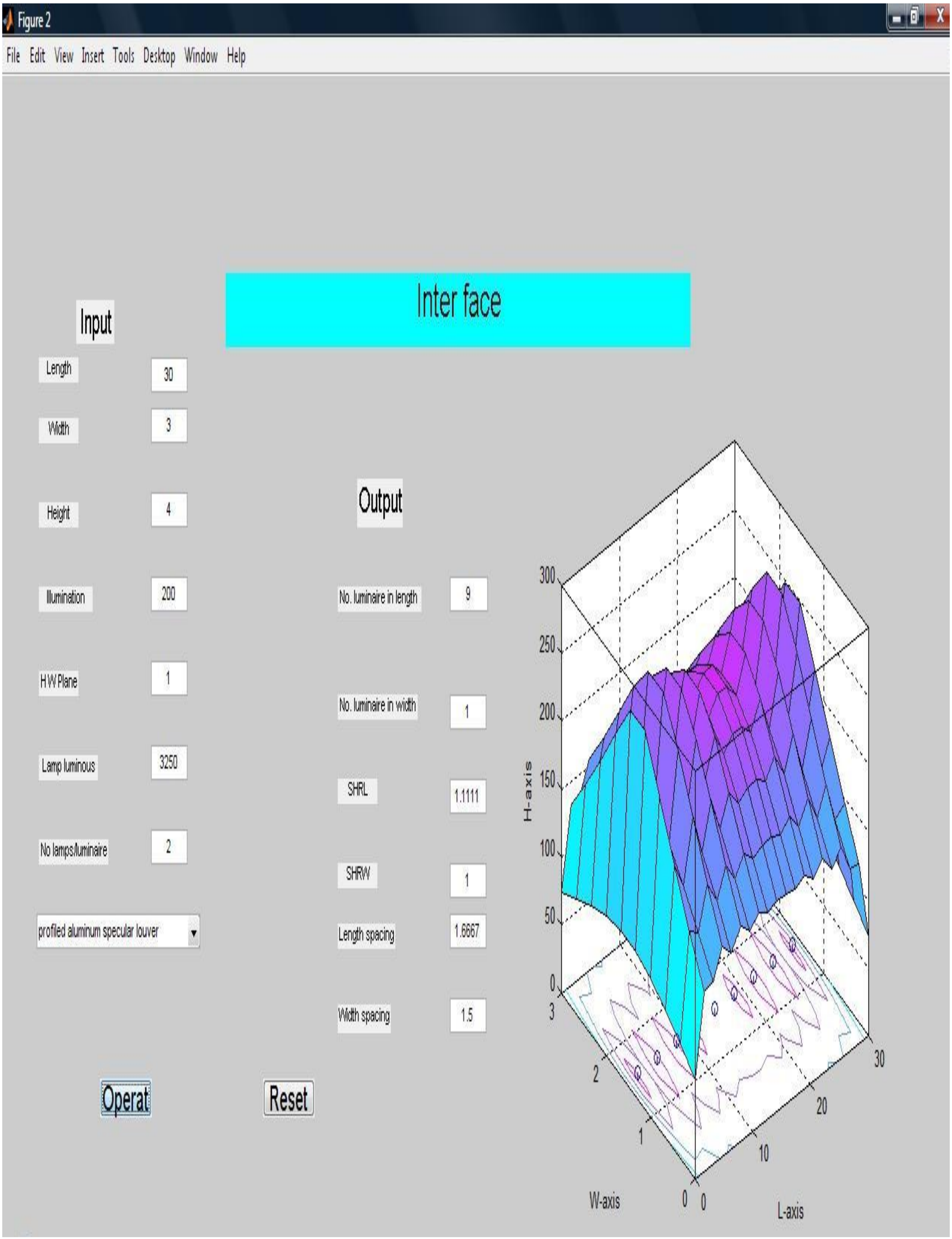
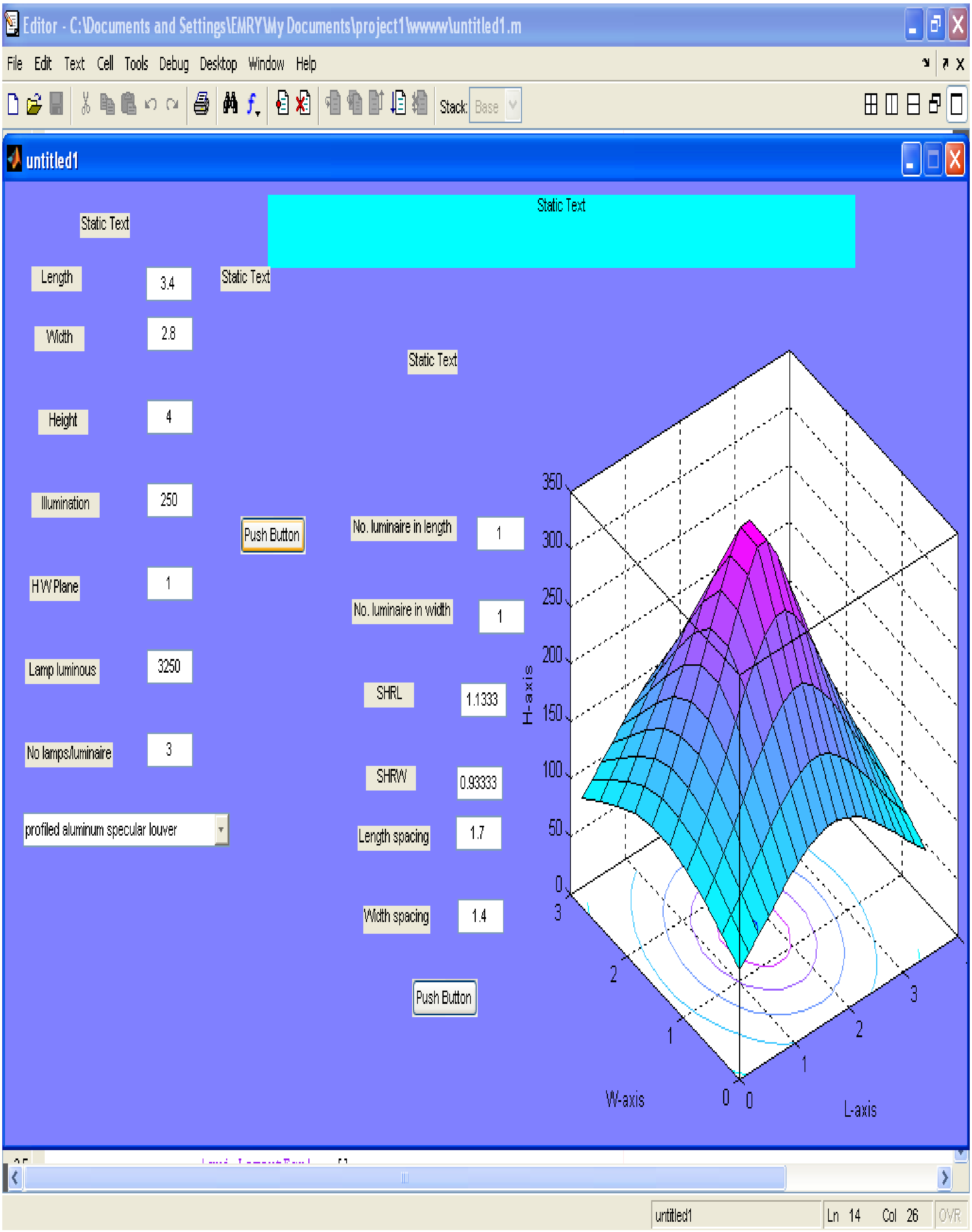
