Sensitivity analysis of work plane illuminance to room surface reflectance values

تحليل حساسية الإضاءة لمستوى العمل لأسطح الغرفة

by

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ABSTRACT

Nowadays, the employees spend around 8 to 10 hours a day in their offices , therefore, the creating of right work environment is an essential matter in today's designs for offices. However , some people till today don't know how could the lighting influences the workers at the offices . In this study , the researcher has explored the effects and impacts of one parameter which is the 'surface reflectance' in interior spaces as walls , ceiling and floor , on the illuminance level that is visible on the work plane by employees .

For the purpose of proving it , two digital models were created in this study in order to run the simulations. Significantly, the small area office illuminance increased with high values when the wall surface reflectance is high . In the large open spaces , and when the ceiling surface reflectance is high , the illumination will be increased more than results of increasing wall reflectance values .

In this study , the researcher addressed the effects of the wall reflectance through a variety of simulations for the reflectance's of ceiling , walls and floor , to demonstrate the effects of the surface reflectance on increasing the space illumination , which can play a role as an energy saving as well as cost saving while the high demand of lighting is needed .

الملخص

في الوقت الحاضر، يقضي الموظفون حوالي 8 إلى 10 ساعات يوميا في مكاتبهم، وبالتالي، فإن تهيئة بيئة العمل المناسبة أمر أساسي في تصميمات اليوم المعاصرة للمكاتب. ومع ذلك، لا يعرف البعض حتى اليوم كيف تؤثر الإضاءة على العاملين في المكاتب. في هذه الدراسة، استكشف الباحث تأثيرات "الانعكاس السطحي" في الفراغات الداخلية كالجدران والأسقف والأرضيات، على مستوى الإنارة الظاهرة للعاملين في مساحة العمل.

لغرض اثبات ذلك، قام الباحث بإنشاء اثنين من النماذج الرقمية في هذه الدراسة من أجل اختبار و تقييم النتائج. ازدادت إضاءة المكاتب الصغيرة إلى حد كبير عندما يكون انعكاس سطح الجدار مرتفع. أما في مساحات المكاتب الكبيرة، وعندما تكون انعكاسات سطح السقف عالية، تزداد الإضاءة أكثر من نتائج زيادة في الانعكاس بالنسبة للجدران.

في هذه الدراسة، قام الباحث بتوضيح مدى تأثيرات انعكاس الأسطح من خلال مجموعة من الاختبارات لقيم انعكاسية الأسقف والجدران والأرضية، لإظهار تأثير الانعكاس السطحي على زيادة إضاءة و إنارة المساحة، مما يمكنه أن يلعب دورا كبيرا في توفير استهلاك الطاقة، فضلا عن توفير التكاليف في حالة الاحتياج لمستويات إضاءة أكبر.

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Table of Contents

List of Figures

List of Tables

List of Diagrams

List of Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Official
IEA	International Energy Agency
LENI	Lighting Energy Numeric Indicator
LED	Light-Emitting Diode
EN 12464	European Standard for lighting requirements for occupants
CS	autonomy the “circadian counterpart” of daylight autonomy
IESNA	Illuminating Engineering Society of North America
CIE	Commission International Eclairage
LG7	Lighting guide 07
LG3	Lighting guide 03
CRI	Color Rendering Index
VDU	Visual display unit
VDT	Visual display terminal
CIBSE	Chartered Institution of Building Services Engineers
EEC	European Economic Community
HSE	Health and Safety Executive

Chapter 1: Introduction of the Research

1.1 Introduction

In the Aim of recognizing the surface reflectance impacts on the lighting effectiveness within interiors, one needs to initially get the meaning and understanding of the interior spaces, its matual association with vitality productivity, energy efficient required procedures , strategies and the ideas of reflectance ,light and colour. the relevance can be accomplished by:

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1-The Design of interior space

The interior space is involved with any existing thing inside a space , windows ,walls ,doors, finishing, light, textures, furniture and decorations. These components are utilized by originators and designers to build up an safe, functional, and satisfying area. The objective is creating a space that have harmonious and coordinated properties. The configuration of Inside Space is the route toward the experience molding of inside space, through the spatial volume controlling and furthermore the surfaces treatment.

2- Design of the Interior Space and Energy Efficiency

The inside space must involve with code and the requirements of regulations, and energize the standards of natural sustainability. In this manner, the planning of interior space work relies on numerous controls considering the psychology of environment, lighting, cooling and style, and so on. For reaching more integrated approach and effective solutions, it isn't just the area of an interior planner designer or a planner however lighting designers, consultant of HVAC, structural designer, the electrical specialists, and so on.

3- The design of Interior lighting and needed strategies for Energy Efficiency

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Design of Lighting as it stratifies to the inside fabricated condition. Far reaching lighting configuration requires a thinking of the proportion of valuable light gave, the devoured imperativeness, and the good impact given through the structure of lighting. Lighting incorporates utilization of both counterfeit light sources and characteristic sunlight. Be that as it may, fake lighting speaks to a noteworthy segment of vitality utilization, representing a critical piece of all vitality devoured around the world. Discoveries from a review on vitality end utilize forces in business structures, by the U.S. Energy Department,

demonstrates that lighting is consuming 25 –30% of vitality as appeared in Figure 1. Likewise, business structures, specifically the Buildings of the Office are considered as a part of the biggest parts in Building that uses and requires high electricity .

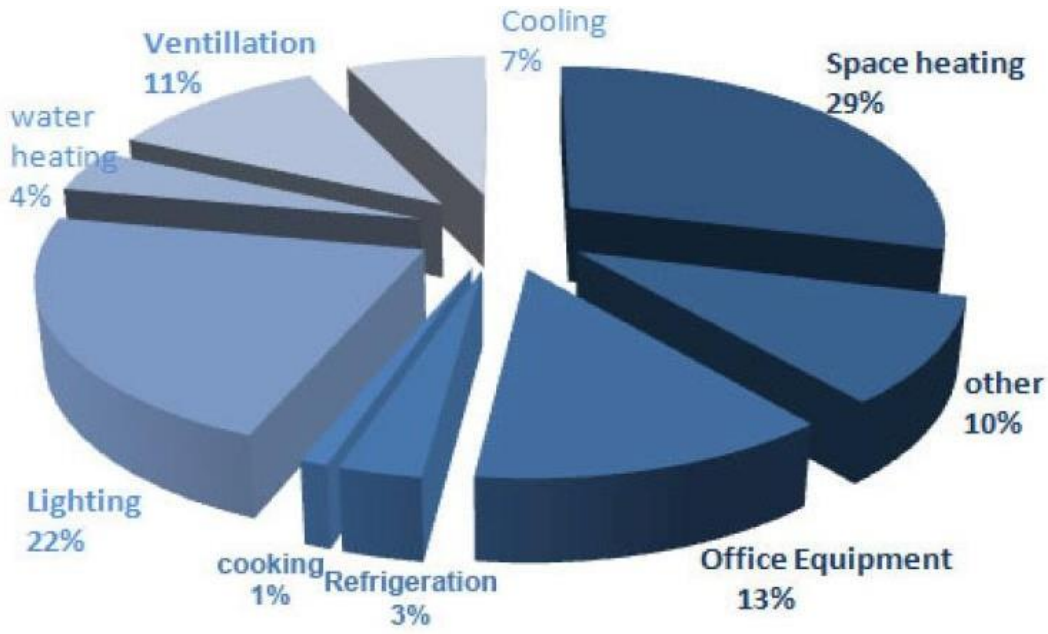

Figure 1.1: Energy of lighting Use comparing by other energy uses

(Source: Makaremi et al., 2017)

Tending to Indian context, the offer of power and utilized, around 15% and 18 % of electricity created is utilized because of purposes of lighting. In this way it speaks to segment of vitality utilize.

Notwithstanding, there are a few methodologies accessible to limit the building lighting vitality utilization. Numerous research measures have created logical foundations for lighting, considering and recognizing colour of surface, reflectance, sunshine accessibility, light dispersion and glare as elementary issues to propagate effective interior, as IRC and IESNA.

People, Nowadays, in developed countries especially, invest the majority of their time inside the buildings. Subsequently, structures are in charge of a noteworthy extent of worldwide consumption of energy with the end goal to give an agreeable indoor atmosphere to inhabitants. It was noted and stated that around 2980 TWh of the worldwide

electrical vitality is identified with purposes of lighting In a specialized report done by the International Agency of Energy (IEA) .(Scott Linney, 2008)

Concentrating on the utilization of lighting in the case of European zone, an information were gathered officially in 2014 by the European Environmental Agency revealed that the lighting represents around 10 percent of the family power utilizations .(Cai et al., 2018). According to (Makaremi et al., 2017), In building segment, enhancement of lighting execution when keeping up a coveted condition of indoor is striking centrality to enhance generally speaking vitality proficiency. Then again, with the end goal to meet the flow principle worry of overall worldwide associations to control a dangerous atmospheric devation issues, lessening interest for electric vitality could prompt relieve carbon discharge and natural contamination. In the previous decade, there has been a developing enthusiasm for inactive plan systems with the end goal to enhance the vitality execution of structures as far as lighting power request. Streamlining criteria ,in this view,to coordinate fake lighting and sunlight to be as a financially and clean savvy elective in the direction to the manageability, is one of the considerations of key research in the building field of plan and advancement (Cai et al., 2018). Notwithstanding detached sun oriented plan, numerous other techniques for lighting control have been connected in order to be met the EU's objective for 20 percent expansion within vitality effectiveness by the year of 2020. Utilization of profoundly vitality effective lighting advances (LEDs), savvy controlling lighting frameworks , programmed diminishing, change of factor support and utilization of lighting for errand/encompassing are for the most part considered to enhance the vitality execution of structures prompting decrease of aggregate vitality utilization for lighting (Clements-Croome, 2013). Then again, late investigates exhibited that circulation of light inside structures very impacted by attributes of indoor condition . Consequently, inside design and physical interrelated highlights could be counted as a generous perspective within request of lighting, and using vitality in structures. A few examinations ,In this display, explored the role of window's orientation, height and depth of the room, partitions height, coating properties and in addition inside shades and indoor curtains in improvement of sunlight to spare vitality and limit the interest for fake lighting in structures. Power utilization and vitality productivity techniques ought to be executed as per the visual solace criteria (Building Materials , thermal efficiency and reflectivity, 2013). Consequently, giving agreeable conditions visually is as critical as guaranteeing low vitality utilizations.

European standard EN 12665 characterized visible solace as "an emotional state of visual prosperity incited by the visual condition".

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4- Interior Light ,Colour, Reflectance of Surface and Efficient space design:

The most standout predominant spatial components within the built environment interior is Colour. Withal, space's colour has the ability to influence the lighting of an Interior dramatically and even subtly. It is so because shades of an interior surface colour.

Studies and some researches have demonstrated that 33% of the energy that used by lighting system relies on the surrounding interiors features, as height of the ceiling , windows ,room surfaces colors and reflectivity . Along these lines, one would take a look at the color scheme of the interior , thinking in provision of the design of the space, artificial lighting as well as the efficiency. (Dubois and Blomsterberg,2011)

Furthermore, theories of colour and model propose that the measure of light reflecting from a surface shading it play a role as its value of reflectance of the light (Ebaomonthly.com, 2011) . This infers that the value of grey color can alone be ventured to adjust the luminous and glowing light character. It isn't basic to investigate all shading reaches, tones, and so on. Likewise, it is discovered that the system of Munsell color straightforward reliable for value of Gray scale adjustment.

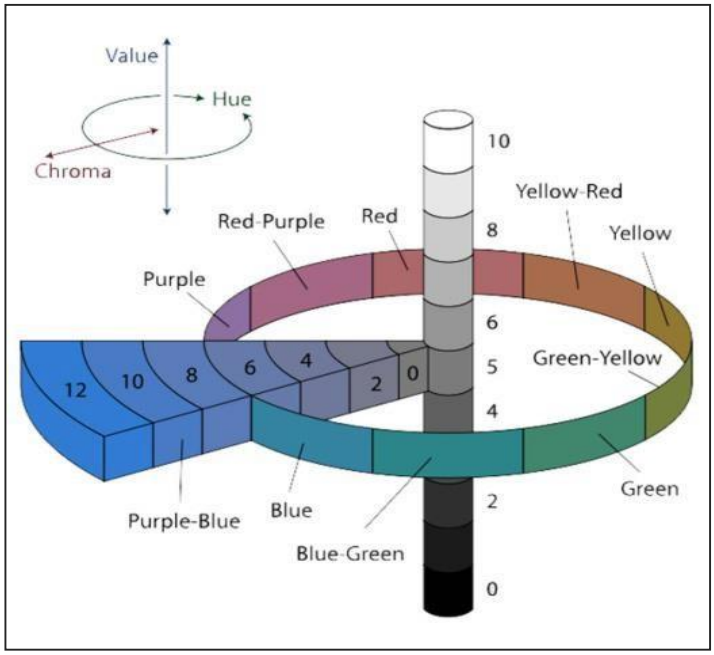


Figure 1.2: Color system of Munsull
(Source: Ebaomonthly.com, 2011)

Efficiency of the energy is an attractive, but on the other hand, the design of the lighting must consider different factors ,as health and visual comfort, etc.
Its important to understand that the light quantity can be addressed only after issuing of proper luminance ratios , glare reduction ,etc.
Many codes and standards have created rules to choose the colour of interior surface wherein it proposing a scope of reflectance estimations of significant surfaces of a room ceiling , wall , floor. however, the writing researches to date demonstrates little agreement about favored room surface reflectance and work plane. Additionally very little consensus is obvious as far as evaluation as for lighting consumed loads. (Clements-Croome, 2013)

In the light of this ineptness, it would be worth examining the extent of reflectance surface for surfaces of the room , partitions and work plane of the interior, which are considered as the most energy proficient and observe to the visual of the space balance. The fundamental collection of work means to be powerful and proficient, on the grounds that it doesn't plan to decrease the nature of the space and however therefore enhance the execution of the lighting of the space. (Singh and Rawal, 2011)

"The light amount", "the light uniformity", "the rendering colors quality", and "the glare risk for occupants" are playing the role as being the essential physical factors which with each other characterize visual comfort (Singh and Rawal, 2011). Hence, numerous criteria and standards were produced to determine lighting prerequisites for people in various indoor work spots and conditions. Within such manner, lighting examinations for indoor as for counterfeit light and sunshine are generally helped out through test field estimation and also computational reproduction using diverse measurements and records such as :"illuminance", "uniformity of ", "light factor", "Brought Unified Glare Rating", "day light factor", and so on.
A few examinations demonstrated that the worthiness of a light space for fulfillment of tenants as far as adequate light for the undertaking not just relies upon the right brightening of the area of the task, but in addition on dissemination of light on the vertical surfaces, and henceforth encompassing lighting (Singh and Rawal, 2011).Likewise, a few examinations have been led to discover a legitimate scope of helpful reflectance for inward surfaces. In an examination by (Reinhart,2014), the computational reenactments

discovered the connection between decrease of segment reflectance and diminishing the measure of sunlight in an open-plan office. Also, the previously mentioned investigation demonstrated that expanding the reflectance of the roof decidedly impact the consistency of the light dispersion and energy sparing inside the spaces. (Dubois and Blomsterberg, 2011) . likewise, (Gratia and De Herde, 2003) concentrated on the parameters that influence consumption of energy in structures and set up a general outline rule for low energy places of business. Their examination proposed high reflectance values somewhere in the range of 70% and 80% for roofs and reflection Coefficient over half for dividers with the end goal to amplify the appropriation of sunshine in the region. As per their examination, the creators suggested coefficient of reflection higher than half for level surfaces in spite of the fact that they noticed that clients want to have dim ground with the end goal to encourage support . Also, a simulation examine dependent on an Italian authentic building cleared up the impact of the reflectance estimation of the dividers on the decrease of the index of LENI (Lighting Energy Numeric Indicator) (Ciampi et al., 2015). In fact, it is demonstrated that optical interior surfaces properties and its impact on the energy consumption of lighting is a main factor to the quality of indoor lighting and amount optimizing (Singh and Rawal, 2011) .In purpose of reality, in configuration stage, it is important to consider reflectance of surface as one of the principle factors to improve the reflection and dispersion of dividers electric lights and thus level of illuminance in the space. As indicated by the lighting necessities for inhabitants, the European Standard EN 12464 according to (Joanne, 2009) has suggested the accompanying scopes of helpful reflectance for real surfaces of interior i.e. ceiling , wall , floor within work places at indoor:

- Ceiling : from 0.70 to 0.90
- Walls : from 0.50 to 0.80
- Floor : from 0.2 to 0.40

In spite of the fact that there is a reflectance extend proposed for the inside diffusely surfaces reflecting still a need is there to examine the relevance between the conditions of indoor lighting and characteristics of reflection of interior surfaces to control indoor lighting consumption of energy. Actually, there is an absence of data on the measurable investigation of various visual solace criteria. In like manner, exploring the impact of inside

surface reflectance on the conveyance of lighting in structures is the protest of the ebb and flow inquire about. Along these lines, this investigation tries to measure the impact of reflectance of the surfaces interior on the indoor lighting execution as key technique which leads to decrease the consuming of electricity.

1.2 Research Motivation

The reserch's motivation is providing the lighting planners or designers as possible with analysis and detailed data regarding the surface reflectance parameter as a different percenrages that can affect the lighting and controle it specially for the work area zone in offices .

The varity of analysis that will be resulted will clarify and show the relationships between inhancing the reflectance parameter for surfaces and the illumination level .

This is aims to expand the literature review in strong way for stakeholders , which will help decision-makers within the selection procedure ,that will be based on the resulted detailed data and analysis that covers the different reflectance parameter percentages for interior surface as ceiling, walls and floor , in the field generally of LED standard lightings in offices and LED lightings for work plane in specific.

This can help in implement and designing the office lighting to provide a good and comfortable working areas for the workers within the office space.

1.3 Aim and Objective

The intent of this research is studying the impacts of reflectance of surface on the lighting and illumination levels and efficiency of interior space as it compares the different values that are generated by the software .

The study is evaluating the surface reflectance in office space with using of LED standard lighting for offices as a case in order to highlight the impacts of surface reflectance on the illumination .

Added to that, the research addresses what was found as a lack of data on the reflectance of surfaces in interiors , with mentioning its advanteges and disadvantages, especially for office spaces .

The objectives of this thesis are :

1. To compare the work plane illuminance resulting from using different reflectance values than the default reflectance values..

2. Evaluate the relationship between illumination and surface finishing reflectance .

3. To Study how sensitive the illumination level is to changes to the reflectance value of various room surfaces.

The resulted scores of the analysing the data is satated through two different stages. First stage is involving testing the globally standards for the surface reflectance in the interior space with a standerd LED lighting type for offices for 2 models: small office area (15 m2)and large office area (450 m2) .

Secod phase is to examin the different reflectance percentages of the surfaces for the two creatd models for simulation , in order to address the differenties in illumination levels within the office space with the same standard LED lightis which is used for offices .

1.4 Research Questions

Three research questions were addressed in this research that elaborate and guide the investigation of the reflectane of surfaces impact on the lighting .

Question 1:Is there a strong relationship between surface reflectance and illumination in the interior space ?

Question 2 : Which surface of (walls , ceiling , flooring) has the largest impact on increasing lux level ?

Question 3 : Can the surface reflectance be used as a guide line to enhance the lighting level instead of installing more lights?

1.5 Research Scope and Limitation

The research's scope of work includes two empty office spaces computer models The research will be focusing on enhancing lighting and illumination level in office spaces in terms of provide the comfortable visibility for the workers during work time.

After an articles's review and previous studies that dealed with office with relationship to surface reflectance values, it was necessary to address some of the limitations that faces the author while making this research.

Firstly that it was a lake of previous investigations and researches that are focusing on same research topic .

Secondly that the tested models were an furnished spaces which are considering the elements in the space as coloumns, furniture , number of occupants , screens , wall angels, etc. , as this reseaech was conducting an empty office spaces .

Chapter 2: Research Literature Review

2.1 Introduction

With the end goal to consent to the examination targets talked about earlier in chapter one, it is important to peruse and think about various papers covering similar subjects. This helps in understanding diverse parameters influence the exploration extent of work notwithstanding extraordinary benchmarks and confinements that different specialists confronted while examining comparative points.

This part presents and examines numerous research papers connected to this research subject notwithstanding national and worldwide directions and codes which control an official choice that would agree and satisfy exploration addresses which were featured before in chapter 1.

2.2 Lighting at offices and Work places

Well illumination balance is important for the foundation of a sheltered and profitable workplace; optimizing light in the modern work environment requires various contemplation including sort of equipment, consideration of environment, objectives, and kind of work, and so forth. Mostly, factors that influence the adequacy of illumination are amount and nature of light, measure of glimmer, measure of glare, difference and shadows. Each factor must be balanced contrastingly to enhance light in crisis, tasks, and security conditions. Mechanical Lighting Standards serve to address these worries, notwithstanding the plenty of different concerns related with the outline, position, establishment, and energy necessities of illumination in modern work environments. (Webstore.ansi.org, 2018)

"Proper illumination" is important for the optimization of security, solace and efficiency in the working environment; work environment lighting additionally manages nature of recognition, disposition, and execution levels of representatives. Rules for lighting apparatuses are illustrated for various modern situations, and in addition an assortment of quite certain settings including producing plants, energy plants, and that's only the tip of the iceberg. Safe practices with respect to accessibility of crisis lighting, particularly the task and execution testing of clearing lighting frameworks are additionally given.

The lighting quality in the environment of work can affect significantly the profitability. With agreeable lighting workers can make more things with less errors, which may lead to an expansion in efficiency by 10-50 %. Major lighting can reduce errors by 30-60 % , furthermore, lessen eye-strain, headaches, ailment, and torment of neck which much of the time run with eye weakness. Adequate lighting empowers workers to concentrate better on their work that expands profitability. The lighting level that workers require shifts depending upon the possibility of the task, the sharpness of the authorities' visual recognition. For example, separated work, for instance, examination, a gathering of little parts or concentrated representation, needs a great deal of light. On the other hand, Coarse work, for instance, stacking or purging materials, materials treatment or packaging, needs less light. The advantages of having great lighting in the work environment are:

1. Reduced peril of medical issues and word related mishaps..
2. Exactness and focus in work in a better way .
3. More dynamic, mind blowing, cleaner workplace achieving a more unique, joyful condition.
4. Improving the excusion of the work .
5. better detectable quality, enhanced accuracy and extended the speed of work as well as enhancing creation.

It is difficult to enhance lighting without expanding the quantity of lights, light apparatuses or the bill of electricity. Enhanced lighting can be accomplished by utilizing more sunlight, by changing the situation of light sources or workstation formats and by successfully utilizing reflected light. \there are a guidelines that must be in consideration when intending to enhance the lighting conditions in the work environment: 1. decide the issue:

I. converse with laborers and see whether they experience the ill effects of cerebral pains, neck agony, or sickness, which may all be caused by eye-strain. Inquire as to whether they experience issues seeing their work. It is fundamental to execute security exercises with the specialists' full participation as they may have exceptionally positive thoughts for enhancing wellbeing and profitability. The laborer doing the activity can best assess the effect of a change; ii. See with own eyes if there are any undeniable lighting issues. In the event that specialists have their eyes unnaturally near the question they are chipping away at, it is likely there is an issue, or if laborers feel there is a need to endeavor additional

endeavors to make out subtle elements when it is shady, stormy or at specific occasions of the day :

1. Consider elective arrangements which are best adjusted to the organization's abilities. Contemplate these before executing a change;

2. Get guidance and watch a comparable change under comparable conditions in another venture or working environment.

3. Make little however ceaseless changes by experimenting with the thought first on a little scale to perceive how it functions; 4. Consider speedy usage of thoughts that can be incorporated instantly to show positive change. (Webstore.ansi.org, 2018)

(Shikdar and Sawaqed, 2003) pointed in their study that workers' productivity improving, safety and health of occupants are essential worries and concerns of industry, particularly in developed countries. Be that as it may, these industries are included with inappropriate working environment outline, not well sorted out occupations, confound between workers' abilities and business demands, antagonistic condition, poor human-machine framework plan and ill-advised organization programs.

Such conditions could prompt work environment risks, poor specialist well-being, inabilities, and influence the profitability of laborers and nature of items. Work wounds make critical financial and compassionate outcomes to the society. Furthermore, the injuries during the work have been related with mental distress, diminished cooperation in every day living activities and a negative consequences for the well-being of the family as stated by (Kirsh and McKee, 2003).

(Olesen, 1995) mentioned in his research that the factors which has an important impacts on performance and comfort ability of the occupants are : air quality , noise , light and thermal environment . As (Dua ,1994) stated , the lower passionate health is showed as mental pain, misery and tension, while bring down physical well being is showed as coronary illness, a sleeping disorder, headaches, and diseases. These health problems as stated by (Tarcan et al., 2004) could prompt organizational effects, such as work disappointment, non-appearance, added to the poor quality of work . Bothered, sore eyes and throat, dryness, stuffy congested nose, over the top mental weariness, cerebral pain and irregular tiredness were all indications of the negative environmental situations in

workplace . (Ettner and Grzywacz ,2001) in their Previous research, demonstrated that the workplaces were related with seen impacts of work on well-being. This examination utilized a national example of 2,048 laborers who were solicited to evaluate the effect from their individual occupations work on their physical and emotional wellness. Regression investigations demonstrated that the responses of workers were essentially associated with well-being results.

Additional to that , it was pointed out by (Shikdar and Sawaqed ,2003) that there was high connection between indicators of performance and well being, offices, and natural characteristics. As it were, organizations with higher well being, offices, and ecological issues could confront more execution related issues, for example, low profitability, and high truancy. Representatives with protests of inconvenience and disappointment at work could have their efficiency influenced, aftereffect of their failure to fulfill their work appropriately . (Leaman, 1995).