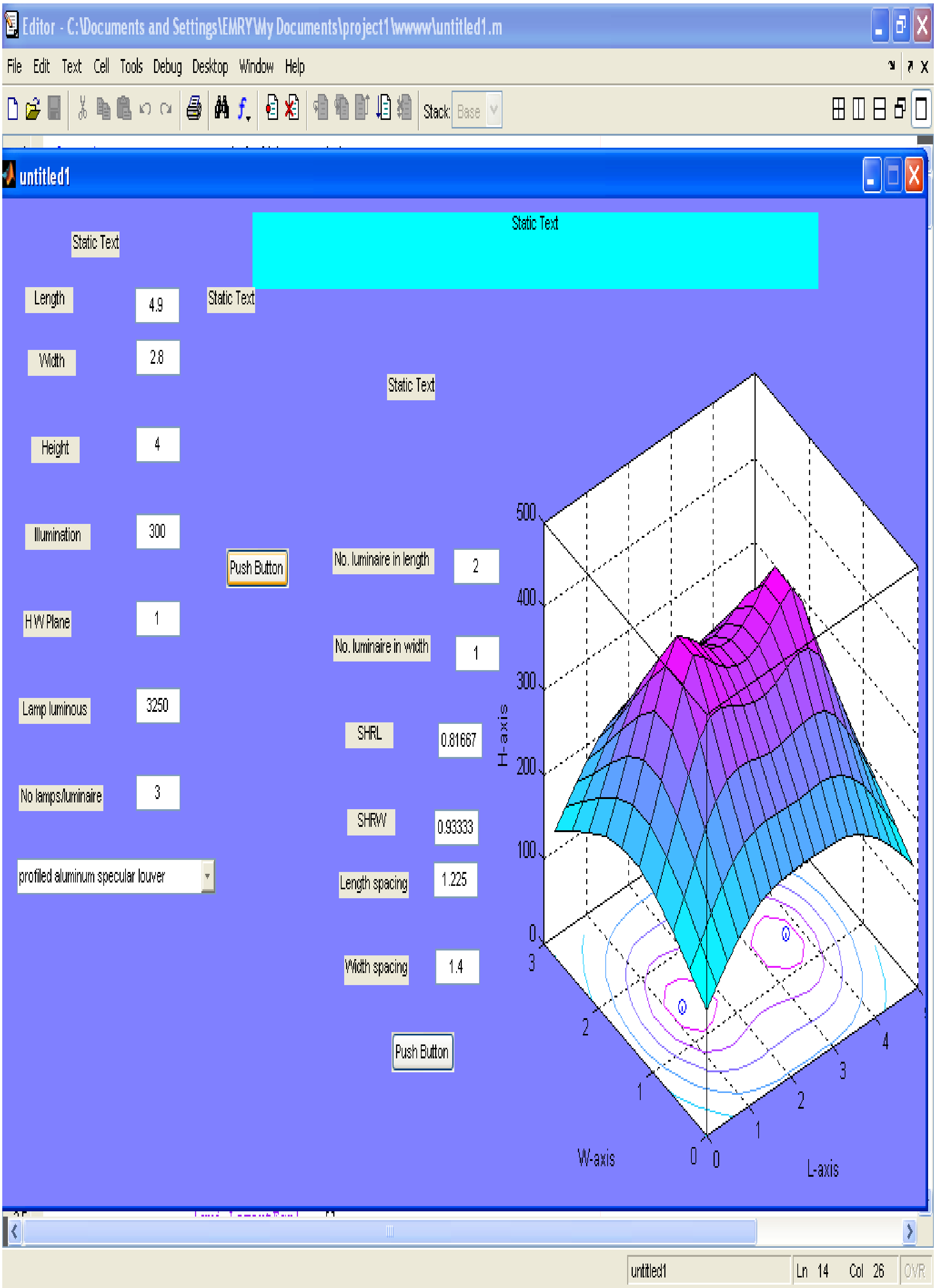