As indicated by the (Fisk and Rosenfeld ,1997), profitability and productivity were a standout amongst the most essential factors influencing the general execution to any association, from little undertakings to whole countries. Expanded consideration had concentrated on the connection between the workplace and efficiency since the 1990s. Field studies and laboratory demonstrated that the physical and concoction factors in the workplace could notably affect the wellbeing and execution of the tenants, and thus on the profitability. Environmental conditions of Work environment, for example, lighting, indoor quality of air, and acoustics have critical associations with workers' fulfillment and execution (Tarcan, et al., 2004; Marshall et al., 2002; Fisk, 2000). Indoor quality of air could directly affect medical issues and prompts uncomfortable work environment conditions

In a the industry of Metal, (Van Bommel et al.,2002) led an examination of expanding the illuminance in the metal business dependent impact on expanded undertaking execution, decrease of rejects and the diminished number of mishaps. The aftereffect of the examination uncovered that the illuminance expanding from the base required 300 lux (least) to 500 lx , could prompt an expansion of efficiency in the range from 3% - 11%

dependent on the practical suspicions that the illuminance increment from 300 lxx to 2000 lx would build the profitability from 15% - 20%.

On account of the quick association between visual undertaking characteristics and illuminance on the assignment, standard lighting of indoor design practices base on the illuminance arrival at working planes (Cuttle, 2010) . Starting late, the essentialness of work plane illuminance consistent to increment. This is in light of the fact that work plane illuminance, or vertical illuminance at eye stature all things considered, is particularly profitable while evaluating basic parts of lighting limits, for instance, light indication, visual correspondence, and non-visual circadian effect (Dai et al., 2017). For example, round and empty illuminance (mean estimation of vertical illuminance on a barrel) is started to be recommended in codes and models: according to the present arrival of EN 12464-1 (Krigsvoll, Fumo and Morbiducci, 2010) , the mean cylinder molded illuminance should be not less than 150 lx for spots where visual correspondence is basic (e.g., working environments, meeting and classrooms). Moreover, the non-picture forming disclosure characteristically retinal ganglion photosensitive cells (Berson and Dunn, 2002) ,and the ceaseless research on non-visual effect of light reveal that a significantly bigger measure of work plane illuminance might charm in structures where people stay for a long time in the midst of the day. It is by and by particularly recognized that light accept a central employment in keeping up a sound circadian musicality, and the proportion of light got at eyes is one of the key segments. Sufficient "light part" in the midst of the day together with low light overhaul in the midst of the night can propel synchronization of human body's "regular clock" with the area time on Earth , while lacking day-time light introduction or graceless light around night time (LAN) could cause circadian interference ,which, if continues for a long time, could provoke a wide collection of infirmities, for instance, rest issue, diabetes, chest danger, and cardiovascular ailment. Disregarding the way that the right proportion of work plane illuminance required is still under dialog, one thing clear is that at present, "the step by step light part gotten by people in western (industrialized) countries might be too low" (according to the CIE).

(Granzier, Brenner, Smeets, 2009) stated that people are great at deciding the commitment of reflectance of surface to the light that reaches eyes. The legitimate connections fundamental this capacity clearly don't convene for surfaces which radiate light, for which

the light achieving the eye can be very autonomous of the enlightenment. One motivation to believe that there might be, is that a few coordinated subjects fixes at a PC screen diversely when taught to make them appear to be indistinguishable in tint and immersion than when trained to make them look as though they were painted surfaces in a similar shading (Cornelissen and Brenner, 1995). In those investigations, subjects were told to treat the patches in various ways. The inconvenience of unequivocally teaching subjects to coordinate the shading contrastingly is that subjects are urged considering the setting in a way that they presumably ordinarily would not, like when requesting that individuals arbitrate the separation to a question in an image, instead of the separation to the image itself. Additionally soliciting subjects to pass judgment on the reflectance from reenacted surfaces might be especially confounding on the grounds that even the improvement itself is vague (Hurlbert, 1999). A few color vision researchers have along these lines composed cunning frameworks for showing surfaces of whatever shading they need inside an apparently indigenous habitat, either by independently lighting up one question (De Almeida 2004) or by inserting a screen inside a scene in such a way, to the point that it is difficult to see that it's anything but a genuine surface (Hansen and Gegenfurtner, 2007; de Almeida, Fiadeiro, 2005).

Such precautionary measures are taken to guarantee that subjects regard the basic surfaces as genuine surfaces. In any case, do subjects truly treat reflected or transmitted light diversely when safety measures are not considered? Do they change from assessing a surface's reflectance to assessing the structure of the light reflected to the eye when it is clear that the surface isn't genuine? We as of late found that subjects improve shading matches when genuine surfaces must be coordinated in shading and luminance by choosing the fitting example from a color selector , than when they must be coordinated with a surface on a PC screen (Granzier and Brenner, 2006).

Possible clarification for this is surface which been simulated on the PC screen was dealt with on a very basic level uniquely in contrast to the genuine surfaces. Be that as it may, as made reference to over, the picture on the screen is vague when deciphered as a reflecting surface, so the poorer execution may basically be a result of this vulnerability. If a basic refinement is made between light released by a screen and light reflected by a surface, and subjects can condemn both unreservedly, subjects should be better at planning

the shades of two pictures on PC screens and at organizing the shades of two bona fide surfaces, than at organizing a certified surface's shading with that of an image on a PC screen. Whenever radiated and reflected lights are treated in a similar way, there need not be a central distinction among genuine and recreated surfaces. In any case, if this handling is something other than estimating the light achieving the eye, attempting to separate among reflectance and brightening is probably going to present extra variability for any match that incorporates pictures on a PC screen, especially when the surfaces that are to be composed are under different edification. He tested every one of the four possible mixes of the behavior by which reference and planning tones can be presented.

Conversely with the previously mentioned examinations in which care was taken to keep subjects from understanding that a few surfaces discharged light (Hansen et al., 2007; Nascimento et al., 2005) they did their best to guarantee that it was in every case totally certain whether a surface reflected or radiated light. Interestingly with their very own past examination (Granzier et al., 2006) it was utilized a similar enlightenment for all surfaces. The light achieving the eye from the reference when it was displayed on a PC screen was likewise the equivalent as the light reflected from the reference when it was a bit of paper. This implies coordinating the light achieving the eye would likewise coordinate surface reflectance if this were completed in a similar way for the two sorts of reference, along these lines they can hope to discover settings inside a similar district of shading space for all examinations except if individuals coordinate reflected and transmitted light generally in an unexpected way.

2.3 Lighting Problems in offices and work place

Terrible lighting can be a wellbeing and wellbeing danger in the work environment. On the off chance that you are dealing with a business, you should know about the best possible security strategies for lighting. There are various types of terrible lighting including glare, gleam, insufficient light, an excessive amount of light, differentiate issues and poor light situation. (Vogel, 2018)

1-Low Productivity

Terrible lighting won't just negatively affect workers however on your business too. Terrible lighting will make laborers feel drowsy and tired, which will make a wide range of issues in the workplace. The measure of work, the nature of work and the exactness of work will all decrease when the lighting is awful. On the off chance that you give better lighting to your representatives, they will likewise thus compensate you through the efficiency, precision and high caliber of their work. (Clements-Croome, 2013)

2-Eye Strain

Bad lighting causes steady eye strain, which can cause different issues. In the event that your representatives are reliably stressing their eyes because of the poor lighting, they will be awkward and experience the ill effects of consuming, aggravated, tearing, red or dry eyes. Eye strain will likewise cause superfluous exhaustion and stress. Legitimate vision will likewise experience the ill effects of eye strain. Workers with eye strain because of poor lighting may encounter affectability to differentiate, decreased vision sharpness, absence of vision center, terrible profundity recognition, and twofold vision.

3-Bad Posture

Terrible stance and clumsy body positions can be an impact of awful lighting. This can cause other medical issues, for example, back agony, neck torment and carpal passage disorder. (Vogel, 2018)

4-Frequent Accidents

Without lighting properly, it is difficult to see the profundity, closeness, shape, speed and nearness of articles and people around you. Mishaps can wind up successive issues due to poor lighting. Workers could turn out to be truly harmed because of poor lighting. As a chief or proprietor of a business, it is your duty to guarantee wellbeing to your workers, and lighting is a factor that should be considered. (Clements-Croome, 2013)

2.4 Illumination Standards for offices

Normal and Recommended Levels of Light Indoors is 300-600 lux, and the outside light level is roughly 10,000 lux on a sunny morning. In the working, in the region nearest to windows, the light level might be lessened to around 1,000 lux. In the center territory its might be as low as 25 - 50 lux. Extra lighting hardware is frequently important to remunerate the low levels. (Webstore.ansi.org, 2018)

Prior it was regular with levels of light within 100 - 300 lux range for typical exercises. Today the level light is more typical in the range 500 - 1000 lux - relying upon action. For accuracy and definite works, the light level may even process 1500 - 2000 lux. Table 2.1 beneath is a guide for prescribed level of light in various workspaces:

Table 2.1: Standard Light Levels depends on activity
(Source: Recommended Light Levels for Indoor Venues, 2018)

Activity	**Illumination** *(lux, lumen/m²)*
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Generally, the factors that influence the illumination of effectiveness are amount and nature of light, measure of glimmer, measure of glare, differentiation and shadows. Each factor must be balanced contrastingly to improve light in crisis, wellbeing, tasks, and security conditions, as examples. Lighting Standards likewise serve to address the plenty of different concerns related with the plan, arrangement, establishment, and least requirements of the energy and effective distribution of enlightenment in various areas with various purposes, and also the effectiveness, toughness, cost, and viability.

Additional Recommended Indoors Light Levels

Table 2.2 : Recommended Indoors Light Levels
(Source: Recommended Light Levels for Indoor Venues, 2018)

Office Space	
Normal work station space, open or closed offices[1]	500
ADP Areas	500
Conference Rooms	300
Training Rooms	500
Internal Corridors	200
Auditoria	150-200
Public Areas	
Entrance Lobbies, Atria	200
Elevator Lobbies, Public Corridors	200
Ped. Tunnels and Bridges	200
Stairwells	200
Support Spaces	
Toilets	200
Staff Locker Rooms	200
Storage Rooms, Janitors' Closets	200
Electrical Rooms, Generator Rooms	200
Mechanical Rooms	200
Communications Rooms	200
Maintenance Shops	200
Loading Docks	200
Trash Rooms	200
Specialty Areas	
Dining Areas	150-200
Kitchens	500
Outleased Space	500
Physical Fitness Space	500
Child Care Centers	500
Structured Parking, General Space	50

2.5 Surface Reflectance

Colors and materials of an interior surface can reflect or absorb the light. This property of surface is named as 'Surface Reflectance'. Because of this property of surface shading; it either can minimize or maximize the circulation of light from the source of light. So at the end of the day, they can affect the effectiveness of the luminaries, conveyance and successively the lighting proficiency of the space.. Accordingly, one would take a gander at interior surfaces colors and materials plan as a brought together entire, thinking as far as space planning and design, artificial lighting and effectiveness as well.

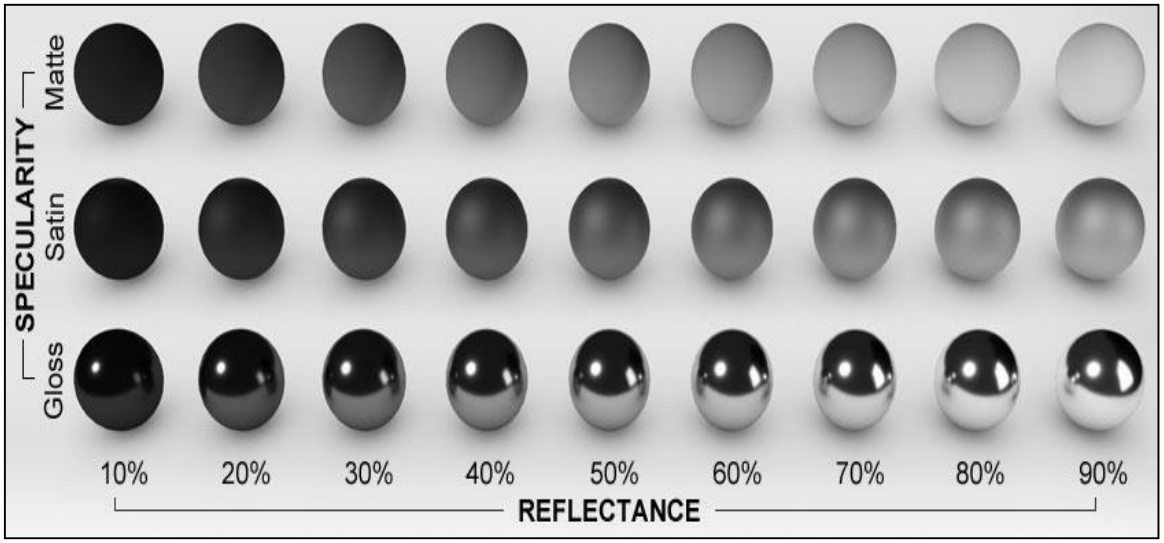


Figure 2.1: Reflectance for Materials
(Source: Performativedesign.com, 2018)

It is important to understand that the reflections just happen when light or radiation hits the limit between two media in which light goes at various rates, as estimated by their refractive list. In the event that two media have the equivalent refractive record, light and radiation will be unaffected by the limit between the two so there will be no reflection or refraction. In the event that they are unique, the measure of reflection is administered by the properties of the two materials, so the reflectance of a material neighboring air will be altogether different to the reflectance of that equivalent material . (Performativedesign.com, 2018)

Along these lines, except if generally indicated, when alluding to building materials and in actuality most physical materials, some random reflectance values certainly accept the limit between that material and air.

Reflection Direction

At the point when the people think about reflection, mostly they consider just specular reflection. Nevertheless, the reflectance property is not worried in any capacity with the heading of the reflected energy, just the generally total amount. This is on account of the precise conveyance of reflected light or radiation is a component of surface treatment. A similar material with a specific shading could be made relatively matte with an unpleasant complete or specular with a finish which is highly polished, but the general reflectance of the two surfaces would even now be the equivalent.

It is important to understand that matte white materials can frequently have in general a higher reflectance than sparkling or glossy materials, including a run of the mirror of glass.

Visual Estimation

Another imperative note is that it is in reality extremely troublesome for us to decide or even think about the levels of reflectance and specularity of various materials and hues just by taking a look at them.

For instance, polished cars in black color dependably look the shiniest as you can plainly observe the impression of lights and different protests off their surfaces. In any case, a comparatively cleaned white auto will commonly have a higher specular part, it is only that the diffuse segment is such a great amount of more noteworthy too that it covers the brightness of the specularly reflected pictures. In this manner, it doesn't look as sparkly as the car in black color except if saw from near touching rate.

At near effictive frequency (where the view edge is near 90° to the surface typical), diffuse reflections are altogether less because of Lambert's cosine law, so the specular segment from the white auto turns out to be less conceal and subsequently more plainly characterized. (Clements-Croome, 2013)

2.5.1 Samples of some finishing materials reflectance values

Table 1.3 below is showing some values for finishing suface materilas reflectances

Table 2.3: Samples of some finishing materials reflectance values
(Source : Leaderflushshapland.co.uk, 2015)

	Material	Surface type	Surface texture	Reflectance	Reflectance value
	Timber floor	Timber	Glossy	Relfective	0.42
	Painted brick wall	White paint	Matte	Reflective	0.7
	Exposed clay tiles	Clay tiles	Matte	Reflective	0.57
	Timber decking ceiling	Timber	Glossy	Reflective	0.42
	Velvet curtains	Fabric	Matte	Non-reflective	0.3

Table 2.4: Samples of some finishing materials reflectance values
(Source: Leaderflushshapland.co.uk, 2015)

Material	Reflection Factor *(%)*
Aluminum, pure, highly polished	80 - 87
Aluminum, anodised, matt	80 - 85
Aluminum, polished	65 - 75
Aluminum, matt	55 - 75
Aluminum coatings, matt	55 - 56
Chrome, polished	60 - 70
Vitreous Enamel, white	65 - 75
Lacquer, pure white	80 - 85
Copper, highly polished	70 - 75
Nickel, highly polished	50 - 60
Paper, white	70 - 80
Silvered mirror, behind glass	80 - 88
Silver, highly polished	90 - 92
Oak, light polished	25 - 35
Granite	20 - 25
Limestone	35 - 55
Marble, polished	30 - 70
Plaster, light	40 - 45
Plaster, dark	15 - 25
Sandstone	20 - 40
Plywood, rough	25 - 40
Concrete, rough	20 - 30
Brick, red	10 - 15
Paint, white	75 - 85
Paint, medium grey	25 - 35
Paint, dark blue	15 - 20
Paint, light green	45 - 55
Paint, dark green	15 - 20
Paint, light yellow	60 - 70
Paint, brown	20 - 30
Paint, dark red	15 - 20

2.5.2 Spectraflect Reflectance Coating

Spectraflect is a uniquely planned barium sulfate covering which delivers flawless diffuse of reflectance surface. Spectraflect is for the most part utilized as a reflectance covering in the UV-VIS-NIR area and is best over the wavelength run from 300 to 2400 nm. The range can be extended to 185 nm before cover absorbtion tops start to show up. The reflectance of Spectraflect, similarly as with all reflectance coatings, is reliant on the thickness of the covering. At thicknesses above 0.4 mm (0.016 inches), the covering is dark with reflectance of >98% over the wavelength go from 400 to 1100 nm. Spectraflect is thermally steady to roughly 160° C. Over that temperature, it gradually diminishes in reflectance, particularly in the 250 to 450 nm go. The covering outgasses gradually in high vacuum because of remaining water captured in the fastener. Spectraflect has been tried for laser harm edge utilizing a Q-exchanged YAG laser at 532 nm, the harm edge is 1.7 J/cm2. Spectraflect is a reasonable, safe, non-poisonous, high reflectance covering that is valuable over a genuinely wide range of wavelength . The material is exceedingly lambertian in character. Spectraflect is restricted by the way that the cover is water solvent, in this way the covering isn't usable in high mugginess applications. For applications where this thought must be considered, Labsphere Duraflect coatings are prescribed. Spectraflect is connected by splashing the covering onto an uncommonly arranged surface. Surface arrangement for the most part comprises of degreasing pursued by sandblasting to roughen the surface. Spectraflect covering can be connected to essentially any substrate, and is a perfect reflectance covering for things, for example, optical parts,light lodgings and otherworldly diffuser boards. (Diffuse Reflectance Coating, 2017)

2.6. The Relationship between Illuminance and surface reflectance

To address and clarify the relationship between surface reflectance and illuminance , a concentrated study was taken through literature review those which are searching in same field of this research .

As Sheedy state his last investigation, the wall was consistently light by projection using. In an examination performed by him ,rooms with a non-uniform luminance circulation seemed more brilliant for the subjects than the uniform variations. The non-uniform rooms required less illuminance to the work plane to accomplish a quality comparable impression

to the rooms with a uniform apportionment of luminance. Sullivan and Donn declared in their composition review that the a lot of studies suggest that more uniform lighting appears to be more magnificent than less uniform lighting . In the pilot consider presented in a comparative paper, Sullivan and Donn show that less uniform spaces were evaluated to appear to be more splendid , like the outcomes which is expressed in Tiller and Veitch look into. The difference in the writing about the bearing of this impact raises the likelihood that the relationship among spatial brightness and uniformity might be more convoluted than this.

(Moore, D. Carter, A. Slater,2004) expressed two highlights involve with preferred visually environments, which are the brightness and variation in luminance . In an earlier study by(Newsham et al,2014) There is a breaking point showed up in a preceding concentrate that people require spaces that are uniform, anyway not repetitive. Veitch and Newsham express that a refinement may exist between the favored splendid conditions and the interesting nature of a space, which increases with a more broad variety of luminance. Most examinations do prescribe dividers to be particularly essential to impact the obvious quality. This may at any rate similarly be a result of their transcendence in the watched visual field, or their lead work in performed thinks about. Sullivan and Donn report that it is 'possible' that the dividers are of particular noteworthiness to the wonder impression of a space, yet that composing does not give sufficient verification to help such cases . In an open office, dividers were encasing the working environment are shared by the customers of the working environment as a noteworthy part of their visual field. In perspective of past examinations, the dividers are acknowledged to affect the quality impression of the working environment space, and with that influencing the favored endeavor illuminance of customers, as imparted by near and dear control. (Chraibi et al., 2017)

In view of past examinations, the authors trust that while giving office worker lighting control for tasks, users do not just choose a favored undertaking illuminance to meet identities necessities for their visual task, They other than find in the individual control a way to set a favored outwardly lighting condition. This joins the lighting for the assignment, yet moreover the circulation of luminance allotment. In this manner, it is speculated that the divider luminance in the visual field of the customer will affect the customer's favored endeavor lighting. The dividers which have high luminance levels are

acknowledged to provoke bring down favored illuminances of the errand, due to a higher perception of brilliance. Large amounts of the divider luminance are accepted to diminish the qualification in favored illuminance of assignment between the inhabitants. By depending on the utilized luminaires, Walls can be lit up with an other consistency level. As showed up in his study,a non-uniform divider luminance scattering is depended upon to assemble the wonder perception stood out from a more uniform illuminated divider. Due to this higher quality impression, a non-uniform divider luminance scattering is acknowledged to incite bring down favored task illuminances. Non-uniform dispersal luminance of divider is acknowledged to in like manner reduce the refinement in favored illuminance of undertaking between the tenants.

Situa tions that prompt preferred lower undertaking illuminances make saving of energy chances. Reducing the distinction in favored undertaking illuminance between inhabitants will diminish the danger of contention between individuals because of lighting.

(Chraibi et al., 2017) recommends an impact of the luminance from surfaces which are non-horizontal in the visual field on the visual and mental evaluations of the space of office. Those evaluations are accepted to specifically identify with our communicated favored undertaking illuminances. His paper addressed an assessment in a mock-up office, wherein conditions of the wall with a non-uniform and a more uniform light appropriation of three walls normal levels of luminance have been assessed in regards to their impact on clients' desired illuminance for the task. Each condition is assessed beginning from three distinctive starting work area illuminances. For all test conditions, a divider with a non-consistently dispersed normal luminance of 200 cd/m2 prompts altogether bring down chosen work area illuminances than a consistently lit wall with a similar normal level of luminance. Moreover, favored undertaking illuminances set were fundamentally lower when displayed the most reduced beginning level for 300 lx of dimming. The range of illuminance-preferred levels between subjects was, likewise, observed as being smaller for diminishing with the beginning level of 300 lx at work area level. His examination recommends that while furnishing clients with the individual control they will control the aggregate apparent splendor in the visual field, despite the fact that they are just straightforwardly influencing their errand illuminance level. Setting off the determination of lower favored illuminance levels because of an individual control level beginning of 300

lx will influence the used lighting energy efficiency. A little scope of favored levels of illuminance between subjects toward the start of 300 lx could reduce the risk of the lighting tendency related conflict between people. In any case, more research is relied upon to confirm that these more diminutive complexities are similarly perceivable by the clients. Besides, the impacts of lighting are not constrained to examination and air discernment, as studies have shown that distinctive lighting conditions can likewise trigger changes in temperament and passionate state , which, contingent upon setting, may prompt changes in conduct. (Küller, Ballal, , Laike, , Mikellides, , Tonello, 2006)

In contraindication , (Baron, Rea and Daniels,1992) study found that environments of dimly light could build positive judgments of the others. the outcome was proposed to start from an expansion in positive influence actuated by the environment.

Also, Steidle and partners showed how participation and inventiveness turned out to be more probable in diminishing conditions, due to the grounded and encapsulated comprehension . As these precedents demonstrate, numerous mental components (mindfulness, influence, intellectual affiliations) may rise because of the equivalent visual improvement (e.g., faintly lit conditions) contingent upon the unique situation. Additionally, they may even bring about restricting impacts. By these more conventional examinations, the mental impacts of light have likewise gotten consideration in the more particular case of office work.

The broadest research in this field is crafted by the researcher Veitch, who exhibited that lighting may impact office representatives' work commitment by means of lighting examination, which may affect workers' effectiveness. As lighting examination can be affected in a few distinctive ways within the design of the lighting, this still leaves open very a few avenues. For instance, the level of complexity and additionally consistency can adjust the visual intriguing quality of a space .

Numerous examinations have shown that assessment can be immovably upgraded by extending the clear brilliance of a space, for example by affecting the illuminance of various surfaces , or by changing the temperature of the shade of the light . Splendor, it shows up, is a typical subject while looking at the assessment of spaces. As quality is

basically directed by what we find in our field of view, one of the critical supporters of the clear brightness of a room is the illumination of the dividers and ceiling .

Albeit seen by lighting planners and lighting industry, the illumination of roof and dividers was not considered at all in European lighting benchmarks going before the introduction of the 2011 type of the European indoor workplace lighting standard (EN12464– 1:2002; EN12464– 1:2011), the single spotlight being on the level of the work plane .

However, in practice, level illuminance and ceiling and walls luminance are regularly interlinked as both are intensely affected by a similar general lighting arrangement and installation (light proposed to light the undertaking surface additionally achieves the dividers and roof). In that capacity, splendor in spaces normally relies upon the accomplished level illuminance as opposed to being the consequence of a cognizant structure decision. This does, be that as it may, prompt basic ramifications for concentrates in the field of the impacts of lighting on people. Because of these interdependencies, the danger of frustrating the impacts of for instance changing the level illuminance with the impacts caused by the concurrent increment in the brightness of the general condition is very high.

2.7 Types of lights used in Offices

In many workplaces, it is seen that the lighting isn't legitimately done. With the assistance of our eyes, we can do any measure of work but at the same time some measure of general lighting is required or else there will be a strain on the eyes and it will be hard to work. There is a wide range of paperwork, or, in other words workplaces, and for that propose you require reflected lights, which function admirably. Aside from this, there are PCs, which give their own lights because of which both the lights are blended and the vision ends up troublesome. One can significantly experience the ill effects of low vision and needs to wear exhibitions for it. (Karlen and Benya, 2012)

1-Ambient light

It is the general type of lighting, it works well when it installed on the ceiling or fluorescent tubes are utilized. Interestingly, this light ought not to be utilized in a direct way, as it can

influence the eyes and additionally your work. The light ought not to bounce nor should it have low luminance that produces dark impact.

2-Task Lighting

This light is for the individual purpose as it is the best type to be used for workstations. Both the surrounding and in addition the task lighting are vital in any office thus there ought to be a correct mix of the two. The low power encompassing light can be joined with the required task light for better impact. The task lighting is not available in each office but appropriate lighting for task ought to be there for the workers to work without strain or stress on their mind.

3-Accent and Directional lighting

This type of lighting is used for featuring and highlighting the elements and objects. This light ought not to be blended with the task lighting as the elements of both the lights are totally different.

4-Natural light

Light originating from the sun is the normal wellspring of light and it can originate from windows, walls sides, entryway and so on. This type of light is critical in an office as it lights up the room yet for the general population who take a shot at PCs can discover it an issue. It is on account of the characteristic light can converge with the light of the PC and deliver a glare.

Other Light Considerations

-Brightness/Contrast:

The light of the room and the light of the specific region ought to never be unique. In spite of the fact that a little contrast is conceivable but it ought not to give off an impression of being extraordinary. The measure of light which is falling on person's workstation should never be more in general lighting case, as it can make a bad impact.

At the point when the radius is around 25 degrees, then the proportion of the brightness should be 3:1 and when the range increments from 25 degrees it tends to be 10:1. Aside from this, it is imperative to comprehend the measure of light which is required by the

individual while taking a shot at the PC. On the off chance that the earth is dull then the high proportion will expand the measure of light around there and afterward it will be easy to work. Be that as it may, when the light is diminishing there will be an expansive distinction in cover and it will influence your vision as well. Thus it is basic that you guarantee whether the features of the proper lighting are installed within the office area or not.

- Glare

Glare can be caused because of various light sources. It can either happen when a substantial measure of light is falling on your eyes or a light source is kept near you or now and then it might happen that light is reflected through sparkling surfaces. Glare is for the most part experienced by the more seasoned in contrast with youthful age. Exposed lights are not ideal for work environments and along these lines, the correct sort of light ought to be utilized. The position ought to be so that there is no reflection and no glare. The walls colors or the items can reflect the light for the workstation, which can make an issue so it's important to be sure that the chosen color combination is the best. For instance, reflection for dark shading is 1%, for dim blue, it is 8%, light blue is 55% and for dim it is most extreme at 75%.(Karlen and Benya, 2012)

Moreover, going for anti-glare filters is playing the role of controlling the glare. There is a variety of filters that can be used, but the best type of filters which have neutral density, also which have polarized circular light. Filter with neutral density is a radiant alternative as it is reasonable but the picture can be dull. The circular captivated ones are costlier, however, give a superior impact when contrasted with neutral density.

- Color of Light

The lights are available in such huge numbers of one of a kind hues that it winds up hard to choose which is the best one.

colored lights are utilized on the grounds that it includes an alternate inclination. For instance, you can make a cool state of mind and at the equivalent a warm climate. The white shading is for the most part utilized as it gives an extraordinary look to the place. Despite the fact that hued lights are an individual decision henceforth the choice is yours

however the white light is suited to all reasons. The white light is each accessible and is modest when contrasted with other hue lights.

Some Important Areas

- Conference room Lighting :

The conference room is additionally a fundamental place of the office, as the user cuts down the new arrangements and takes critical decisions for the association. In the event that any new task must be begun procedures are surrounded with the end goal that the workers can substantiate themselves. The right lighting feature can add a dynamic quality to the room and make it intentional purposeful.

While choosing a conference room lighting you can either go for the fluorescent lighting for its functionality or even have elegant lights that are installed on the wall. They look appealing and set the disposition. Lights can likewise be added to achieve a homely atmosphere. Lamps give the required measure of light as well as gives a personal feeling within the conference room.

- Lighting for Public spaces

Public spaces are even critical in the workplace and if right feature of lighting is used, the space can be utilized for different works. The lighting can make a domain which users need, as it will assist users with highlighting a particular part of the room while with pendants , the users can expand the interest of the space. (Leaderflushshapland.co.uk, 2015)

-Light Fixtures

-Recessed Lighting

This type of lighting is utilized for general purposes and. It makes an ideal environment and gives enough brilliance to space.

- Occupancy Sensor

These lights are programmed, when anyone enters the workplace the lights will turn "on". It will give lamination for the whole day except if the workplace is empty so it will not be

necessary to have an on/off switch. The working is controlled by the sensors whose writing computer programs is done in such a way. For open workplaces those sensors are perfect.

-Track Lights

It is ideal when the user requires more lights and in the meantime a finished appearance.

- Directional Lights and Surface Mounted Spotlights

Those are used for beautiful purposes when track lights can't be utilized. With the assistance of these lights users can enhance any image or backdrop, Foyers, gathering rooms etc., are places where this light will demonstrate the best shading.

-Under Cabinet Lighting

Lights, which are set underneath the cabinets, which give a superior impact to the workstation. In addition, it helps in simple working and evacuates the glare. (Karlen and Benya, 2012)

2.8 Office Lighting Design Criteria

30% of a business building's electrical bill is credited to lighting. Regularly, these structures are fitted with traditional fluorescent luminaires that require energy more than they really need. The employee may diminish the electrical utilization by half by supplanting their old system of lighting with LED innovation. The cutting-edge lighting is required to guarantee employee's health and comfort; moreover, poorly balanced lighting can cause visual fatigue, headaches, and peevishness: issues that can influence worker efficiency. (Karlen and Benya, 2012)

The general office lighting recommended value based on UK codes is 500 lux on average. This is the primary region that can regularly cause troubles – this esteem can be taken as the errand territory (worktop) just or the entire space. The average value is taken as the proportion of least illuminance to average illuminance value, not less than 0.8 over the applicable region.

The issue is additionally befuddled in that two rooms with indistinguishable flat illuminances could appear to be very unique to the eye (the physiological reaction) if the

finishes of the walls are generally different, an example, light or dark hue finishes. The light dissemination qualities of the light installation would likewise be huge.

Previous studies likewise to demonstrate that more old individuals require extensively more light than more younger individuals to perform comparative tasks. For instance, a 50-year-old needs around four times the light of a 20-year-old for a similar undertaking. The eyes' reaction to the energy of light is logarithmic, as opposed to straight, which confounds the issue more. The primary concern, in any case, is that a solitary parameter of 500 lux normal (level) for good general office lighting is "nonsense" – that is the reason we have a guide. . (Karlen and Benya, 2012)

The structure criteria segment proceeds with a short section on shading. This is useful a similar number of laymen are overwhelmed by shading stating, appearance, and rendering. They are not related, but instead free. By taking a gander at the reasonable shade of the source with the shade of splendid metal, it is possible to assign a shading temperature on the Kelvin scale. The lower the temperature of shading, the more smoking the shading. The higher the temperature of shading, the cooler the source appearance. Various tungsten light sources have shading temperatures in the extent of 2,800/3,000K. Daylight fluorescent cylinders and some metal halide lights have a cool appearance of the demand of 5,000/6,000K.

The manner in which that a light has a warm appearance, for instance, the standard fluorescent warm-white light, that is streamlined for most outrageous business light yield, does not mean it is minding to the warm/red tones. The warm-white light has poor rendering properties of shading, and bends reds when seeing surfaces and shading at the red end of the range. In numerous business applications, this shading oddity isn't noteworthy and brilliant. Viability is the prime necessity. Shading severing of the light source identifies with the presence of hues lit up This is useful a similar number of laymen are overwhelmed by shading stating, appearance, and rendering. They are not related, but instead free. By taking a gander at the reasonable shade of the source with the shade of splendid metal, it is possible to assign a shading temperature on the Kelvin scale. The lower the temperature of shading, the more smoking the shading. The higher the temperature of shading, the cooler the source appearance. Various tungsten light sources have shading

temperatures in the extent of 2,800/3,000K. Daylight fluorescent cylinders and some metal halide lights have a cool appearance of the demand of 5,000/6,000K. shading rendering list (CRI) is given to a source, 100 being recognized as faultless, e.g. the sun tungsten lights with a relentless range yield. Ordinary points of reference would be available day triphosphar fluorescent sources CR1, more than 80; business halophosphate fluorescent cylinders CR1, around 60; and standard high weight sodium CR1, in the mid-20s. The elective method is to band the light source into one of the CIE (Commission International of 'Eclairage) social events, 1 to 4. Social affair 1A compares to above CRI 90, where tungsten lights and multi vapor lights are fitting. Social occasion 1B squares with 80/90 CR1, e.g. triphosphar, metal halide and some white SON. Get-together 2 makes back the initial investment with CR1 60/80; total 3 CRI 40/60, e.g. high-weight mercury/sodium; and social occasion 4 CR1 20/40. An examination of light source usually infers that for extending CR1 execution there is a trade off in splendid adequa .

Glare

In the present current office, with huge visual display unit (VDU) utilization, it is foremost that apparatus glare is wiped out in view of reflectances on VDU screens.

Previously, the utilization of recessed ceiling luminaires with base opal dishes, or kaleidoscopic sheet, required our architect to compute and take a view that the establishments restricting glares file were underneath a reasonable and pronounced esteem. The present lighting establishment for workplaces perpetually has VDT use and is required to agree to EEC/HSE necessities, which additionally implies CIBSE No. LG3 Areas for Visual Display Terminals . To consent to the characterized LG3 classifications, predetermines the utilization of the so-called low-brilliance apparatus, which is surface or recessed, illustrative molded reflectors and louver cutting edges, which give glare values well beneath the basic levels

Illuminance Redefined

Consistently, an arrangement of terms have been used to portray and describe the suggested illuminance for errand exercises and regions, as advantage illuminance, typical illuminance and plan illuminance being the most recognized. These proposals were bolstered by plan procedure and estimation systems that are by and by renamed –

particularly related to a period scale. The ordinary illuminance on any foundation will vacillate in time owing to light yield cheapening, earth affirmation on the light, luminaire and room surfaces when the light structure is being utilized. Progressing lighting codes LG7 and Code for Interior Lighting demonstrate a period related illuminance as "cared for illuminance" and "beginning illuminance".

The kept up illuminance is the illuminance over the reference interface at the time bolster must be finished by superseding lights with the true objective to clean the apparatus and room surfaces.

Introductory illuminance is the ordinary illuminance while the new establishment added to the ideal room surfaces. The kept up illuminance is related to each other by the help factor on the "light misfortune factor".

The support of Light lumen is open from light supplies, dependent upon the sort, together with a studied cleaning and substitution organization. It is possible to register the conventional ordinary kept up illuminance regards for different light substitution choices.

Inside this period, ordinary illuminance was rethought as taken care of illuminance (MI), e.g. the ordinary illuminance over the reference surface at the time upkeep must be finished by overriding the light or conceivably cleaning the equipment and room surfaces.

The lighting Interior code has sufficient illustrative notes and timetables regarding the matter but still alludes to the way that CIE and CEN (Technical Committee TC 169) still can't seem to finish strategies. The code consequently foresees this endorsement.

Chapter 3: Research Methodology

3.1 Introduction

"Methodology" term refers to steady approaches to the data and information collection and analysis with thought of methods and techniques used in previous examinations and studies.(University of Manchester, 2017).

The Chosen Methodology by the researcher should be described well in details to let other to re-use it and re-define it as their future study need . (Author,2018)

This chapter identifies the suggested methodology to this research in order to clarify the relation between the surface reflectance and illumination of the work plan area and it's impacts on increasing and decreasing the illumination in the space.

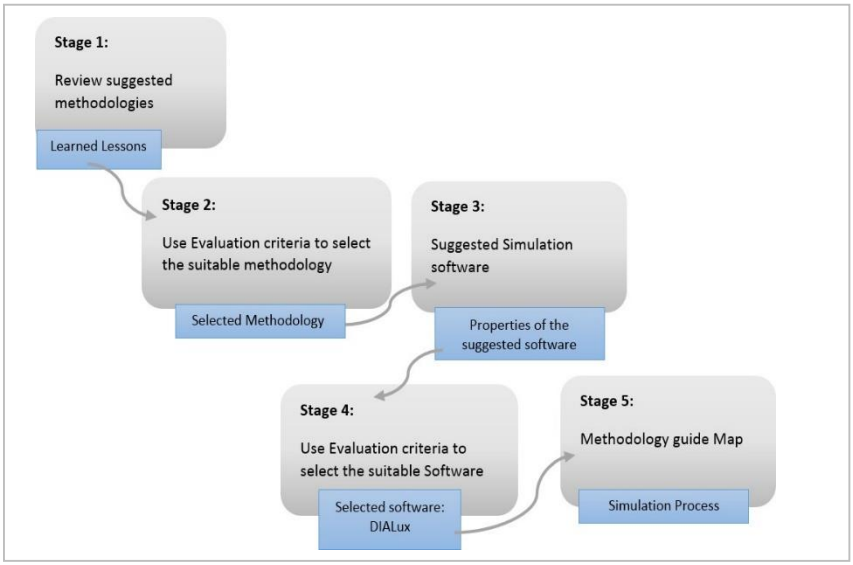


Diagram 3.1: Methodology Map
(Source: Author,2018)

The technique determination process started with checking on the reasonable of contextual investigation, field estimation, and reproduction systems. These strategies incorporate exercises realized, which would bolster the destinations of this examination. To choose the most appropriate philosophy, assessment criteria were built up, then the simulation methodology was chosen.

3.2 Methodologies in Similar Researches topics

The published studies and articles revealed different methodologies that may have been appropriate for this research. Those methodologies were condensed to clarify their highlights, features, and advantages. The experiment method and the computer simulation methodologies were addressed as the most appropriate for the accomplishing the point and destinations of this research.

3.2.1 Experiment method

(de Vries et al., 2018) in his latest study used the experiment methodology. he prepared an office space with 7.2m length ×7.2m width ×3.0m height to simulate office environment, which was arranged and equipped with the standard office components as segments, work areas, seats and capacity cupboards reliant on a symmetrical way. the commitment of sunlight was discarded using murky screens and access to the corridor was obstructed by utilizing a window ornament in light dim shading. As the luminance of the divider was the basic self-governing variable, the dividers were painted in an unprejudiced white paint (reflection coefficient of 90%) and were kept revealed. Four workstations were accumulated in the point of convergence of the space. Solid with an 'open office plan' structure, the individuals were sitting reverse to each other, secluded by a divider with a stature of 40 cm over the work region. A fifth work territory was incorporated at the leader of the work area's gathering to empower the test pioneer. To have the ability to control the divider luminance autonomously from level endeavor illuminance and vertical illuminance on the eye, two separate lighting foundations were used. The general lighting, proposed to achieve a reliably lit even errand illuminance (centers as demonstrated by EN12464-1 normal: 500 lux), was made by six standard 600×600 mm, low glare LED-based office luminaires with a (luminaire) radiant movement of 3400 lumens motion, with an inside on center scattering of 1800×1800 mm. The luminance of the divider was controlled by two lines (one on each side of the space) of five semi-recessed LED spots per line with a center on center isolating of 1200 mm. Each LED spot was outfitted with a wide shaft reflector, had a most extraordinary (luminaire) splendid movement of around 2300 lumen, and was mounted at around 900mm from the divider.

Using the blend of these two frameworks, three particular lighting conditions were changed. The appropriate condition was set before the individuals arrived. In all of the three conditions the illuminance on the work zone was set to roughly 500 lux consistency necessities (as exhibited in EN12464– 1:2011) were checked reliant on lighting propagations using lighting reenactments programming (DIAlux). The divider luminance inside the three conditions was evaluated using an adjusted Techno group LMK 5 Color luminance camera, set at a stature of 1.2m (appeared as sitting tallness in EN12464– 2011), arranged at the individual sitting region of the individuals. The divider luminance was described as the typical divider luminance of the obvious bit of the divider as saw from the part's viewpoint. Next to this, luminance regards were settled for the 40° band as delineated by(Leo , Mansfield, and el.Rowlands 1994) and proposed in CIE 213:2014 traditions for depicting lighting . Besides, starting from a comparable report, the logarithm of the best to the base luminance (LMM) on the divider was incorporated as a marker for visual fascinating quality. Three various divider luminance settings were used in the investigation. The most insignificant condition with a touched base at the midpoint of divider luminance of 12 circle/m2 was set to address a foundation with a low evident splendor while so far consenting to the illuminance necessities for dividers as communicated in the European benchmarks for lighting workplaces (EN12464-1: 2011). To achieve this level, the spots were slaughtered completely. The middle condition (with an ordinary divider luminance of 36 cd/m2) was set to target favored lighting conditions, for instance declared in focuses on favored luminance in office circumstances. The most hoisted divider luminance was set to 72 album/m2 and was made an extensively more impressive, yet still effectively lit up the divider. Unavoidably, the development in divider luminance achieved an unassuming augmentation in vertical illuminance at the eye. Regardless, due to the degree of the space, and the parcel of the lighting foundations, these effects were pretty much nothing. In general, the development in vertical illuminance at the eye was 48 lux while standing out the most raised from the minimum setting. In light of the range (as assessed with an adjusted JETI spectrometer) and the power at the eye, an indication of the non-picture surrounding lift can be resolved. Using the computation apparatus as conveyed by (Lucas et al,2014), the weighted illuminance on the eye would be 128 lux at all setting versus 140 lux in the medium setting and 157 lux in the most shocking setting .

Furthermore, the PC shows expanded the vertical illuminance on the eye in each condition by roughly 15– 20 lux.

Another experiment were addressed with simulating an office space by (Chraibi et al., 2017), an analysis has achieved for theories assessing the. A framework of the lighting was introduced to make distinctive conditions of lighting. During this experiment , the members were invited to encounter those conditions to let them make changes communicating their preferred and desired lighting.

The researcher had led the study in a lab in Netherlands ,that is where a full-scale taunt up the office with an area 7.2 x 2.8 m was fabricated. The member's visual field incorporated different work areas, the roof and a divider, recreating a circumstance in a real office which has an open space. Below figure (fig. 3.1) demonstrates the space which was used for the experiment . Four work areas were furnished with a mouse, a console and a Philips 2400 Brilliance LCD screen, set to an indistinguishable screen luminance with a normal of 100 cd/m2. The member's work area (work area 4) additionally had a UI to choose the coveted undertaking illuminance. The fifth work area was outfitted by having two PCs , and control board for analyst to turn between conditions of the light. Screens before the windows obstructed the daylight with the end goal to exclude the effect of outside light minor departure from the investigations.

Figure 3.1: simulated office space

(Source: Chraibi et al., 2017)

The electric system of lighting comprised of twelve dimmable ceiling recessed Philips Power Balance LED (600 mm, 4000 K) and 10 no's of Philips Compact power LED spots (4000 K). The lighting framework was isolated into five luminaire control gatherings to acquire the coveted light settings amid the examination. Three luminaire bunches lit up the walls; 6 recessed luminaires and 5 spots lit up the 'test divider' before the client, and 5 spots lit up the divider behind the client (gather 3), to maintain a strategic distance from an uneasy dull foundation. Two luminaire bundles lit up the work zones in the working environment space; the 'control gathering' existed of two recessed luminaires controllable by the part, and four recessed luminaires were energized to light substitute work zones at a predictable level in the midst of the test. The 'control gathering' involved two luminaires to reproduce shared control in open office conditions, and consider a decreasing degree from around 300 lx to 700 lx ordinary work region illuminance.

The test was driven in August and September of 2015, on weekdays in the scope of 9 am and 6 pm. Every preliminary session included one part on the double with a total range of 1.5 h. Each test day had four exploratory timetable opening. Individuals were arranged at work zone 4, and started with negligent acclimation to the standard light setting, named at an ordinary level work zone illuminance of 500 lx. Both, the 'test divider' and the divider behind the customer were non-reliably lit, with a first luminance condition of the 'test divider' set according to the part's preliminary progression. In the midst of this adaption time, the investigator cleared up the test strategy and the part filled in an online examination on the PC. The review included measurement questions and a self-assessed preoccupation level. The individuals were asked for amid the test to play out a scrutinizing undertaking given on the PC screen. The examining task contained a page with discretionarily picked "did-you-know" facts. The clear scrutinizing undertaking was avoided significant visual focus on the PC screen, and enable impression of the working environment condition. Each The finally set favored illuminance was logged for each condition. At the complete of the examination, in a talk between the master and the part additional experiences the part expected to share were gotten. (Chraibi et al., 2017)

In this study, it has been demonstrated that for a normal luminance of walls equaled 50 cd/m2 or 100 cd/m2, the consistency of the wall does not influence the chosen undertaking illuminances by clients. A divider with a non-uniform appropriated normal luminance of

200 cd/m2 prompts bring down chosen work area levels than circumstances with a normal divider luminance of 50 cd/m2 or 100 cd/m2. A non-consistently enlightened divider with a high normal luminance of 200 cd/m2 has been found to bring down chosen favored illuminances of clients contrasted with all the more consistently lit up dividers with comparable or bring down normal levels of luminance. Results show that when controls are given, users don't just choose the needed lighting for their errand visually, however, the perceptions consolidating visual field in chosen inclination by them . The examination demonstrated that in the visual field the level of luminance and consistency dispersions of dividers affect the chose favored illuminance assignment of users. Resulted outcomes demonstrate that high most extreme estimations of luminance in the visual field of the wall and with it high seen levels of splendor prompt lower chosen work area levels of illuminance.

3.2.2 Computer simulation

The Methods of computer simulation are at this point a built-up tool in numerous parts of science. The motivation and inspirations for computer simulation of physical frameworks and systems are complex. One of the primary inspirations is that one dispenses with approximations. As a rule, to treat an issue systematically one needs to depend on some sort of estimate; for instance, a mean-field-type guess. With a computer simulation, we can think about frameworks not yet tractable with scientific techniques. The computer simulation approach enables one to think about complex frameworks and gain knowledge into their conduct. In fact, the intricacy can go a long ways past the compass of present expository strategies .

Computer simulation methodology was addressed in the most studies and researches. (Makaremi et al., 2017) has tested a room in full scale which constructed in Italy at Perugia University , which aims to get appropriate validation and understanding in better way of room surface parameter . The room was selected to be a study model for simulating the variety of situations and conditions . Within process of research , in the first stage , the characteristics and geometry of the selected room for test , and inner surfaces reflectance coefficient have been assessed to be used as the room modeling inputed data . Morover, the area of the room was 10.385 square meter , and a height of 2.75 meter , with a

fluorescent light , which has 36 Watts an electric power and of 3350 lm of flux of luminous, that was introduced in the room focal point .

In the wavelength range which is visible of (from 360 nm to 740 nm) the reflectance values of interior surfaces were calculated by the taking the measurements that occurs were performed through the portable spectrophotmeter(Konica Minolta CM-2500.C). The spectrum of reflection was used after that in order the light reflectance value calculating within involvement with (EN 410). Therefore, the light reflectance was utilized in the (DIALux)software, in order to address the optical behavior reflectance of the room elements. The researcher used the DIALux software which plays the role as a prospect tool , that could calculate and simulate in proper way both natural and artificial light, which aims to analyze and address the relevance between the room illuminance level and the surfaces reflectance of interior . Through his consideration, the calculation model variables were main surfaces reflection coefficient for (Ceiling, walls and floor) were considered in the calculation model . in the primary stage , In aim for accuracy of simulation data examining , a procedure validation has been carried out prior to running nemours scenarios. He concentrated on the situations of artificial lighting in this study as mentioned previously, therefore, on the day of getting the measuring, the selected time was after sunset , with taking care of avoiding the entering sunlight into the room , as curtains also was closed in the same time. A grid with size of (50 x 50 cm , with height from the floor :80 cm) was assessed to be a work plane (that follows the European standards). The meters of lux were installed on the grid , then they have recorded the amount of light within room area (in the range of measuring: from 0 to 100 Klux). With a differentiation between simulation results , and the experimental data has been conducted. The percentage of the error of the results was never exceeds the 10% value, which states that the Produced model through DIALux evo accuracy for the purpose of the study was acceptable. By validating the room through 3D model, 64 scenarios accordingly with the reflectance range which is suggested by EN 12464-1 (European Standard) were performed through DIALux software , in order to clarify the relevance between the reflectance of interior surface and the apparent comfort items that have been selected. On the other hand, the simulations were began when selecting the values of the minimum reflectance separately for each surface as (wall=50, ceiling=60 and floor=20) to the highest reflectance values as(wall=80,

ceiling=90 and floor=50). For all scenarios which are 64 , the system of lighting and dimensions of the room were kept in being fixed and coefficient ofthe reflectance was the only varied case to case parameter .

3.3 Selected Methodology of Research

To achieve the objectives and aim of the research, it is a critical portion of valuable study conducting to choose a proper methodology that answers the questions of the research. This will be achieved after well studying and understanding of the methodologies in most related case studies, simulations and key questions asking :

- Which methodology is relating to data and reality?

- Which methodology supports the parameters variables ?

- What are the consideration and limitation that influence research's data flow ?