Figure 2
File Edit View Insert Tools Desktop Window Help
Inter face
Input
Length
30
Width
3
Height
4
Illumination
200
H W Plane
1
Lamp luminous
3250
No lamps/luminaire
2
profiled aluminum specular louver
Output
No. luminaire in length
9
No. luminaire in width
1
SHRL
1.1111
SHRW
1
Length spacing
1.6667
Width spacing
1.5
Operat
Reset
H-axis
W-axis
L-axis

Corridor



Manager office



Work station

3 Outdoor Lighting

- **Calculation of Luminaries**

1) Determining the level of luminance by using table number (4)
2) Light uniformity along the roadway is the second element of illuminance design. It is measured in terms of ratio of the average to minimum illuminance along the roadway Uniformity.
3) Determining the lamp type sodium, mercury, halogen,
4) We select the height of pole acc. Table no (5).
5) If $w \leq h$ then select single side design
   Where: - h = pole height, w = street width If $h<w < 1.5h$ then select zigzag design
6) If $w > 1.5$ h then select double side design
7) A luminaire is composed of a light source, a reflector, and usually a glass or plastic lens or refractor.
8) In designing alighting system, maximizing spacing of luminaries consistent with good illumination design.
9) We determine the lumen of lamp according to the lamp catalogue.

10) Use the next Formula for calculation of the spacing between two poles

$$S = \frac{Ø \times U \times M}{W \times E}$$

S = Luminaire Spacing

W = Road width

E = Nominal illuminance level.

M = maintenance factor.

U= Utilization factor

Ø =Initial lamp lumens

item	Type of rood – way	Lux level
1	Highway, main road and main streets	20- 30 Lux
2	Secondary rood /secondary streets	15- 20 Lux
3	Residential area streets, industrial area streets	10-15 Lux

Table no. (4)

item	Luminous flux of luminaire (lumen)	Mounting height of luminaire
1	3000 - 10000	6-7 meter
2	10000 – 20000	7-9 meter
3	20	> 9 meters

Table no. (5)

REFERENCES

Software Programs

- AutoCAD – Drawing Software
- MATLAB program for calculation of indoor lighting.

Products Catalogues

- Eleswedy catalog for calculation street and outdoor lighting.
- EGY LUX for indoor calculation Lighting Catalogue.

Scientific References

- William D. Stevenson, Jr., "Elements of Power System Analysis," 4^{th} Edition, McGraw-Hill Book Company, New York, 1982
- J. B. Gupta, "Utilization of Electric Power & Electric Traction," 6^{th} Edition, Technical Education International Company, India, 1981