Therefore, the weaknesses and strengths and of each methodology were been assessed while thinking about the productivity of the information investigation. The contextual investigation strategy, and its utilization in past examinations, was utilized as a benchmark to for guiding the researcher, as it tends to be utilized to explore contemplate subjects to discover and watch answers to speculations.

The researcher can use the software in the computer simulation method to investigate the information and test the factors distinguished separately. This sort of programming is regularly simple to utilize, permits persistent changes, and conveys results rapidly. The outcomes can be converted into exact Figures and Tables because of the quantity of preliminaries and the simplicity of correcting the errors.

Therefore, the following components were viewed as while picking an exploration strategy:

• Dependability: the nature of the information and data can be utilized as a benchmark in further examinations and research.

• Realism: resulted outcomes address and answer the questions of the research

• Time: suitable time is accessible to gather, order, and investigate information utilizing this technique.

• Value: since it opens ways to new research and even techniques based on the establishment of past investigations.
• Validity: the strategy estimates what it should measure, and results do not change when inconsequential factors changed.
• Flexibility: easy data inputting, analyses conducting, roll out improvements and adjustments.

All through the information gathering procedure to permit more thorough testing and in this way limit mistakes and errors in the analysis of the data .

• Accuracy: the fundamental and basic information is exact, and propelled apparatuses, strategies, and programming is accessible to guarantee exactness in the information investigation.

The researcher assessed the proposed procedures by considering these attributes, as this enabled him to pick a technique that upheld the goals of the examination and encouraged findings to answer the questions of the research.

3.4 Selected Software for the Research

Due to selecting the methodology of the research which was the simulation, it was critical to choose reasonable simulation program or software that would enable the analyst to test impacts on and changes in the factors by setting a steady factor and modifying alternate factors. In the meantime, the researcher had to have the ability to test the offices under examination through model testing. The properties assessed to pick a proper software program were :

•The simplicity of Structural and usability: the software is easy to learn how to use it and how to input the necessary data to generate statistics and figures.

• Indoor lighting examination features: It incorporates a module for investigating the lighting levels for indoors and related information.

• Compatibility with another programming: It can peruse and break down information from different projects, for example, Revit and AutoCAD, or the applicable information must come pre-loaded.

• Convenient with international standards: It can incorporate and assess international standards identified with interior space lighting as the American and British standards.
• Cost: It is available for free download.
• Recommended to be used for different building stages: software is recommended to be used in the stage of tendering and contracting as well.
• Accuracy : the software is providing an accurate data and calculations .
• Wide spread use : as the software can calculate the indoor and outdoor lighting .

After studying the characteristics and properties of the simulation software, the DIAlux software was been selected as simulation program which concentrates on lighting measurements of lighting in office spaces to address the lighting levels recognizing especially at work plane to ensure the comfortability and productivity of the workers .

Chapter 4: DIALux Simulation

4.1 Introduction

The researcher in this chapter clarifies the examination procedure and the selected parameters to test the impacts of surface reflectance of interior on the work plane illumination values .

The testing parameters picked were gotten based on the standard reflectance values and the minimum and maximum reflectances for the finishing materials and colors for the surfaces: ceiling, walls and flooring . The simulation procedure was separated into four stages that shaped a structure to manage the examination of appropriate outputs, as appeared in diagram 4.1.

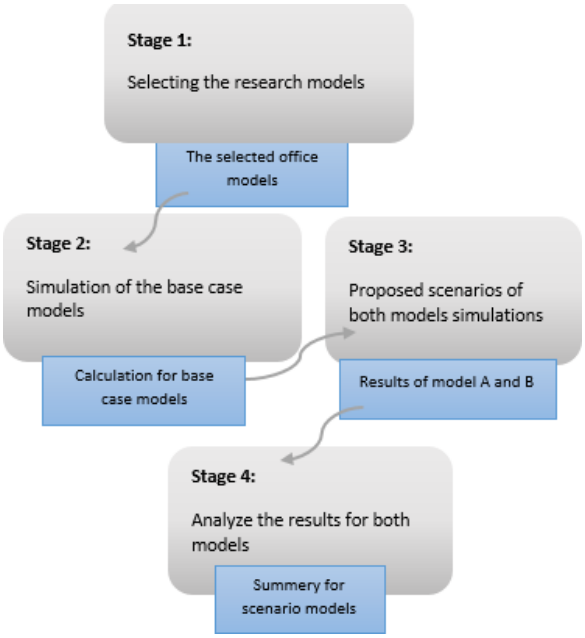


Diagram 4.1: Simulation stages
(Source: Author,2018)

As the Diagram 4.1 above shown, the investigation started with stage 1, which included choosing the case models of offices. In stage 2, the recreation setups were set for the base case models, which would fill in as a standard, concentrating on the percentages of the reflectance value for the selected surfaces. In stage 3 ,the proposed scenario of examining the surface reflectances with selected luminaire data has been done to investigate the results. Lastly in stage 4 , the results are shown with the summery of the scenarios for both tested models.

4.2 Model (A) : Small Office Space

The first model (Model A) was a small office space with a dimensions:

-Width: 3 meters - Length: 5 meters - Height: 2.8 meters - Work plan height: 0.80 m

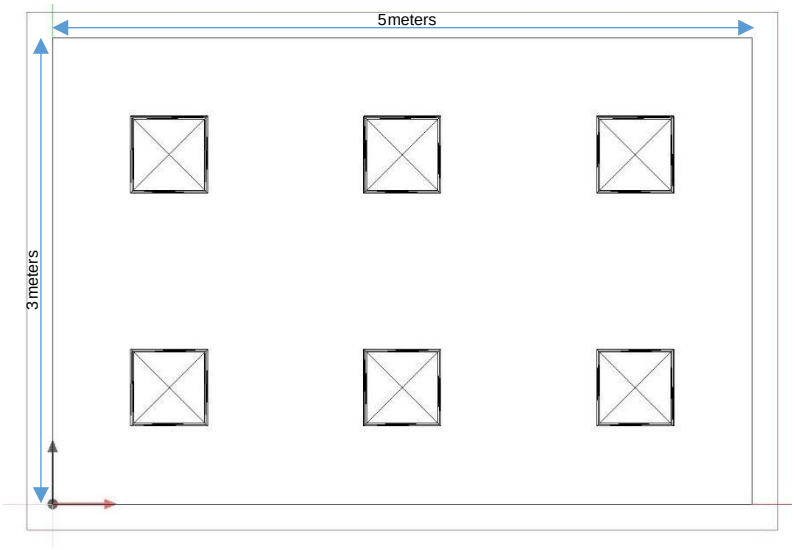


Figure 4.1 : model A, office plan

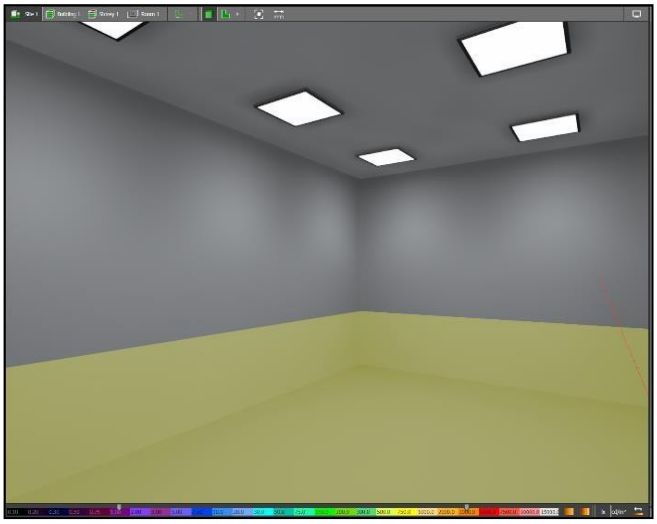


Figure 4.2: Work plan position

(Source: Author through Dialux software, 2018)

4.2.1 Simulation of the Model –Base Case

The base case model was created for model A with the standard reflectance for the surfaces which are :

- Ceiling Reflectance = 70 % - Walls Reflectance = 50 % - Floor Reflectance = 20 %

The figure below is showing the model with base case reflectance values on Dialux software .

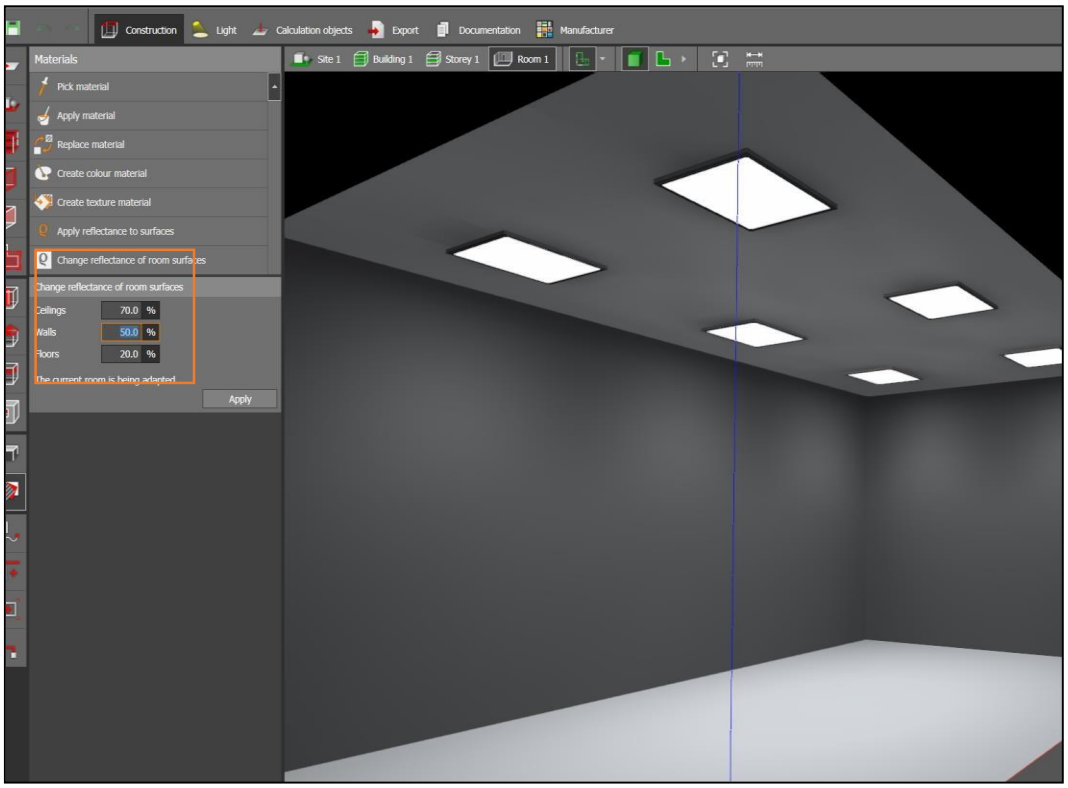


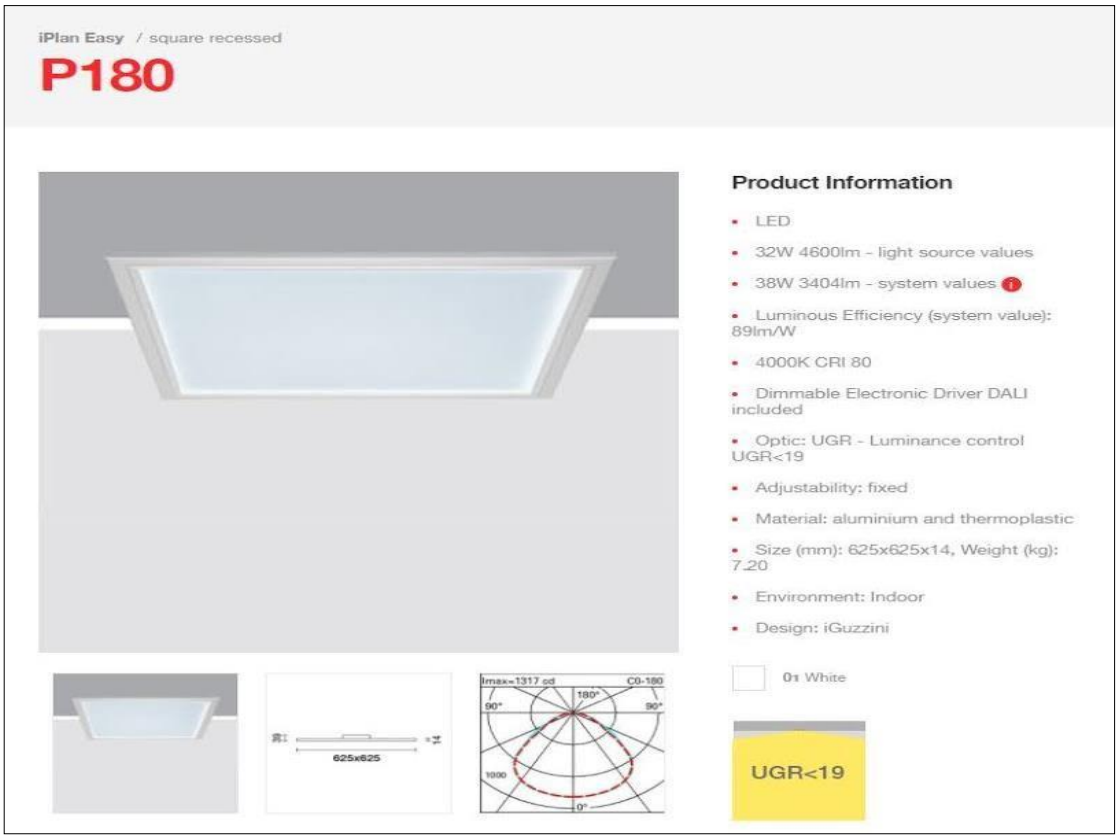
Figure 4.3 : Model A with standard surface reflectance

(Source: Author through Dialux software,2018)

-Selected Luminaire for simulation:

Nowadays, The common type of lighting in offices is 60 x 60 cm LED Lighting.

For this simulation, a type of P 180 was been selected from iGuzzini website, which is a lighting innovation data base to be used by designers and people.



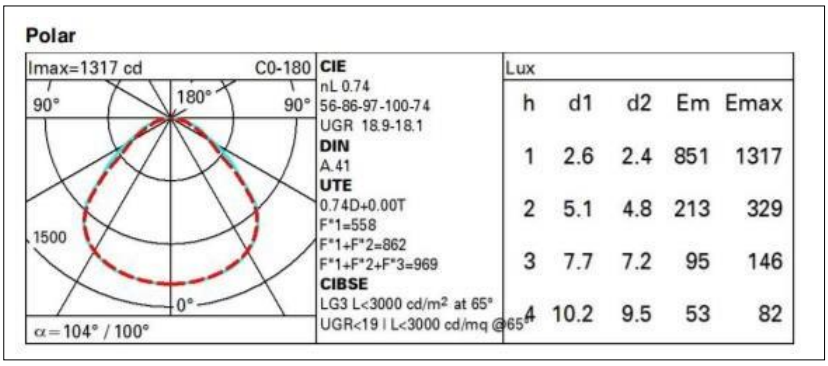


Figure 4.5 :Selected Luminaire Details ,

(Source :iGuzzini.com)

Technical Specification:

A direct Recessed emanation luminaire designed to utilize Neutral White of 4,000K high color rendering LEDs, it introduced in measured false roofs with a 625 x 625 mm step. The optical gathering comprises of a white expelled frame, with a stain screen of methacrylate diffuse.

-Lighting Layout

- As shown below In dialux room model , a 6 no's of luminaires were added to simulate the illumination for the room specifically for the work plan .

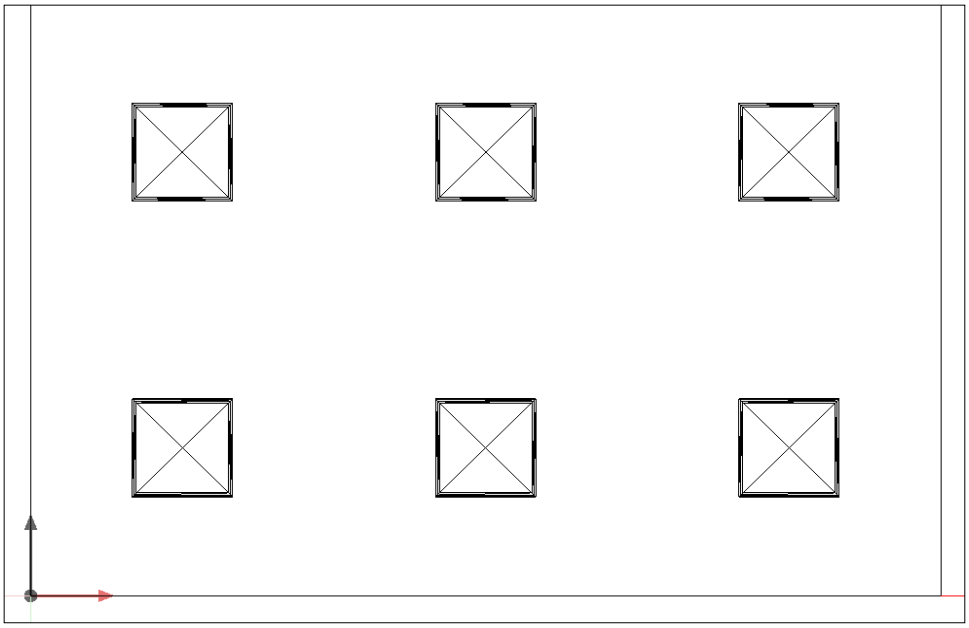


Figure 4.6 : Luminaire layout

(Source :Author through Dialux software,2018)

After inserting the project dimension , the luminance data and and the standard percentages for the surfaces reflectance , the program simulated the result as showed below in figure by starting calculation depends on the inserted data .

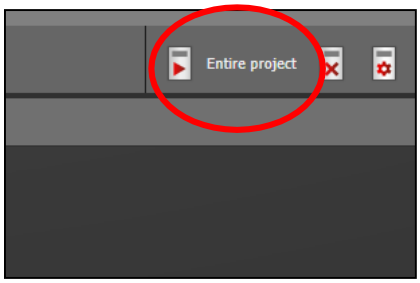


Figure 4.7: calculation starting

(Source: Author through Dialux software,2018)

After finishing the calculation, it gave the result of the average illuminance for the work plane in (lux).

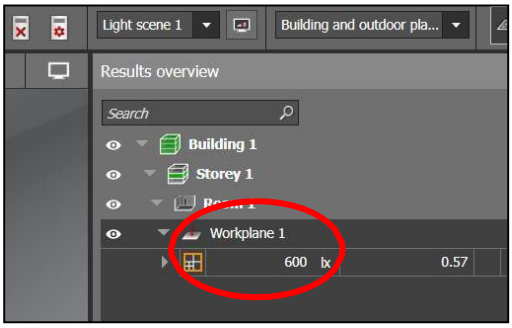


Figure 4.8 : calculation result

(Source: Author through Dialux software,2018)

In addition, the program is giving a detailed documentation that summarizes the projects data as dimension of the room, the selected luminance properties and the reflectance values for the walls, ceiling and flooring.

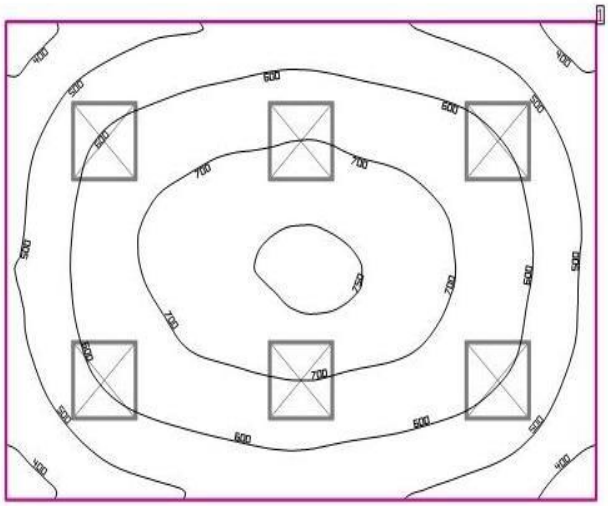
The Figure 4.8 is showing the document which is generated from dilaux software as a pdf file type .

Project 1 9/11/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	600 (≥ 500)	342	761	0.57	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 1.95 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure 4.9 : project documentation with result

(Source: Author through Dialux software,2018)

4.2.2 Simulation of the Model with different Reflectance percentage

The simulation was done for examine the Artificial lights illumination in an empty and windowless space without the furniture units.

Simulation Scenario:

The simulation is calculating the illumination amount for the work plane in lux , after the base case model simulation , a simulations were taken for the ceiling reflectance percentage from 10 to 90% , wall Reflectance percentage from 5 to 90% , and floor Reflectance percentage from 5 to 45 %.

It was necessary to test the different reflectance percentages for all the surfaces (ceiling , wall and flooring) , in order to clarify and evaluate which surface has the most effective reflectance to distribute the illumination in the space .

- Ceiling Reflectance

In this model , the author has changed the percentage gradually from 90% to 10% as mentioned below :

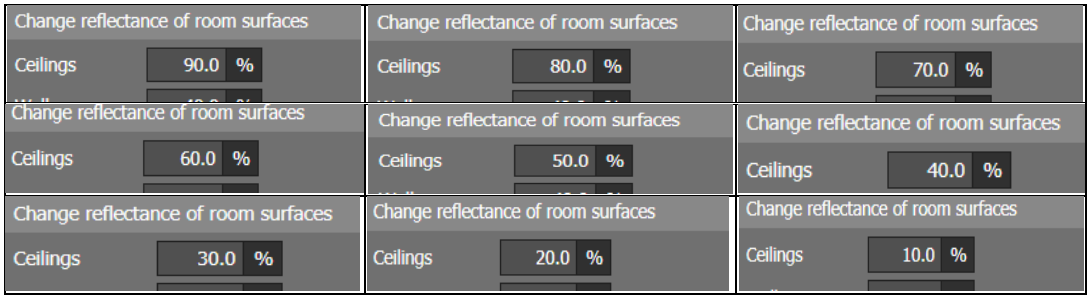


Figure 4.10 : Changing Ceiling Reflectance for simulations

(Source: Author through Dialux software,2018)

- Wall Reflectance

For the wall reflectance , the author has changed the percentage gradually from 5% to 90% as mentioned in the figure below .

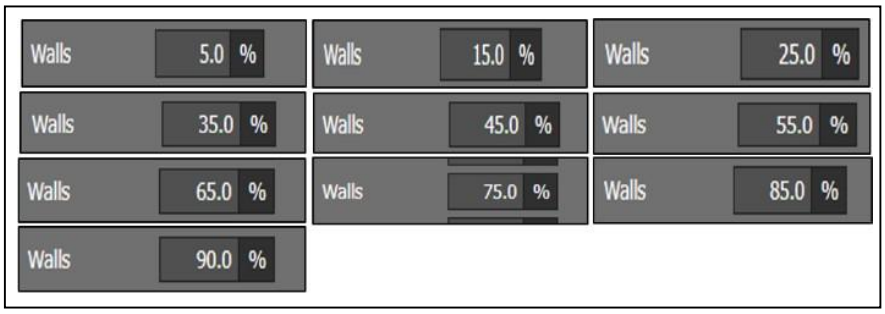


Figure 4.11 : Changing Wall Reflectance for simulations

(Source: Author through Dialux software,2018)

- Floor Reflectance

The author has changed the percentage gradually from 5% to 45% for the flooring reflectance as mentioned below :

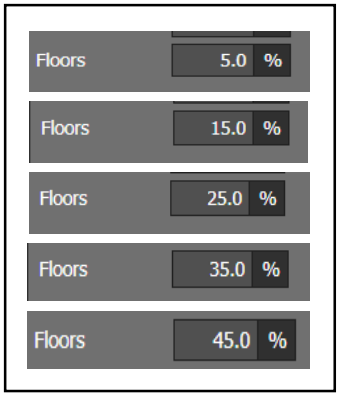


Figure 4.12 : Changing Floor Reflectance for simulations

(Source: Author through Dialux software,2018)

4.2.3 Simulation of the Model with different materials coat reflectance

Another case was tested to evaluate the illuminance value with a glossy materials.

In this case the researcher will test 2 different materials coat reflectance to be applied on two walls only , model (A) which is the small office has been selected to evaluate the simulation , the simulation is based on the base case values of the floor 20 % , and the ceiling 70 % .

The walls reflectance value will be detected from the selected material from Dialux software catalogue for both simulations, the first material reflectance value is 34 % as shown in figure 4.13 A below, and the coat reflectance is 15% .

The second material has a reflectance value of 16%, and a coat reflectance of 98 % as showed in figure 4.13 B.

The results will be compared with the values that resulted from assigning the reflectance value for the material regardless the coat reflectance for both materials.

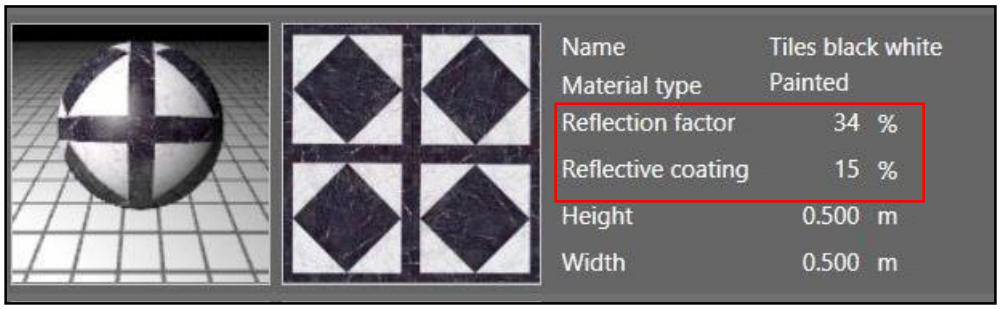


Figure 4.13 A : Selected material (1) for simulations

(Source: Author through Dialux software,2018)

Figure 4.13 B : Selected material (2) for simulations

(Source: Author through Dialux software,2018)

4.3 Model (B) : Large Office Space

Second model (Model B) was a Large office space with a dimensions:

-Width: 15 meters - Length: 30 meters - Height: 3.2 meters - Work plan height: 0.80 m

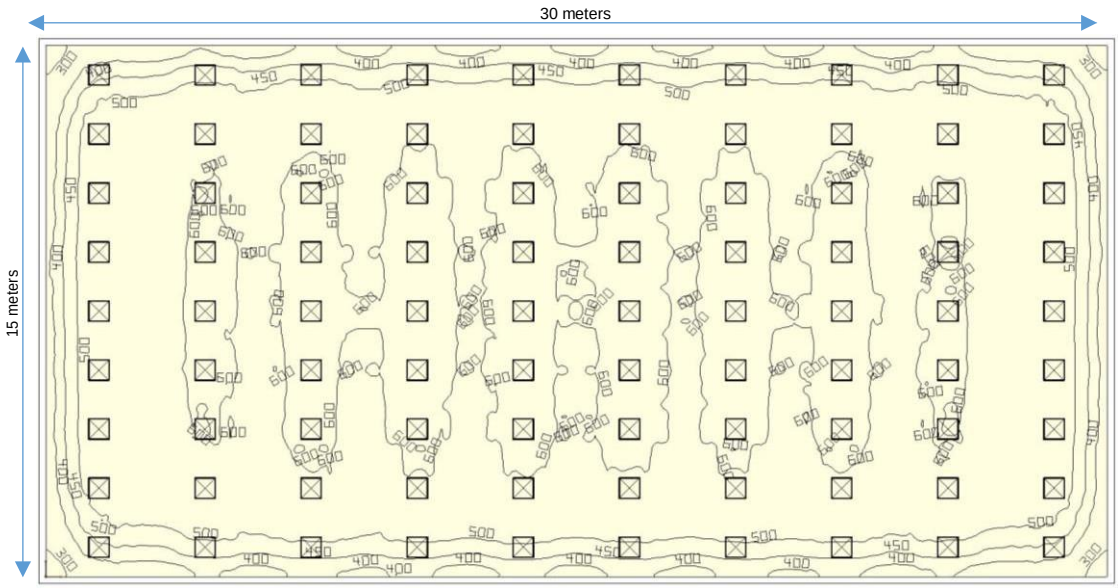


Figure 4.14 : Office plan

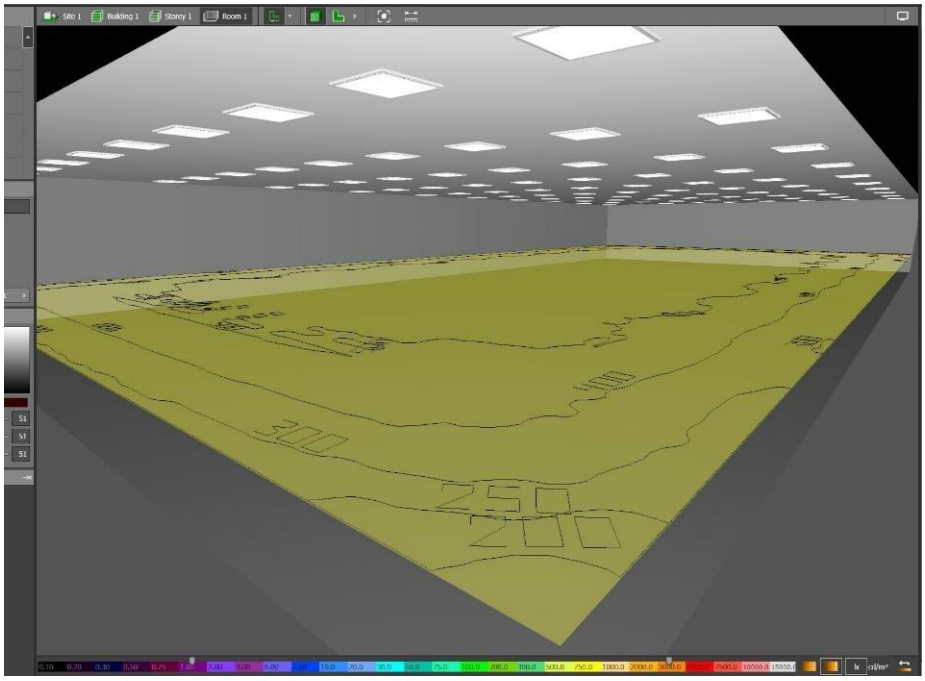


Figure 4.15 : Work plan position

(Source: Author through Dialux software, 2018)

4.3.1 Simulation of the Model B –Base Case

The base case model was created for model B with the standard reflectance for the surfaces which are :

- Ceiling Reflectance = 70 % - Walls Reflectance = 50 % - Floor Reflectance = 20 %

The figure below is showing the model with base case reflectance values on Dialux software

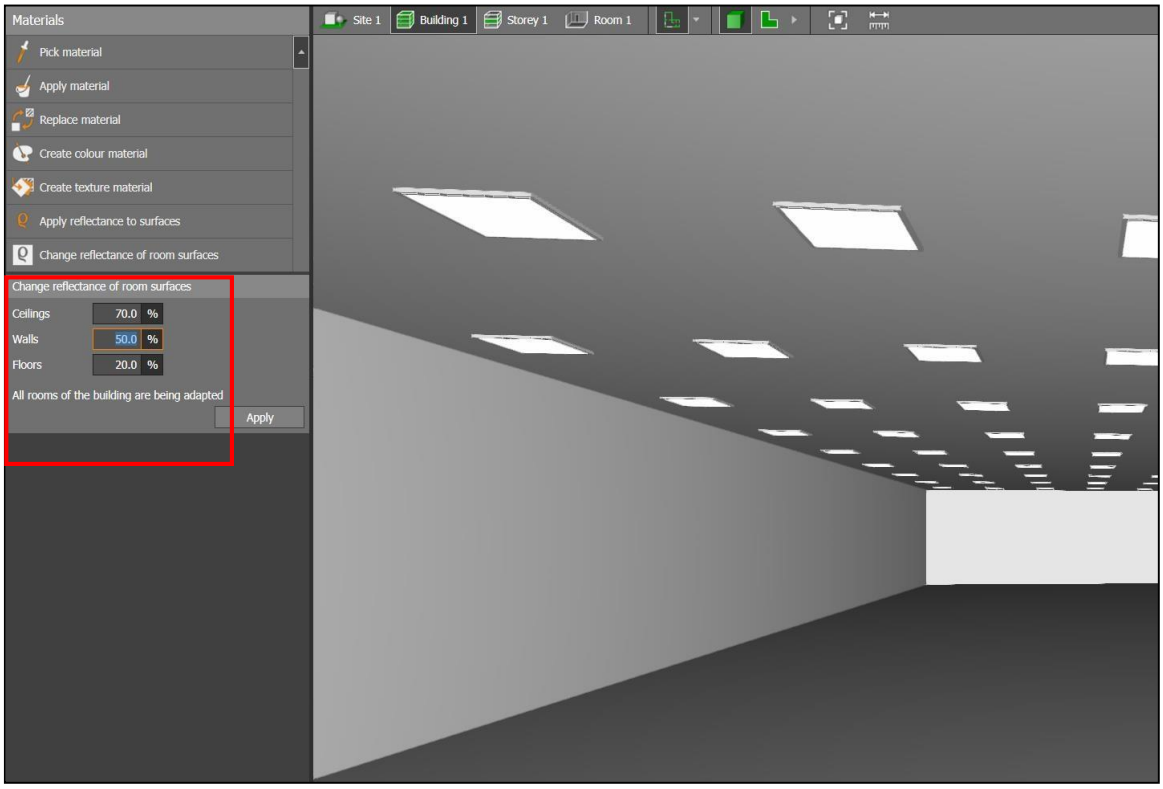


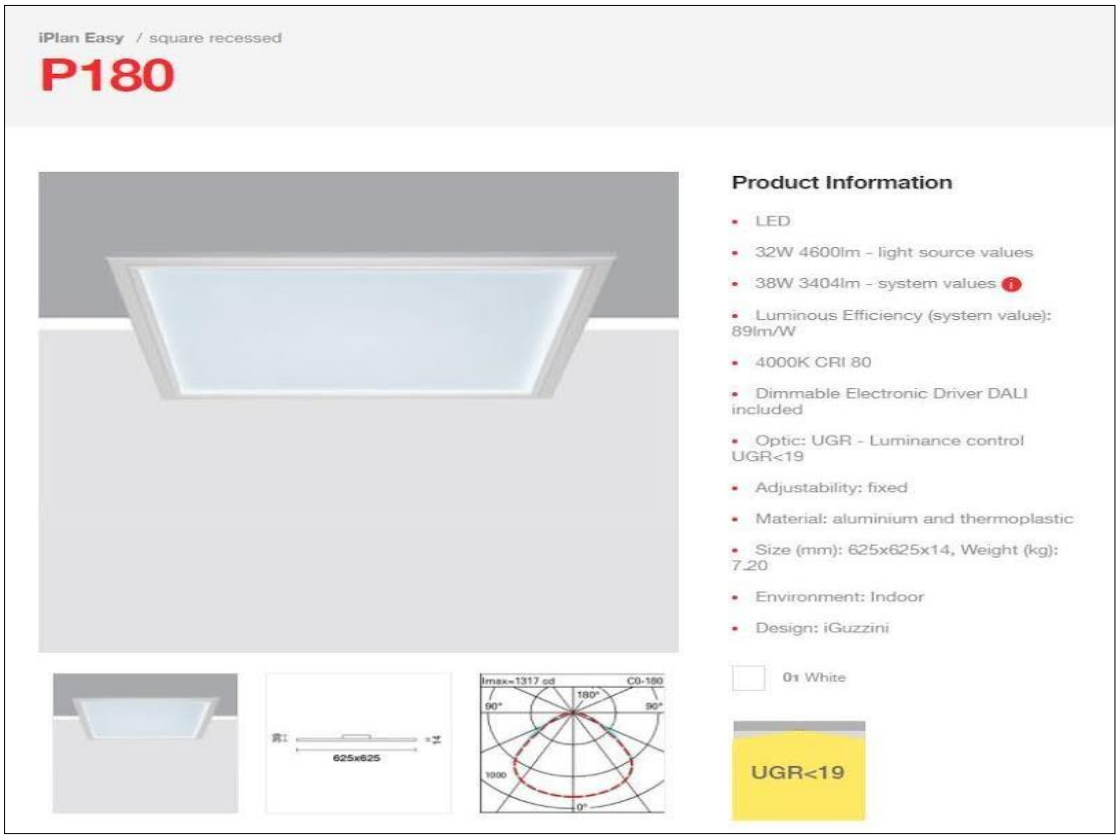
Figure 4.16 : Office model with base case surfaces reflectance

(Source: Author through Dialux software, 2018)

The simulation was done for examine the Artificial lights illumination in an empty and windowless space without the furniture units.

-Selected Luminaire for both models simulations:

For this simulation, a type of P 180 was been selected from iGuzzini website, which is a lighting innovation data base to be used by designers and people.



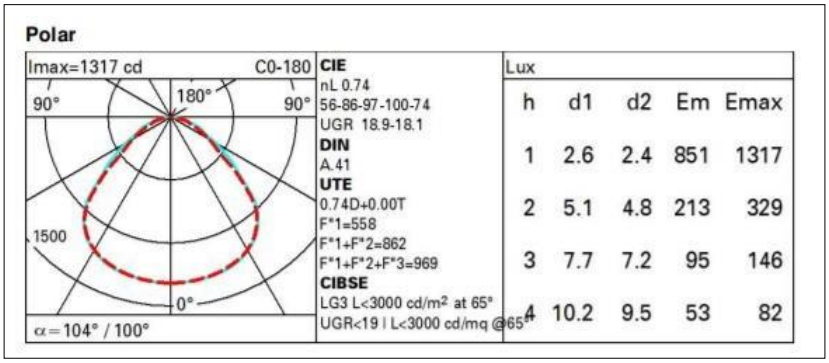


Figure 4.17 :Selected Luminaire Details

Source :iGuzzini.com

-Lighting Layout

- As shown below In dialux room model, a 90 no's of 60 x 60 luminaires were added to simulate the illumination for the room specifically for the work plan .

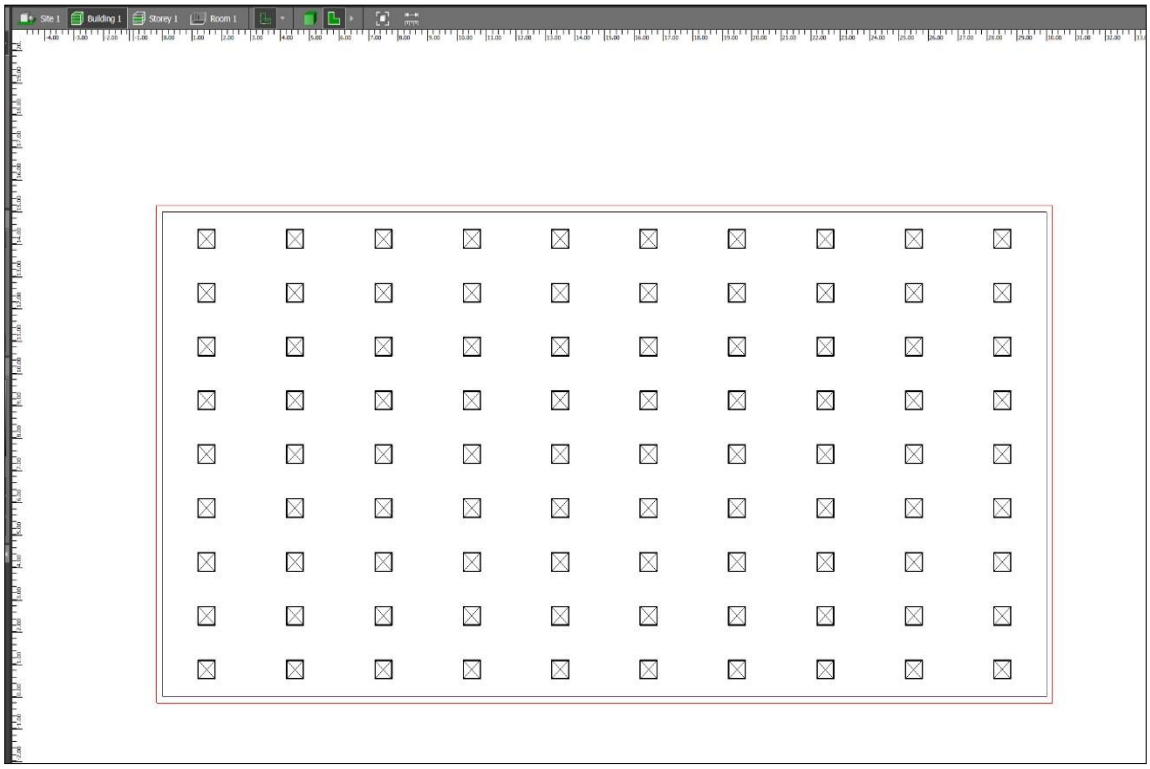


Figure 4.18: Luminaire layout for model B

(Source: Author through Dialux software,2018)

- Simulation Scenario:

The simulation is calculating the illumination amount for the work plane in lux , after the base case model simulation , a simulations were taken for the ceiling reflectance percentage from 10 to 90% , wall Reflectance percentage from 5 to 90% , and floor Reflectance percentage from 5 to 45 %.

After inserting the project dimension, the luminance data and and the standard percentages for the surfaces reflectance , the program simulated the result as showed below in figure by starting calculation depends on the inserted data .

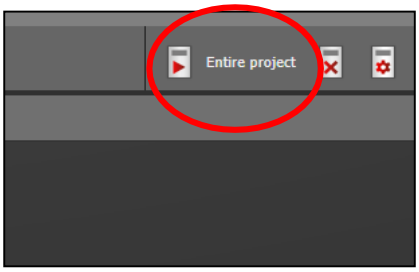


Figure 4.19: calculation starting bottom

(Source: Author through Dialux software,2018)

As same as what has been done for model A ,and after finishing the calculation, it gave the result of the average illuminance for the work plane in (lux).

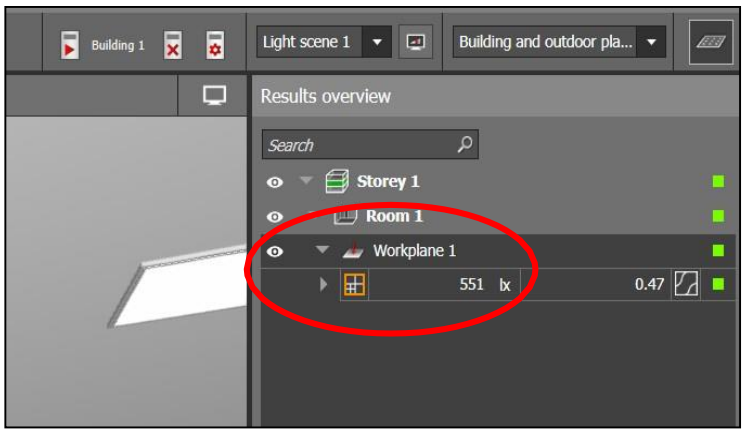


Figure 4.20 : calculation result

(Source: Author through Dialux software,2018)

Added to the mentioned above, the detailed documentation that summarizes the projects data as dimension of the room, the selected luminance properties and the reflectance values for the walls, ceiling and flooring is showed in figure

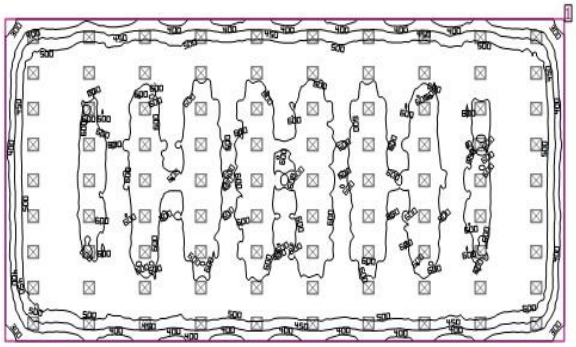
The Figure 4.20 is showing the document which is generated from Dialux software.

Project 2 9/13/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	551 (≥ 500)	257	628	0.47	0.41

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.38 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure 4.21 : Project documentation
(Source: Author through Dialux software,2018)

4.3.2 Simulation of the Model with different Reflectance percentage

The simulation was done for examine the Artificial lights illumination in an empty and windowless space without the furniture units.

Simulation Scenario:

The simulation is calculating the illumination amount for the work plane in lux , after the base case model simulation , a simulations were taken for the ceiling reflectance percentage from 10 to 90% , wall Reflectance percentage from 5 to 90% , and floor Reflectance percentage from 5 to 45 %.

- Ceiling Reflectance

In this model, the author has changed the percentage gradually from 90% to 10% as mentioned below :

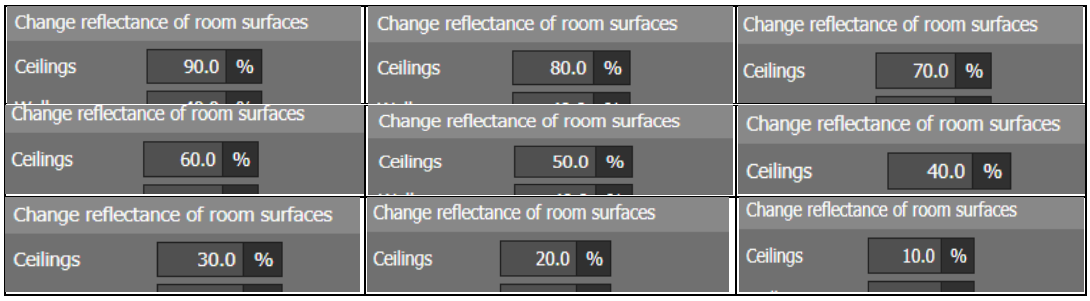


Figure 4.22 : Changing Ceiling Reflectance for simulations

(Source: Author through Dialux software,2018)

- Wall Reflectance

For the wall reflectance , the author has changed the percentage gradually from 5% to 90% as mentioned in the figure below .

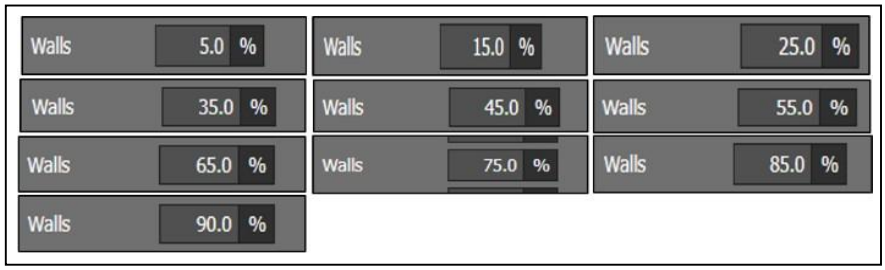


Figure 4.23 : Changing Wall Reflectance for simulations

(Source: Author through Dialux software,2018)

- Floor Reflectance

The author has changed the percentage gradually from 5% to 45% for the flooring reflectance as mentioned below :

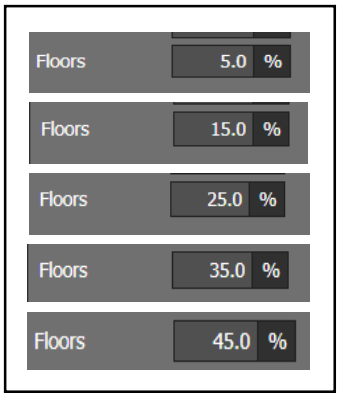


Figure 4.24 : Changing Floor Reflectance for simulations

(Source: Author through DIALux software,2018)

In the simulations, five tables will be resulted with 90 results of Dialux lux calculation . In each table it was taken a fix reflectance value of floor reflectance with 9 different percentage of ceiling and walls reflectance.

Table 4.1 : Dialux calculation results sample

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5									
	15									
	25									
	35									
	45									
	55									
	65									
	75									
	85									
	90									

Resulted lux value from Dialux calculations

Chapter 5: Results and Discussion

5.1 Introduction

The data analysis process started by computing and arranging simulation data within excel sheets. Secondly, the data set was inspected for visual charts to show the increasing levels.

In over all , a number of 900 simulations were created to test the results with changing the reflectance percentage for the surfaces . Those results were divided into :

1- 450 results for model A (small office) 2- 450 results for model B (large office)

For both models , the surface reflectance for ceiling , walls and flooring were tested as :

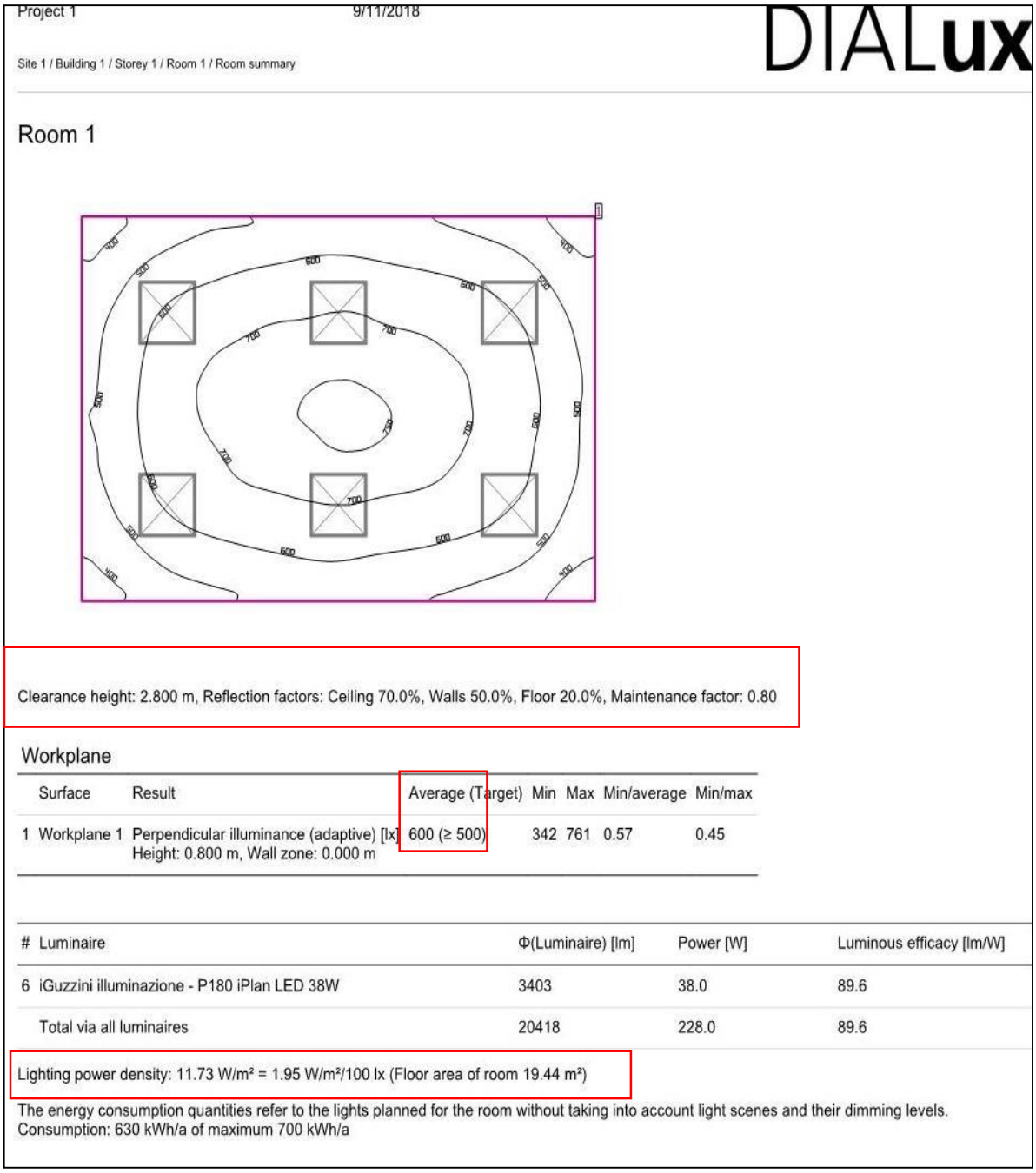
- Ceiling Reflectance : from 10 to 90% - Wall Reflectance : from 5 to 90 % .
- Floor Reflectance: from 5 to 45 % .

Standards recommend that reflectance percentages for the walls ought to be between 50 and 70%, floor between 20 and 40% and for ceiling between 60 and 80%.

In addition , Another case was tested to evaluate the illuminance value with a glossy materials. In this case the researcher will test 2 different materials coat reflectance to be applied on two walls only , model (A) which is the small office has been selected to evaluate the simulation , the simulation is based on the base case values of the floor 20 % , and the ceiling 70 % .The walls reflectance value will be detected from the selected material from Dialux software catalogue for both simulations, the first material reflectance value is 34 % and the coat reflectance is 15% . Second material has a reflectance value of 16% , and coat reflectance of 98% .

5.2 Result and Discussion of model A – base case

The base case model is created based on the standard surfaces reflectance values which are: 70 % reflectance for the ceiling, 50 % reflectance for the walls, 20% for the flooring. By inserting those values into the Dialux created model , the program will calculate the result based on the dimension of the model which is : Width 3 meters , Length 5 meters , Height 2.8 meters , with a work plane height of 80 cm from the finished floor level , in addition to the selected luminaire properties and number which equals 6 luminaries within the model area .



Project 1 9/11/2018 DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1

Clearance height: 2.800 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	600 (≥ 500)	342	761	0.57	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 1.95 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure 5.1 : Dialux calculation results for model A base case

(Source: Author through Dialux software, 2018)

The Figure 5.1 above has shown the calculated illumination in lux based on the inserted parameters for the model , the result is 600 lux , which is more than the normal standard for offices and place work plane illumination .Thus , an optimized values will be tested to evaluate the illumination levels that is perceived on the work plan area .

5.3 Result and Discussion of model A with different Reflectance percentages

As mentioned earliest in chapter 4 , the model will be tested with a changed parameters of reflectance's for the finishing surfaces of interiors , it will pass by 9 different reflectance for ceiling , and 9 reflectance for the walls , with 5 reflectance for the flooring .

The simulation will end with 450 different values of illumination in (lux) , those results will clarify and show the impact of each surface reflectance on the interior space illumination specially on the work plane zone .

5.3.1 Calculated results from Dialux Lighting Software for model A (small office)

Table 5.1 : Dialux calculation with constant floor reflectance of 5% (lux)
(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	475	476	476	477	477	478	478	479	479
	15	489	491	492	493	494	495	496	497	499
	25	505	507	509	511	513	515	516	518	521
	35	522	525	528	531	534	536	539	543	546
	45	542	546	550	554	558	562	566	571	575
	55	564	569	575	580	586	592	598	604	611
	65	589	596	604	611	619	627	636	644	654
	75	619	628	638	648	659	670	682	694	707
	85	654	666	679	693	707	723	739	757	777
	90	673	688	703	714	736	755	775	798	822

Table 5.1 showed 90 results which had been simulated in 90 different files in Dialux.

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 5 % , and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 % , added to the walls surface reflectance percentage from 5 % to 90 % .

To clarify the results in better way, an excel chart was created to show the results which are listed in the table .

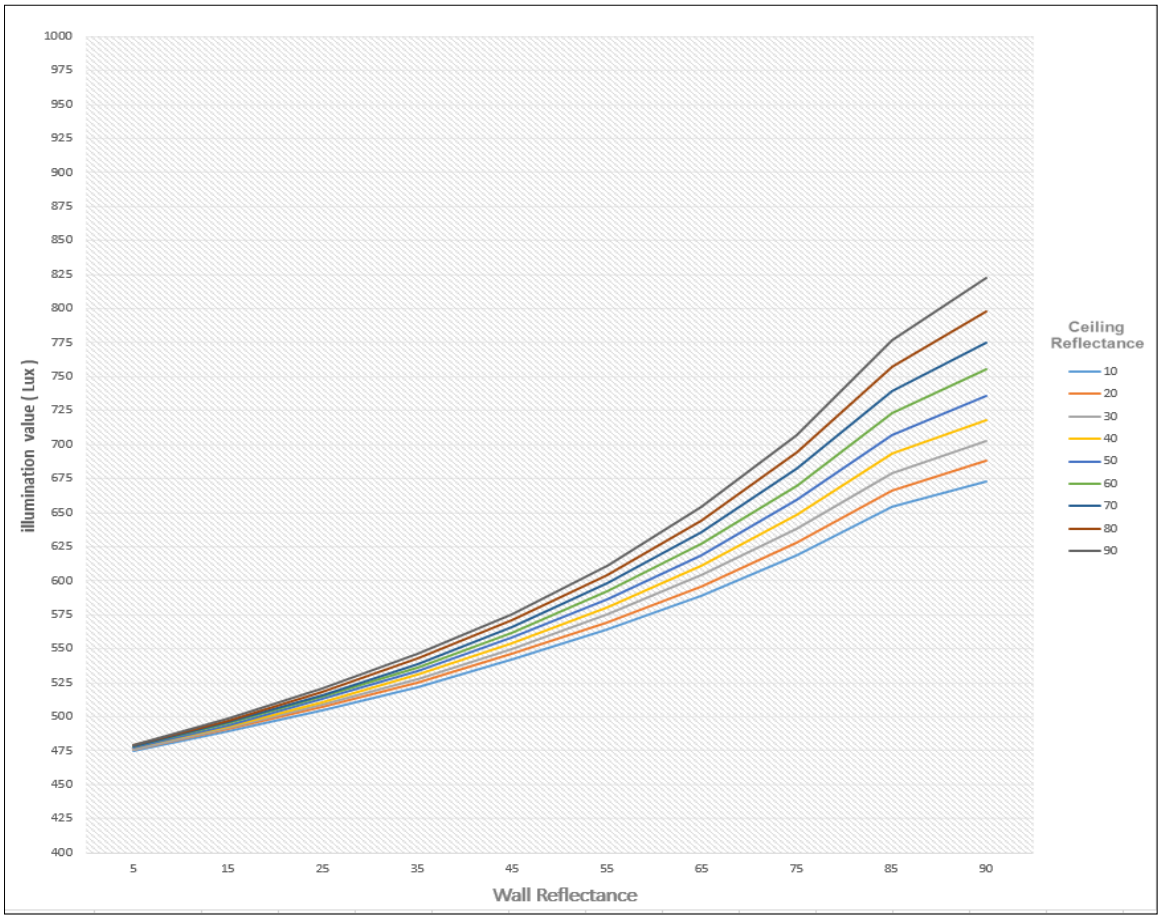


Figure 5.2 : Excel Chart for Dialux model with constant floor reflectance of 5%

(Source: Author through Excel software, 2018)

As the above figure shows, there is a noticeable increase in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 5%.

At the floor reflectance 5% ,and By increasing each 10 % in ceiling reflectance , the illumination level at the work plane is increased between 1 lux only while in the wall reflectance each increase of 10 % is maximize the level of illumination increased between 14 and 20 lux .

Table5.1 : Dialux calculation with constant floor reflectance of 5% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	475	476	476	477	477	478	478	479	479
	15	489	491	492	493	494	495	496	497	499
	25	505	507	509	511	513	515	516	518	521
	35	522	525	528	531	534	536	539	543	546
	45	542	546	550	554	558	562	566	571	575
	55	564	569	575	580	586	592	598	604	611
	65	589	596	604	611	619	627	636	644	654
	75	619	628	638	648	659	670	682	694	707
	85	654	666	679	693	707	723	739	757	777
	90	673	688	703	714	736	755	775	798	822

In the table below, the researcher has divided the highest result in table by the lowest result to show the amount of illumination increasing in clear way for the reader.

Table 5.2 : Excel calculation with constant floor reflectance of 5%

(Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01
	15	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.05	1.05
	25	1.06	1.07	1.07	1.08	1.08	1.08	1.09	1.09	1.10
	35	1.10	1.11	1.11	1.12	1.12	1.13	1.13	1.14	1.15
	45	1.14	1.15	1.16	1.17	1.17	1.18	1.19	1.20	1.21
	55	1.19	1.20	1.21	1.22	1.23	1.25	1.26	1.27	1.29
	65	1.24	1.25	1.27	1.29	1.30	1.32	1.34	1.36	1.38
	75	1.30	1.32	1.34	1.36	1.39	1.41	1.44	1.46	1.49
	85	1.38	1.40	1.43	1.46	1.49	1.52	1.56	1.59	1.64
	90	1.42	1.45	1.48	1.50	1.55	1.59	1.63	1.68	1.73

By dividing the highest result in table by the lowest result, it resulted with a 1.73 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 73 % comparing with the lowest value which occurred when the ceiling reflectance is 10% and walls reflectance is 5% , which shows that the illumination level

has been increased with a value of 73% more , then will have more illumination at the work plane area .

It was important then to evaluate the resulted values based the base case model value . Table 5.3 is showing all the resulted values divided by the base case value which equals 600 lux .

Table 5.3 : Dialux calculation with constant floor reflectance of 5% divided by the base case value (70,50,20) (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	0.79	0.79	0.79	0.80	0.80	0.80	0.80	0.80	0.80
	15	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.83
	25	0.84	0.85	0.85	0.85	0.86	0.86	0.86	0.86	0.87
	35	0.87	0.88	0.88	0.89	0.89	0.89	0.90	0.91	0.91
	45	0.90	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.96
	55	0.94	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02
	65	0.98	0.99	1.01	1.02	1.03	1.05	1.06	1.07	1.09
	75	1.03	1.05	1.06	1.08	1.10	1.12	1.14	1.16	1.18
	85	1.09	1.11	1.13	1.16	1.18	1.21	1.23	1.26	1.30
	90	1.12	1.15	1.17	1.20	1.23	1.26	1.29	1.33	1.37

As shown above in the table , the results are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 600 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 600 lux) .

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 600 Lux) .

Table 5.4 : Dialux calculation with constant floor reflectance of 15% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
15%		10	20	30	40	50	60	70	80	90
	5	476	477	478	479	480	481	483	484	485
	15	491	493	494	496	498	500	502	503	506
	25	508	510	513	515	518	520	523	526	529
	35	526	529	533	537	540	544	548	552	556
	45	546	551	556	561	566	572	577	583	589
	55	570	576	583	590	597	604	612	620	628
	65	597	606	615	624	633	643	654	665	676
	75	629	641	652	665	677	691	706	721	738
	85	667	682	698	714	732	751	772	797	822
	90	689	706	724	744	766	790	816	841	868

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 15 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 % , added to the walls surface reflectance percentage from 5 % to 90 % .

An excel chart was created to show the results which are listed in the table .

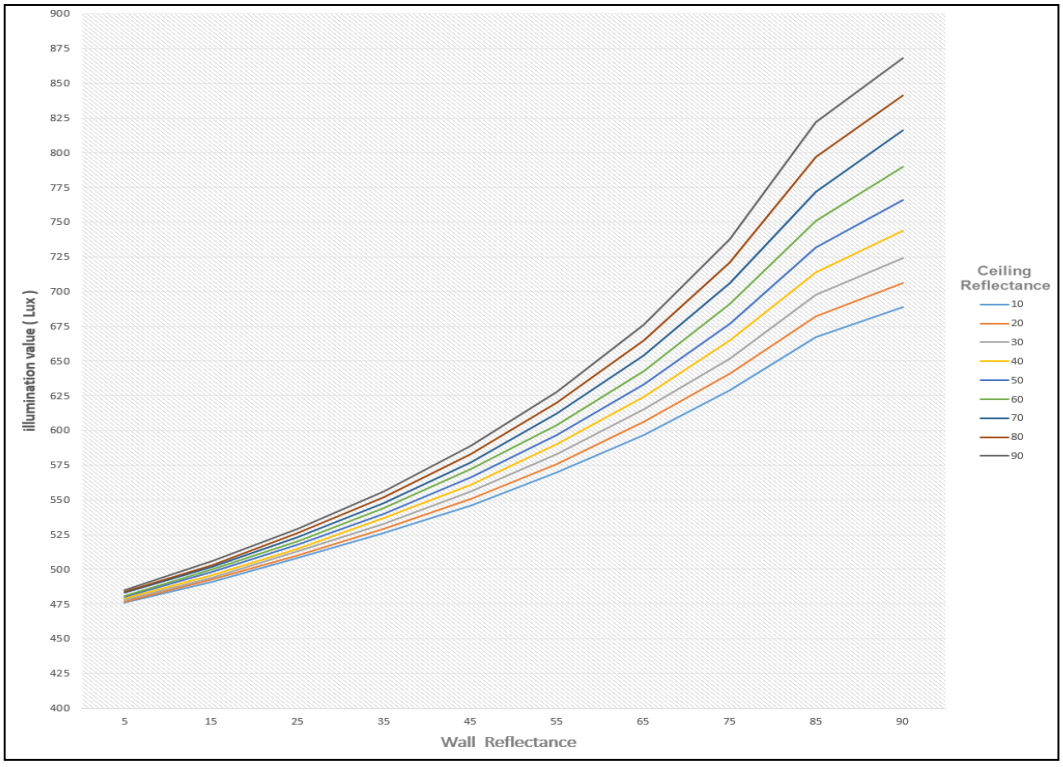


Figure 5.3: Chart for Dialux model results with constant floor reflectance of 15%

(Source: Author through Excel software, 2018)

As shown in the figure 5.3, there is a noticeable increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 15%.

At the floor reflectance 15% ,and By increasing each 10 % in ceiling reflectance , the illumination level at the work plan is increased between 1 to 2 lux only while in the wall reflectance each increase of 10 % is maximize the level of illumination by 15 to 22 lux , which differs just with 1 to 2 lux from the previous table with a floor reflectance of 5 %.

In the table below, the researcher has divided all the values in table 5.4 by the lowest result which is 476 lux to show the amount of increased illumination in clear way for the reader.

Table 5.5 : Results of table 5.4 divided by lowest value

(Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
15%		10	20	30	40	50	60	70	80	90
	5	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02
	15	1.03	1.04	1.04	1.04	1.05	1.05	1.05	1.06	1.06
	25	1.07	1.07	1.08	1.08	1.09	1.09	1.10	1.11	1.11
	35	1.11	1.11	1.12	1.13	1.13	1.14	1.15	1.16	1.17
	45	1.15	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.24
	55	1.20	1.21	1.22	1.24	1.25	1.27	1.29	1.30	1.32
	65	1.25	1.27	1.29	1.31	1.33	1.35	1.37	1.40	1.42
	75	1.32	1.35	1.37	1.40	1.42	1.45	1.48	1.51	1.55
	85	1.40	1.43	1.47	1.50	1.54	1.58	1.62	1.67	1.73
	90	1.45	1.48	1.52	1.56	1.61	1.66	1.71	1.77	1.82

By dividing the highest result in table 5.4 by the lowest result (868 ÷ 476) , it resulted with a 1.82 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 82 % comparing with the lowest value which occurred when the ceiling reflectance is 10% and walls reflectance is 5% , which shows that the illumination level has been increased with a value of 82 % , thus a more illumination amount at the work plane area will be visible .

Table 5.6 : Dialux calculation with constant floor reflectance of 15% divided by the base case value (70,50,20) (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
15%		10	20	30	40	50	60	70	80	90
	5	0.79	0.80	0.80	0.80	0.80	0.80	0.81	0.81	0.81
	15	0.82	0.82	0.82	0.83	0.83	0.83	0.84	0.84	0.84
	25	0.85	0.85	0.86	0.86	0.86	0.87	0.87	0.88	0.88
	35	0.88	0.88	0.89	0.90	0.90	0.91	0.91	0.92	0.93
	45	0.91	0.92	0.93	0.94	0.94	0.95	0.96	0.97	0.98
	55	0.95	0.96	0.97	0.98	1.00	1.01	1.02	1.03	1.05
	65	1.00	1.01	1.03	1.04	1.06	1.07	1.09	1.11	1.13
	75	1.05	1.07	1.09	1.11	1.13	1.15	1.18	1.20	1.23
	85	1.11	1.14	1.16	1.19	1.22	1.25	1.29	1.33	1.37
	90	1.15	1.18	1.21	1.24	1.28	1.32	1.36	1.40	1.45

As shown above in the table , the results are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 600 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 600 lux) .

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 600 Lux) .

Table 5.7 : Dialux calculation with constant floor reflectance of 25% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
25%		10	20	30	40	50	60	70	80	90
	5	477	479	480	482	483	485	487	488	490
	15	492	495	497	500	502	505	507	510	512
	25	510	513	516	520	523	526	530	534	537
	35	529	533	538	542	547	552	557	562	567
	45	551	557	563	569	575	582	589	596	603
	55	576	584	592	600	609	617	627	636	647
	65	605	616	626	637	649	661	673	687	701
	75	640	653	667	682	698	714	732	751	771
	85	682	699	718	738	760	785	811	838	865
	90	706	726	748	773	800	828	856	888	925

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 25 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 % , added to the walls surface reflectance percentage from 5 % to 90 % .

An excel chart was created to show the results which are listed in the table .

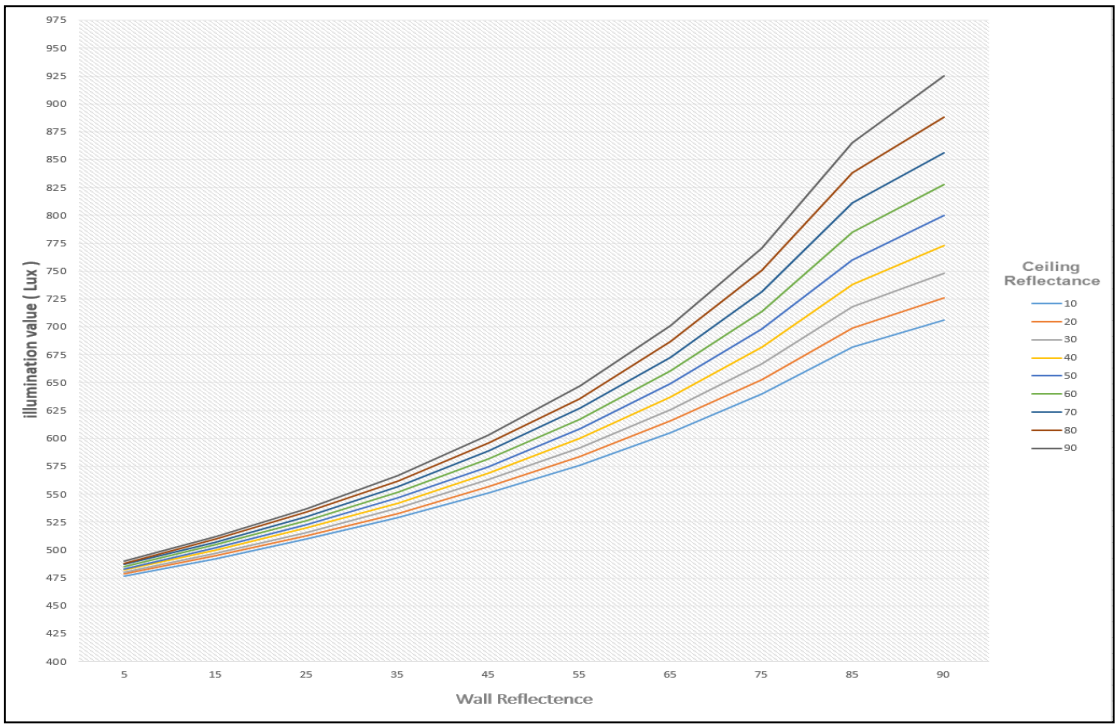


Figure 5.4 : Excel Chart for Dialux model with constant floor reflectance of 25%

(Source: Author through Excel software, 2018)

As shown in the figure 5.4, there is a noticeable increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 25%.

At the floor reflectance 25% ,and By increasing each 10 % in ceiling reflectance , the illumination level at the work plan is increased between 1 to 2 lux only while in the wall reflectance each increase of 10 % is maximize the level of illumination by 15 to 24 lux , which differs just with 1 to 2 lux from the previous table with a floor reflectance of 15 %.

The researcher has divided all the values in table 5.7 by the lowest result, which is 477 lux to show the amount of illumination increasing in clear way for the reader

Table 5.8 : calculation with constant floor reflectance of 25%- values divided by lowest value

(Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
25%		10	20	30	40	50	60	70	80	90
	5	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03
	15	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07
	25	1.07	1.08	1.08	1.09	1.10	1.10	1.11	1.12	1.13
	35	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19
	45	1.16	1.17	1.18	1.19	1.21	1.22	1.23	1.25	1.26
	55	1.21	1.22	1.24	1.26	1.28	1.29	1.31	1.33	1.36
	65	1.27	1.29	1.31	1.34	1.36	1.39	1.41	1.44	1.47
	75	1.34	1.37	1.40	1.43	1.46	1.50	1.53	1.57	1.62
	85	1.43	1.47	1.51	1.55	1.59	1.65	1.70	1.76	1.81
	90	1.48	1.52	1.57	1.62	1.68	1.74	1.79	1.86	1.94

By dividing the highest result in table 5.7 by the lowest result (925 ÷ 477) , it resulted with a 1.94 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 94 % comparing with the lowest value which occurred when the ceiling reflectance is 10% and walls reflectance is 5% , which shows that the illumination level has been increased with a value of 94% , thus a more illumination amount at the work plane area will be visible .

Table 5.9: Dialux calculation with constant floor reflectance of 25% divided by the base case value (70,50,20) (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
25%		10	20	30	40	50	60	70	80	90
	5	0.80	0.80	0.80	0.80	0.81	0.81	0.81	0.81	0.82
	15	0.82	0.83	0.83	0.83	0.84	0.84	0.85	0.85	0.85
	25	0.85	0.86	0.86	0.87	0.87	0.88	0.88	0.89	0.90
	35	0.88	0.89	0.90	0.90	0.91	0.92	0.93	0.94	0.95
	45	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.01
	55	0.96	0.97	0.99	1.00	1.02	1.03	1.05	1.06	1.08
	65	1.01	1.03	1.04	1.06	1.08	1.10	1.12	1.15	1.17
	75	1.07	1.09	1.11	1.14	1.16	1.19	1.22	1.25	1.29
	85	1.14	1.17	1.20	1.23	1.27	1.31	1.35	1.40	1.44
	90	1.18	1.21	1.25	1.29	1.33	1.38	1.43	1.48	1.54

As shown above in the table, the results are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 600 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 600 lux).

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 600 Lux) .

Table 5.10 : Dialux calculation with constant floor reflectance of 35% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
35%		10	20	30	40	50	60	70	80	90
	5	478	480	482	484	486	489	491	493	495
	15	494	497	500	503	506	509	512	516	519
	25	512	516	520	524	528	533	537	542	546
	35	532	537	543	548	554	560	566	572	579
	45	555	562	569	577	584	592	600	609	618
	55	582	591	601	611	621	631	642	654	666
	65	614	626	638	651	665	679	694	710	728
	75	651	667	683	701	719	739	761	785	814
	85	697	717	740	765	792	821	850	882	919
	90	724	748	776	805	836	868	904	945	992

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 35 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 % , added to the walls surface reflectance percentage from 5 % to 90 % . The highest values is occurred when the wall and ceiling reflectances are high percentages .

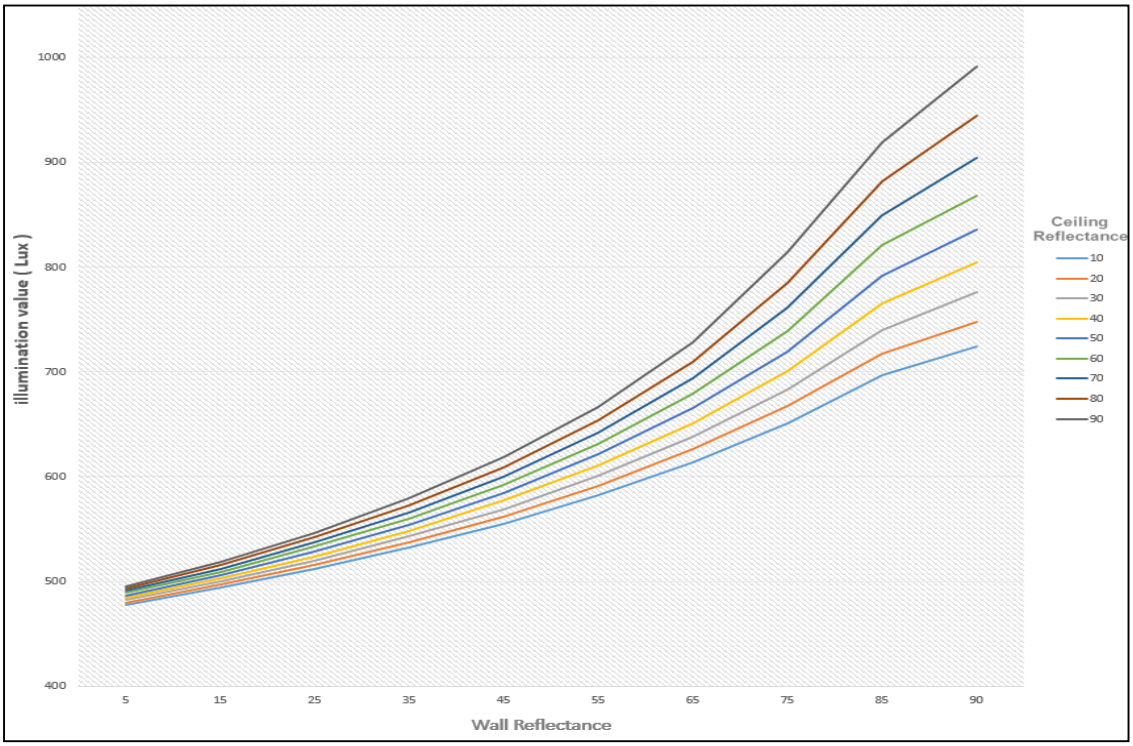


Figure 5.5 : Excel Chart for Dialux model with constant floor reflectance of 35%

(Source: Author through Excel software, 2018)

As shown in the figure 5.5, there is a noticeable increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 35%.

At the floor reflectance 35% ,and By increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 1 to 2 lux only while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination by 15 to 24 lux , which differs with 67 lux from the previous table with a floor reflectance of 15 % when compared the highest value in table 5.10 (992 lux) with the highest value in table 5.7 (925 lux) .

The researcher has divided all the values in table 5.10 by the lowest result, which is 478 lux to show the amount of illumination increasing in clear way for the reader

Table 5.11 : calculation with constant floor reflectance of 35%- values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
35%		10	20	30	40	50	60	70	80	90
	5	1.00	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04
	15	1.03	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.09
	25	1.07	1.08	1.09	1.10	1.10	1.12	1.12	1.13	1.14
	35	1.11	1.12	1.14	1.15	1.16	1.17	1.18	1.20	1.21
	45	1.16	1.18	1.19	1.21	1.22	1.24	1.26	1.27	1.29
	55	1.22	1.24	1.26	1.28	1.30	1.32	1.34	1.37	1.39
	65	1.28	1.31	1.33	1.36	1.39	1.42	1.45	1.49	1.52
	75	1.36	1.40	1.43	1.47	1.50	1.55	1.59	1.64	1.70
	85	1.46	1.50	1.55	1.60	1.66	1.72	1.78	1.85	1.92
	90	1.51	1.56	1.62	1.68	1.75	1.82	1.89	1.98	2.08

By dividing the highest result in table 5.10 by the lowest result (992 ÷ 478) , it resulted with a 2.08 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 208 % which is the double , based on the lowest value (478 lux) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% , thus a more illumination amount at the work plane area will be visible.

Table 5.12: Dialux calculation with constant floor reflectance of 35% divided by the base case value (70,50,20) ,(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
35%		10	20	30	40	50	60	70	80	90
	5	0.80	0.80	0.80	0.81	0.81	0.82	0.82	0.82	0.83
	15	0.82	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.87
	25	0.85	0.86	0.87	0.87	0.88	0.89	0.90	0.90	0.91
	35	0.89	0.90	0.91	0.91	0.92	0.93	0.94	0.95	0.97
	45	0.93	0.94	0.95	0.96	0.97	0.99	1.00	1.02	1.03
	55	0.97	0.99	1.00	1.02	1.04	1.05	1.07	1.09	1.11
	65	1.02	1.04	1.06	1.09	1.11	1.13	1.16	1.18	1.21
	75	1.09	1.11	1.14	1.17	1.20	1.23	1.27	1.31	1.36
	85	1.16	1.20	1.23	1.28	1.32	1.37	1.42	1.47	1.53
	90	1.21	1.25	1.29	1.34	1.39	1.45	1.51	1.58	1.65

As shown above in the table, the results are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 600 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 600 lux).

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 600 Lux) .

Table 5.13 : Dialux calculation with constant floor reflectance of 45% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
45%		10	20	30	40	50	60	70	80	90
	5	479	481	484	487	489	492	495	498	501
	15	495	499	503	507	510	514	518	522	526
	25	514	519	524	529	534	539	544	550	556
	35	535	542	548	555	562	568	576	583	591
	45	560	568	577	585	594	603	613	623	634
	55	589	599	610	622	634	646	659	673	688
	65	623	636	651	666	682	699	717	736	757
	75	663	681	701	721	743	767	796	825	852
	85	713	738	765	795	826	858	894	935	983
	90	744	773	805	838	874	914	960	1011	1072

Table 5.13 is showing the calculated results at a fixed reflectance percentage for the flooring: 45 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 % , added to the walls surface reflectance percentage from 5 % to 90 % . The highest values is occurred when the wall and ceiling reflectances are having high percentages .The table's results is shown below by a chart in figure

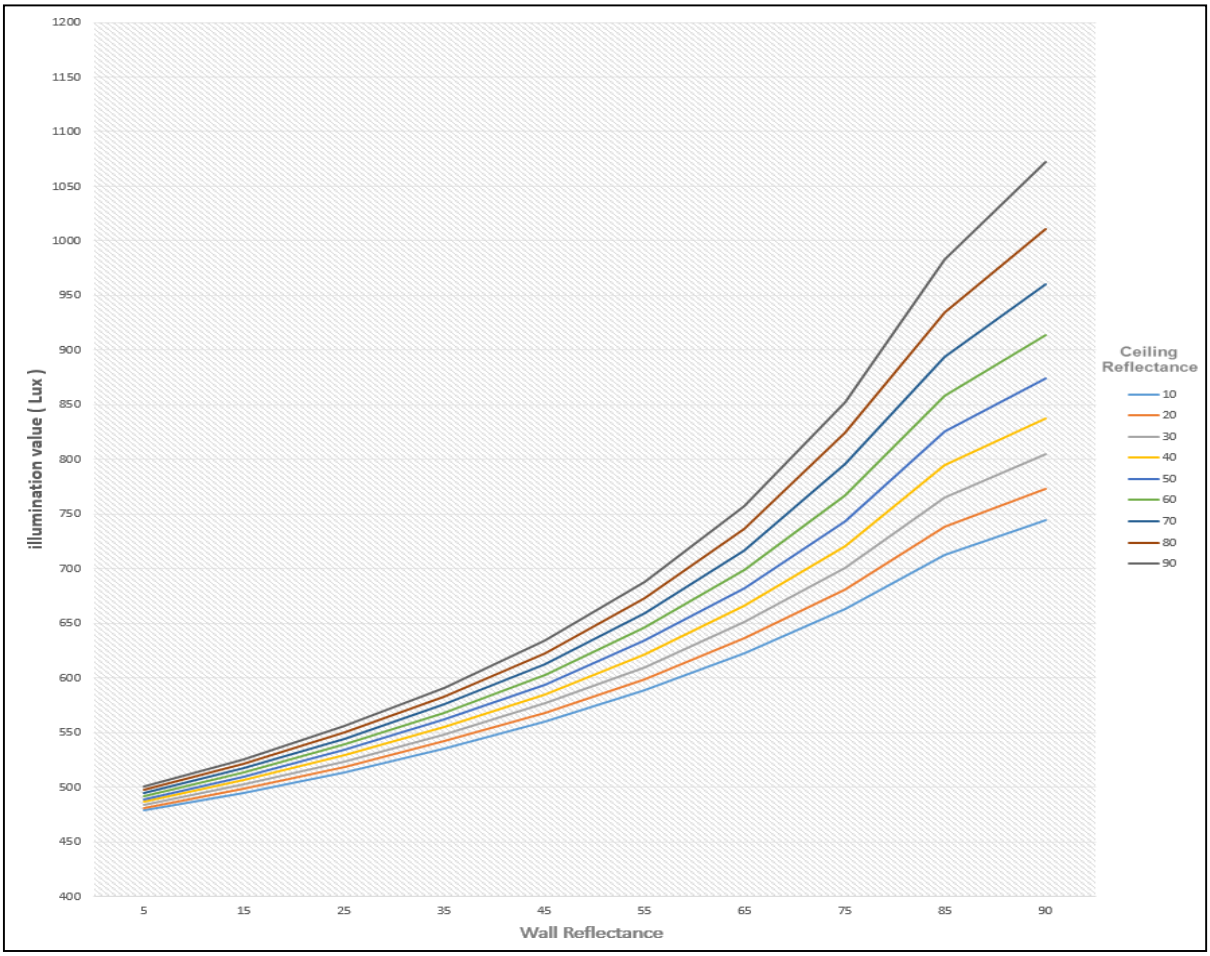


Figure 5.6 : Excel Chart for Dialux model with constant floor reflectance of 45%

(Source: Author through Excel software, 2018)

Figure 5.6, there is showing an increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 45%.

At the floor reflectance 45% ,and by increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 4 to 61 lux , while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination from 16 to 89 lux . When

comparing the highest value in table 5.10 (992 lux) with the highest value in table 5.13 (1072 lux) , it was founded that the result differs with 67 lux between the floor reflectance of 35 % and the floor reflectance of 45% .

Table 5.14 : calculation with constant floor reflectance of 45%- values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
45%		10	20	30	40	50	60	70	80	90
	5	1.00	1.00	1.01	1.02	1.02	1.03	1.03	1.04	1.05
	15	1.03	1.04	1.05	1.06	1.06	1.07	1.08	1.09	1.10
	25	1.07	1.08	1.09	1.10	1.11	1.13	1.14	1.15	1.16
	35	1.12	1.13	1.14	1.16	1.17	1.19	1.20	1.22	1.23
	45	1.17	1.19	1.20	1.22	1.24	1.26	1.28	1.30	1.32
	55	1.23	1.25	1.27	1.30	1.32	1.35	1.38	1.41	1.44
	65	1.30	1.33	1.36	1.39	1.42	1.46	1.50	1.54	1.58
	75	1.38	1.42	1.46	1.51	1.55	1.60	1.66	1.72	1.78
	85	1.49	1.54	1.60	1.66	1.72	1.79	1.87	1.95	2.05
	90	1.55	1.61	1.68	1.75	1.82	1.91	2.00	2.11	2.24

By dividing the highest result in table 5.13 by the lowest result (1072 ÷ 479) , it resulted with a 2.24 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 224 % which is the double , based on the lowest value (479 lux) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% .

Table 5.15: Dialux calculation with constant floor reflectance of 45% divided by the base case value (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
45%		10	20	30	40	50	60	70	80	90
	5	0.80	0.80	0.81	0.81	0.82	0.82	0.83	0.83	0.84
	15	0.83	0.83	0.84	0.85	0.85	0.86	0.86	0.87	0.88
	25	0.86	0.87	0.87	0.88	0.89	0.90	0.91	0.92	0.93
	35	0.89	0.90	0.91	0.93	0.94	0.95	0.96	0.97	0.99
	45	0.93	0.95	0.96	0.98	0.99	1.01	1.02	1.04	1.06
	55	0.98	1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.15
	65	1.04	1.06	1.09	1.11	1.14	1.17	1.20	1.23	1.26
	75	1.11	1.14	1.17	1.20	1.24	1.28	1.33	1.38	1.42
	85	1.19	1.23	1.28	1.33	1.38	1.43	1.49	1.56	1.64
	90	1.24	1.29	1.34	1.40	1.46	1.52	1.60	1.69	1.79

In table 5.15 , the results are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 600 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 600 lux).

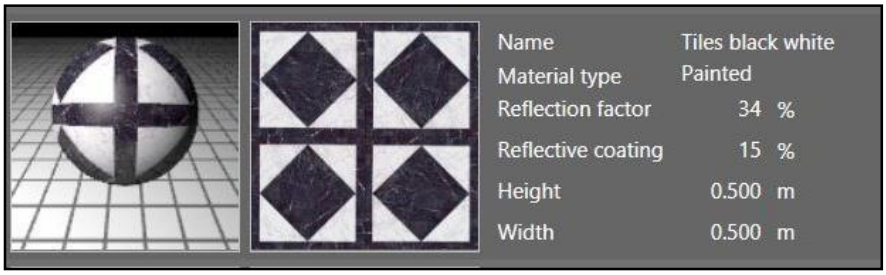
- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 600 Lux) .

5.3.2 Calculated results of the Model with different materials coat reflectance

As mentioned previously in chapter 4 , the researcher will test 2 different materials coat reflectance to be applied on two walls only , model (A) which is the small office has been selected to evaluate the simulation , the simulation is based on the base case values of the floor 20 % , and the ceiling 70 % .

The walls reflectance value will be detected from the selected material from Dialux software catalogue for both simulations, the first material reflectance value is 34 % as shown in figure 5.7 (1) below, and the coat reflectance is 15% . The second material has a reflectance value of 16%, and a coat reflectance of 98 % as showed in figure 5.7 (B).

(1)



(2)

Figure 5.7 : Selected material (1,2) for simulations
(Source: Author through Dialux software,2018)

The results will be comparing with the values that resulted from assigning the reflectance value for the material regardless the coat reflectance for both materials.

1- Results of assigning material (1)

In this case, the selected material was applied on two walls from the four walls in the office as shown below in figure 5.8 .

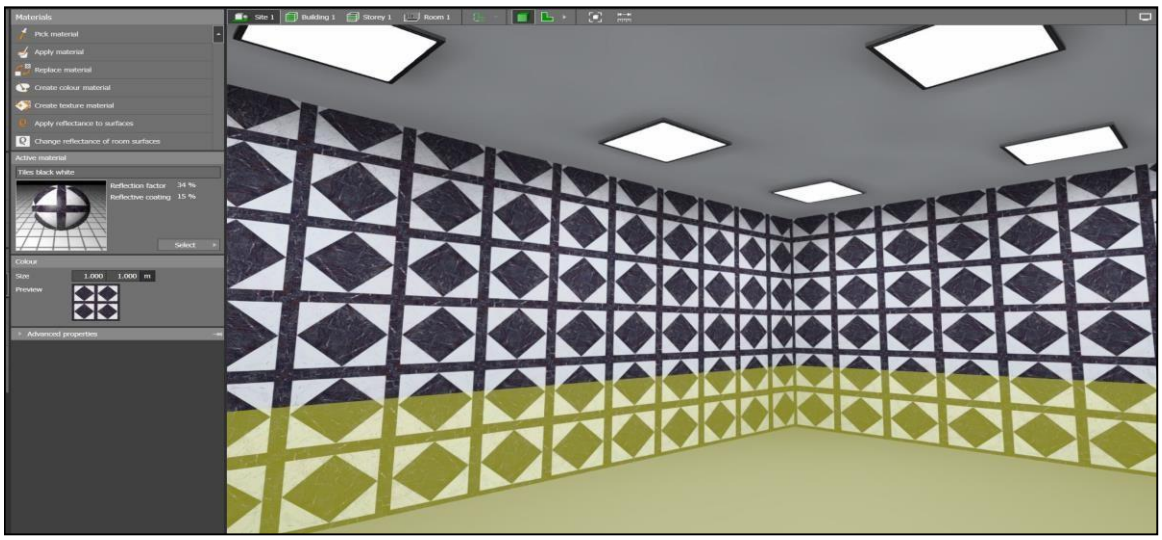


Figure 5.8 : Assigning material (1) on model A for simulations
(Source: Author through Dialux software,2018)

By running the calculation for the inserted material, the resulted value of illumination is 553 lx , as shown below in figure 5.9 .

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	553 (≥ 500)	296	711	0.54	0.42

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.12 W/m²/100 lx (Floor area of room 19.44 m²)

Figure 5.9: calculation of assigned material (1) on model A
(Source: Author through Dialux software,2018)

To evaluate the resulted value, the researcher simulate the percentages regardless the glossiness of the material , as ceiling reflectance is 70% , flooring 20% , walls 34 % ,the simulation gives a value of 550 lx .

Comparing the results of simulation with material glossiness and without assigning the glossiness parameter , it was found that although in both cases the walls have the same reflectance factor which is 34 % , the walls with glossy coating is giving higher value in the illumination which is 553 lx , versus 550 lx for the same wall reflectance with ignoring the glossiness.

2- Results of assigning material (2)

In this case, the selected material was applied on two walls in the office as shown below in figure 5.10.

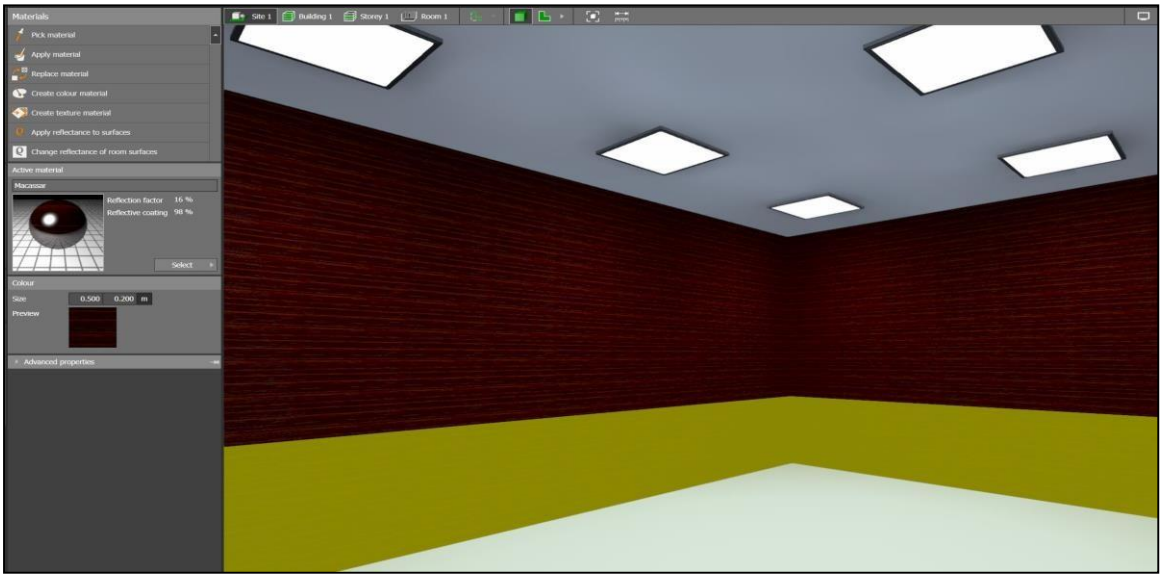


Figure 5.10 : Assigning material (2) on model A for simulations
(Source: Author through Dialux software,2018)

By running the calculation for the inserted material, the resulted value of illumination is 532 lx , as shown below in figure 5.11.

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	532 (≥ 500)	279	692	0.52	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.20 W/m²/100 lx (Floor area of room 19.44 m²)

Figure 5.11 : Assigning material (2) on model A for simulations
(Source: Author through Dialux software,2018)

To evaluate the resulted value , the researcher simulate the percentages regardless the glossiness of the material , as ceiling reflectance is 70% , flooring 20% , walls 16 % ,the simulation gives a value of 505 lx ,

Comparing the results of simulation with material glossiness and without assigning the glossiness parameter , it was found that although in both cases the walls have the same reflectance factor which is 34 % , the walls with glossy coating is giving higher value in the illumination which is 532 lx , versus 505 lx for the same wall reflectance with ignoring the glossiness.

- Results of assigned material (1) and (2)

Although the materials in case (1) are having the same the same wall reflectance which is 34%, the material which was used with a coat reflectance of 15% has increased the illumination by 3 lx, from 550 to 553 , which it seems to be small in value but it shows that the coat reflectance has an effect on increasing the illumination in the area .

Moreover, in case (2) the used material regardless the glossiness has a wall reflectance of 16 % gives the value of 505 lx , and the used material with the coat reflectance of 98% has the same wall reflectance value (16 %) which gives an illumination result of 532 lx . That shows the increasing of 27 lx (532 – 505) as a result of using reflective coat finishing (glossy material) . Thus, the coat material reflective value has an impact on the illumination in the space of the work plan

5.4 Result and Discussion of model B – base case

The base case model is created based on the standard surfaces reflectance values which are: 70 % reflectance for the ceiling, 50 % reflectance for the walls, 20% for the flooring. By inserting those values into the Dialux created model , the program will calculate the result based on the dimension of the model which is : Width 15 meters , Length 30 meters , Height 3.2 meters , with a work plane height of 80 cm from the finished floor level , in addition to the selected luminaire properties and number which equals 90 luminaries within the model area .

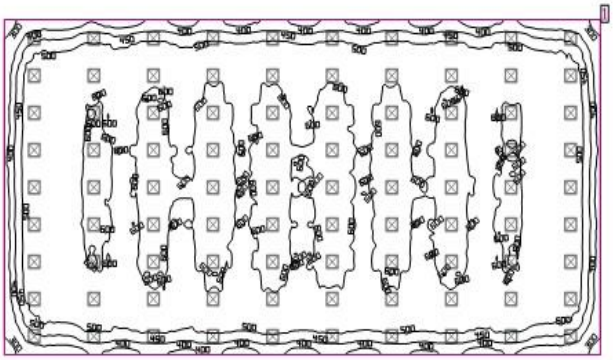
Figure 5.12 is showing the result of Dialux simulation for the base case model .

Project 2 9/13/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 20.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	551 (≥ 500)	257	628	0.47	0.41

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.38 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure 5.12 : Dialux calculation results for model B base case

(Source: Author through Dialux software, 2018)

The Figure 5.7 above is showing the calculated illumination in lux based on the inserted parameters for the model, the result is 551 lx, which is more than the normal standard for offices and place work plane illumination.

5.5 Result and Discussion of model B with different Reflectance percentages

As mentioned earliest in chapter 4 , the model will be tested with a changed parameters of reflectance's for the finishing surfaces of interiors , it will pass by 9 different reflectances for ceiling , and 9 reflectances for the walls , with 5 reflectances for the flooring .

The simulation will end with 450 different values of illumination in (lx) , those results will clarify and show the impact of each surface reflectance on the interior space illumination specially on the work plan zone .

5.5.1 Calculated results from Dialux Software for model B (Large office)

Table 5.16 : Dialux calculation with constant floor reflectance of 5% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	468	470	471	473	474	476	478	479	481
	15	472	474	476	478	479	481	483	485	487
	25	477	479	481	483	485	488	490	492	494
	35	481	484	486	489	491	494	497	500	503
	45	486	489	492	495	498	502	505	508	512
	55	491	494	498	502	506	509	513	518	522
	65	496	500	505	509	513	518	522	527	532
	75	502	507	511	516	521	526	531	537	542
	85	508	513	518	524	529	535	541	547	554
	90	510	516	522	528	534	540	546	553	560

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 5 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 %, added to the walls surface reflectance percentage from 5 % to 90 % . The highest values is occurred when the wall and ceiling reflectance are high percentages.

Figure 5.13 is showing an increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 5%.

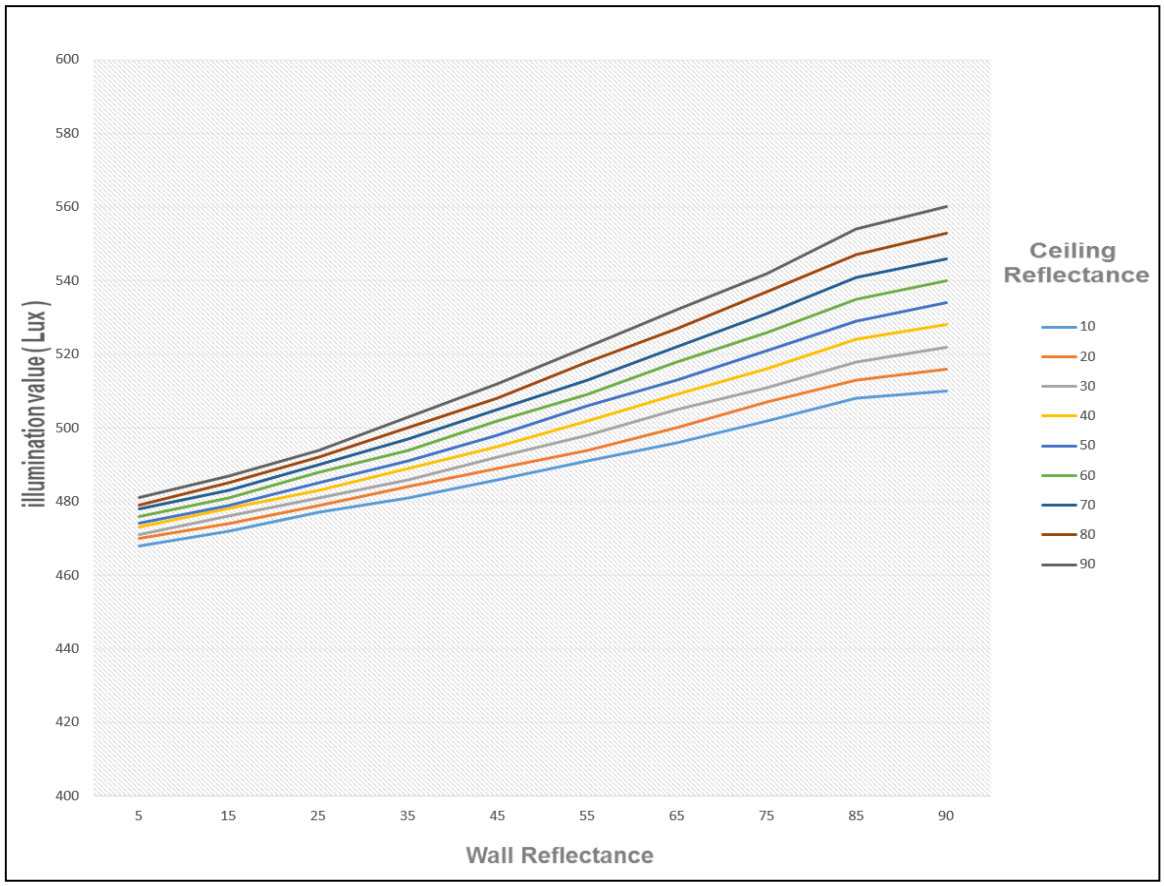


Figure 5.13 : Excel Chart for Dialux model with constant floor reflectance of 5%

(Source: Author through Excel software, 2018)

At the floor reflectance 45% ,and by increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 2 to 7 lx , while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination only from 4 to 6 lx , as those are considered as small values with changing the reflectance values of ceiling and walls.

The researcher has divided all the values in table 5.16 by the lowest result, which is 468 lux to show the amount of illumination increasing in clear way .

Table 5.17 : calculation with constant floor reflectance of 5%- values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03
	15	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04	1.04
	25	1.02	1.02	1.03	1.03	1.04	1.04	1.05	1.05	1.06
	35	1.03	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.07
	45	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.09	1.09
	55	1.05	1.06	1.06	1.07	1.08	1.09	1.10	1.11	1.12
	65	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14
	75	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.15	1.16
	85	1.09	1.10	1.11	1.12	1.13	1.14	1.16	1.17	1.18
	90	1.09	1.10	1.12	1.13	1.14	1.15	1.17	1.18	1.20

By dividing the highest result in table 5.16 by the lowest result (560 ÷ 468), it resulted with a 1.20 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination only by 20 % , based on the lowest value (468 lx) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% .

Table 5.18: Dialux calculation with constant floor reflectance of 5% divided by the base case value (70%,50%,20%), (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
5%		10	20	30	40	50	60	70	80	90
	5	0.01	0.85	0.85	0.85	0.86	0.86	0.86	0.87	0.87
	15	0.03	0.86	0.86	0.86	0.87	0.87	0.87	0.88	0.88
	25	0.05	0.87	0.87	0.87	0.88	0.88	0.89	0.89	0.89
	35	0.06	0.87	0.88	0.88	0.89	0.89	0.90	0.90	0.91
	45	0.08	0.88	0.89	0.89	0.90	0.90	0.91	0.92	0.92
	55	0.10	0.89	0.90	0.90	0.91	0.92	0.92	0.93	0.94
	65	0.12	0.90	0.91	0.92	0.92	0.93	0.94	0.95	0.96
	75	0.14	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.97
	85	0.15	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
	90	0.16	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00

In table 5.18 , the results are divided by two categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 551 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 551 lux).

As shown in table 5.18, it is clear that the increasing in illumination is addressed by only small amount which might not be visible at the work plan illumination.

Table 5.19: Dialux calculation with constant floor reflectance of 15% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
15%		10	20	30	40	50	60	70	80	90
	5	471	476	480	485	489	493	498	503	508
	15	476	480	485	490	495	500	506	511	517
	25	480	485	491	496	502	508	514	520	526
	35	485	491	497	503	509	516	522	529	536
	45	490	497	504	510	517	524	531	539	547
	55	496	503	511	518	526	533	541	550	559
	65	503	510	518	526	535	543	552	562	572
	75	509	517	526	535	544	554	564	574	586
	85	515	524	534	544	554	565	576	588	601
	90	519	528	538	548	559	571	583	596	610

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 15 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 %, added to the walls surface reflectance percentage from 5 % to 90 %. The highest values is occurred when the wall and ceiling reflectance are high percentage (90%).

Figure 5.14 is showing an increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 15%

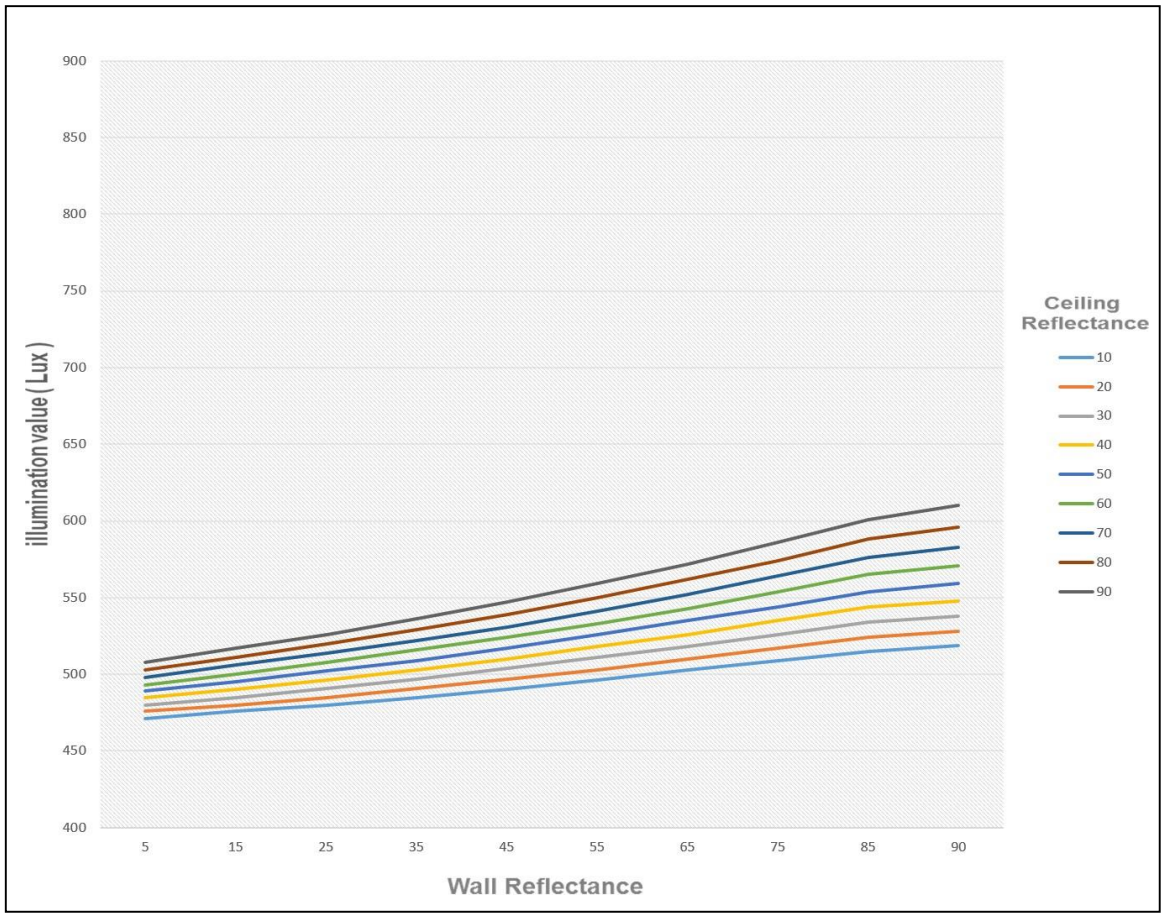


Figure 5.14 : Excel Chart for Dialux model with constant floor reflectance of 15%

(Source: Author through Excel software, 2018)

At the floor reflectance 15% ,and by increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 5 to 14 lx , while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination only from 5 to 9 lx , as those are considered as small values with changing the reflectance values of ceiling and walls.

The researcher has divided all the values in table 5.19 by the lowest result, which is 471 lx to show the amount of illumination increasing in clear way.

Table 5.20 : calculation with constant floor reflectance of 15%- values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
15%		10	20	30	40	50	60	70	80	90
	5	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08
	15	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10
	25	1.02	1.03	1.04	1.05	1.07	1.08	1.09	1.10	1.12
	35	1.03	1.04	1.06	1.07	1.08	1.10	1.11	1.12	1.14
	45	1.04	1.06	1.07	1.08	1.10	1.11	1.13	1.14	1.16
	55	1.05	1.07	1.08	1.10	1.12	1.13	1.15	1.17	1.19
	65	1.07	1.08	1.10	1.12	1.14	1.15	1.17	1.19	1.21
	75	1.08	1.10	1.12	1.14	1.15	1.18	1.20	1.22	1.24
	85	1.09	1.11	1.13	1.15	1.18	1.20	1.22	1.25	1.28
	90	1.10	1.12	1.14	1.16	1.19	1.21	1.24	1.27	1.30

By dividing the highest result in table 5.19 by the lowest result (610 ÷ 471), it resulted with a 1.30 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 30 % , based on the lowest value (471 lx) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% .

Table 5.21: Dialux calculation with constant floor reflectance of 15% divided by the base case value (70%,50%,20%), (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
15%		10	20	30	40	50	60	70	80	90
	5	0.01	0.85	0.86	0.87	0.88	0.89	0.89	0.90	0.91
	15	0.03	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93
	25	0.05	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94
	35	0.06	0.88	0.89	0.90	0.91	0.92	0.94	0.95	0.96
	45	0.08	0.89	0.90	0.91	0.93	0.94	0.95	0.96	0.98
	55	0.10	0.90	0.91	0.93	0.94	0.95	0.97	0.98	1.00
	65	0.12	0.91	0.93	0.94	0.95	0.97	0.99	1.00	1.02
	75	0.14	0.92	0.94	0.95	0.97	0.99	1.01	1.02	1.04
	85	0.15	0.93	0.95	0.97	0.99	1.01	1.03	1.05	1.07
	90	0.16	0.94	0.96	0.98	0.99	1.01	1.04	1.06	1.08

In table 5.21 , the results are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 551 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 551 lux).

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 551 Lux), which was addressed in some percentages in the table from 1 to 6 % as an increasing in illumination.

As shown in table 5.21, it is clear that the increasing in illumination is addressed by only small amount, which might not be visible at the work plan illumination.

Table 5.22 : Dialux calculation with constant floor reflectance of 25% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
25%		10	20	30	40	50	60	70	80	90
	5	474	482	489	496	504	513	521	530	538
	15	479	487	495	503	512	521	530	539	549
	25	484	493	501	511	520	529	539	550	560
	35	490	499	509	518	528	539	549	561	573
	45	496	506	516	526	537	549	561	573	587
	55	502	513	524	535	547	560	573	587	602
	65	509	521	532	545	558	572	586	602	618
	75	516	528	541	555	569	584	601	618	638
	85	523	536	550	565	581	598	617	637	658
	90	527	541	555	571	588	606	626	646	669

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 25 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 %, added to the walls surface reflectance percentage from 5 % to 90 %. The highest value is occurred when the wall and ceiling reflectance are high percentage (90%).

Figure 5.15 is showing an increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 25%

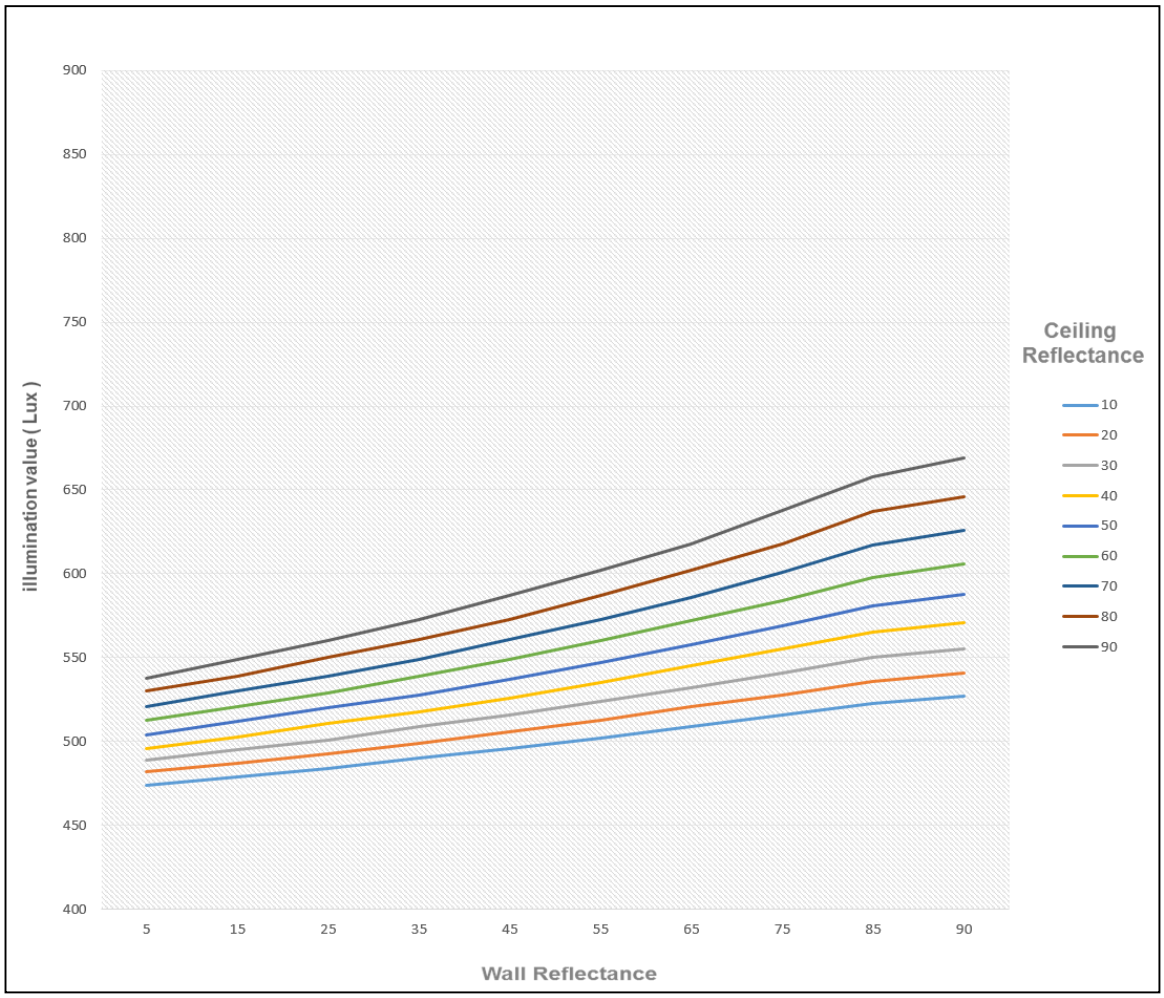


Figure 5.15 : Excel Chart for Dialux model with constant floor reflectance of 25%

(Source: Author through Excel software, 2018)

At the floor reflectance 25% ,and by increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 8 to 23 lx , while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination only from 5 to 11 lx , as those are considered as small values with changing the reflectance values of ceiling and walls.

The researcher has divided all the values in table 5.22 by the lowest result, which is 471 lx to show the amount of illumination increasing in clear way.

Table 5.23 : calculation with constant floor reflectance of 25%- values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
25%		10	20	30	40	50	60	70	80	90
	5	1.00	1.02	1.03	1.05	1.06	1.08	1.10	1.12	1.14
	15	1.01	1.03	1.04	1.06	1.08	1.10	1.12	1.14	1.16
	25	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18
	35	1.03	1.05	1.07	1.09	1.11	1.14	1.16	1.18	1.21
	45	1.05	1.07	1.09	1.11	1.13	1.16	1.18	1.21	1.24
	55	1.06	1.08	1.11	1.13	1.15	1.18	1.21	1.24	1.27
	65	1.07	1.10	1.12	1.15	1.18	1.21	1.24	1.27	1.30
	75	1.09	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.35
	85	1.10	1.13	1.16	1.19	1.23	1.26	1.30	1.34	1.39
	90	1.11	1.14	1.17	1.20	1.24	1.28	1.32	1.36	1.41

By dividing the highest result in table 5.22 by the lowest result (669 ÷ 474), it resulted with a 1.41 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 41 % , based on the lowest value (471 lx) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% .

Table 5.24: Dialux calculation with constant floor reflectance of 25% divided by the base case value (70%,50%,20%), (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
25%		10	20	30	40	50	60	70	80	90
	5	0.01	0.86	0.87	0.89	0.90	0.91	0.93	0.95	0.96
	15	0.03	0.87	0.88	0.90	0.91	0.93	0.95	0.96	0.98
	25	0.05	0.88	0.89	0.91	0.93	0.94	0.96	0.98	1.00
	35	0.06	0.89	0.91	0.92	0.94	0.96	0.98	1.00	1.02
	45	0.08	0.90	0.92	0.94	0.95	0.97	1.00	1.02	1.04
	55	0.10	0.91	0.93	0.95	0.97	0.99	1.02	1.04	1.07
	65	0.12	0.92	0.95	0.97	0.99	1.01	1.04	1.06	1.09
	75	0.14	0.94	0.96	0.98	1.01	1.03	1.06	1.09	1.12
	85	0.15	0.95	0.97	1.00	1.03	1.05	1.09	1.12	1.16
	90	0.16	0.96	0.98	1.01	1.04	1.07	1.10	1.14	1.17

The results in the table above are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 551 lux).

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 551 lux).

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 551 Lux), which was addressed in some percentages in the table from 1 to 17 % as an increasing in illumination.

As shown in table 5.24, it is clear that the increasing in illumination was addressed by only small amount, which might not be visible at the work plan illumination.

Table 5.25 : Dialux calculation with constant floor reflectance of 35% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
35%		10	20	30	40	50	60	70	80	90
	5	478	488	498	509	521	533	546	559	573
	15	483	494	505	517	529	542	556	570	585
	25	488	500	513	525	538	553	567	583	600
	35	494	507	520	534	548	564	580	597	616
	45	501	514	528	543	559	576	594	613	633
	55	509	523	537	554	571	589	609	630	654
	65	516	531	547	565	583	604	625	650	675
	75	523	540	557	576	597	619	644	671	697
	85	531	549	568	589	612	637	664	693	725
	90	536	554	574	596	620	646	675	706	739

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 35 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 %, added to the walls surface reflectance percentage from 5 % to 90 %. The highest value is occurred when the wall and ceiling reflectance are high percentage (90%).

Figure 5.15 is showing an increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 35%

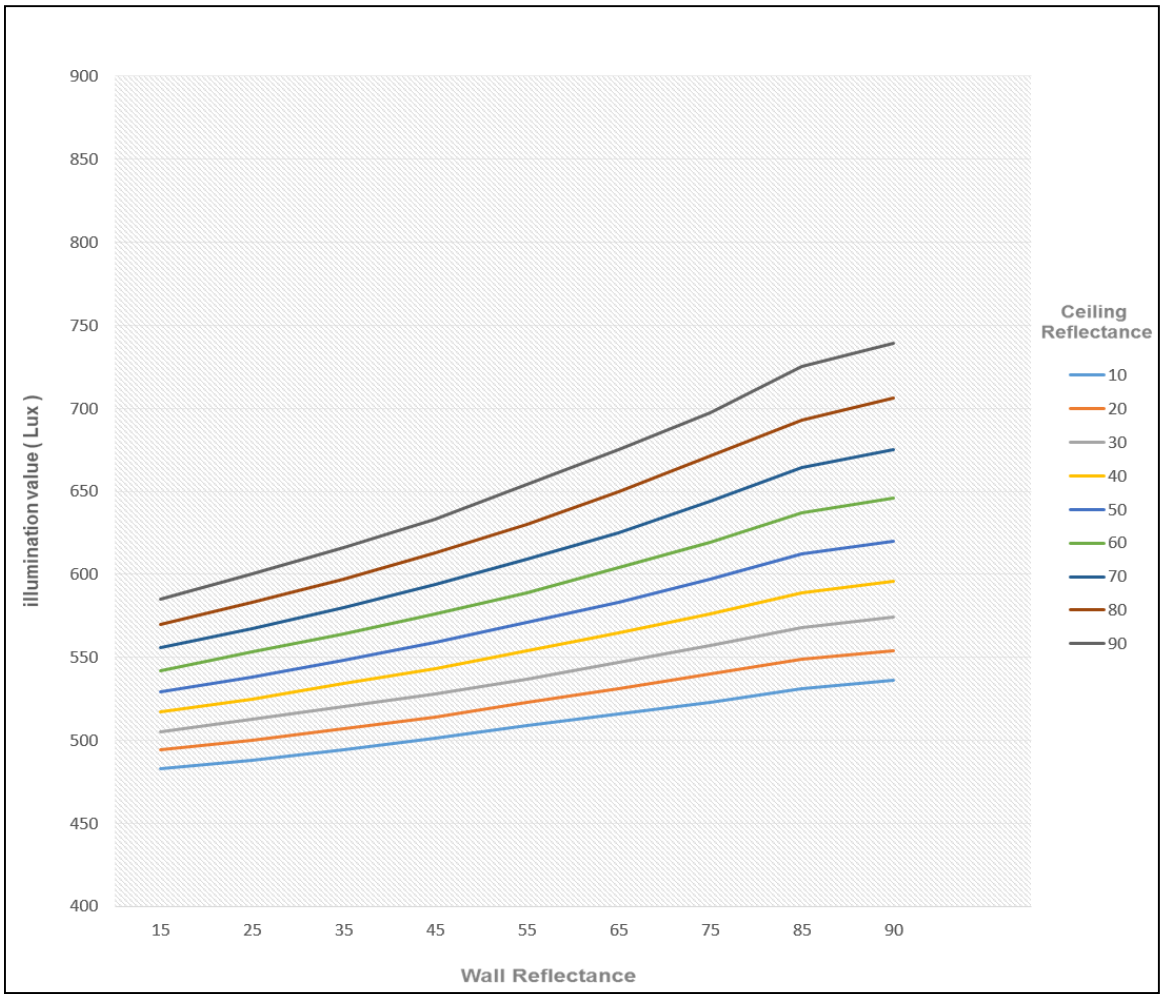


Figure 5.16 : Excel Chart for Dialux model with constant floor reflectance of 35%

(Source: Author through Excel software, 2018)

At the floor reflectance 35% ,and by increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 10 to 33 lx , while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination only from 5 to 17 lx , as shown the ceiling reflectance in this case has the larger impact on the illumination than the wall .

The researcher has divided all the values in table 5.25 by the lowest result, which is 478 lx to show the amount of illumination increasing in clear way.

Table 5.26 : calculation with constant floor reflectance of 35% - values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
35%		10	20	30	40	50	60	70	80	90
	5	1.00	1.02	1.04	1.06	1.09	1.12	1.14	1.17	1.20
	15	1.01	1.03	1.06	1.08	1.11	1.13	1.16	1.19	1.22
	25	1.02	1.05	1.07	1.10	1.13	1.16	1.19	1.22	1.26
	35	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.25	1.29
	45	1.05	1.08	1.10	1.14	1.17	1.21	1.24	1.28	1.32
	55	1.06	1.09	1.12	1.16	1.19	1.23	1.27	1.32	1.37
	65	1.08	1.11	1.14	1.18	1.22	1.26	1.31	1.36	1.41
	75	1.09	1.13	1.17	1.21	1.25	1.29	1.35	1.40	1.46
	85	1.11	1.15	1.19	1.23	1.28	1.33	1.39	1.45	1.52
	90	1.12	1.16	1.20	1.25	1.30	1.35	1.41	1.48	1.55

By dividing the highest result in table 5.25 by the lowest result (739 ÷ 478), it resulted with a 1.55 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 55 % , based on the lowest value (478 lx) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% .

Table 5.27: Dialux calculation with constant floor reflectance of 35% divided by the base case value (70%,50%,20%), (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
35%		10	20	30	40	50	60	70	80	90
	5	0.01	0.87	0.89	0.90	0.92	0.95	0.97	0.99	1.01
	15	0.03	0.88	0.90	0.92	0.94	0.96	0.98	1.01	1.03
	25	0.05	0.89	0.91	0.93	0.95	0.98	1.00	1.03	1.06
	35	0.06	0.90	0.92	0.94	0.97	0.99	1.02	1.05	1.08
	45	0.08	0.91	0.93	0.96	0.99	1.01	1.05	1.08	1.11
	55	0.10	0.92	0.95	0.97	1.01	1.04	1.07	1.11	1.14
	65	0.12	0.94	0.96	0.99	1.03	1.06	1.10	1.13	1.18
	75	0.14	0.95	0.98	1.01	1.05	1.08	1.12	1.17	1.22
	85	0.15	0.96	1.00	1.03	1.07	1.11	1.16	1.21	1.26
	90	0.16	0.97	1.01	1.04	1.08	1.13	1.17	1.23	1.28

The results in the table above are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 551 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 551 lux).

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 551 Lux), which was addressed in some percentages in the table from 1 to 28 % as an increasing in illumination.

Table 5.28 : Dialux calculation with constant floor reflectance of 45% (lux)

(Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
45%		10	20	30	40	50	60	70	80	90
	5	481	494	508	523	539	555	573	592	612
	15	486	501	516	531	548	566	585	606	628
	25	493	508	523	540	559	578	599	622	646
	35	500	516	532	551	570	591	614	640	666
	45	507	524	542	562	583	606	631	659	688
	55	515	533	552	574	597	622	651	680	712
	65	523	542	563	586	612	640	672	703	740
	75	531	552	575	600	629	660	692	730	772
	85	540	563	588	616	646	681	718	760	808
	90	545	568	595	624	656	693	731	777	828

The table above is showing the calculated results at a fixed reflectance percentage for the flooring: 35 %, and a surface reflectance percentage for the ceiling in the ranges between 10 and 90 %, added to the walls surface reflectance percentage from 5 % to 90 %. The highest value is occurred when the wall and ceiling reflectance are high percentage (90%).

Figure 5.17 is showing an increasing in the illuminance level with changing the reflectance percentage of the ceiling and walls with the fixed percentage of the floor: 45%

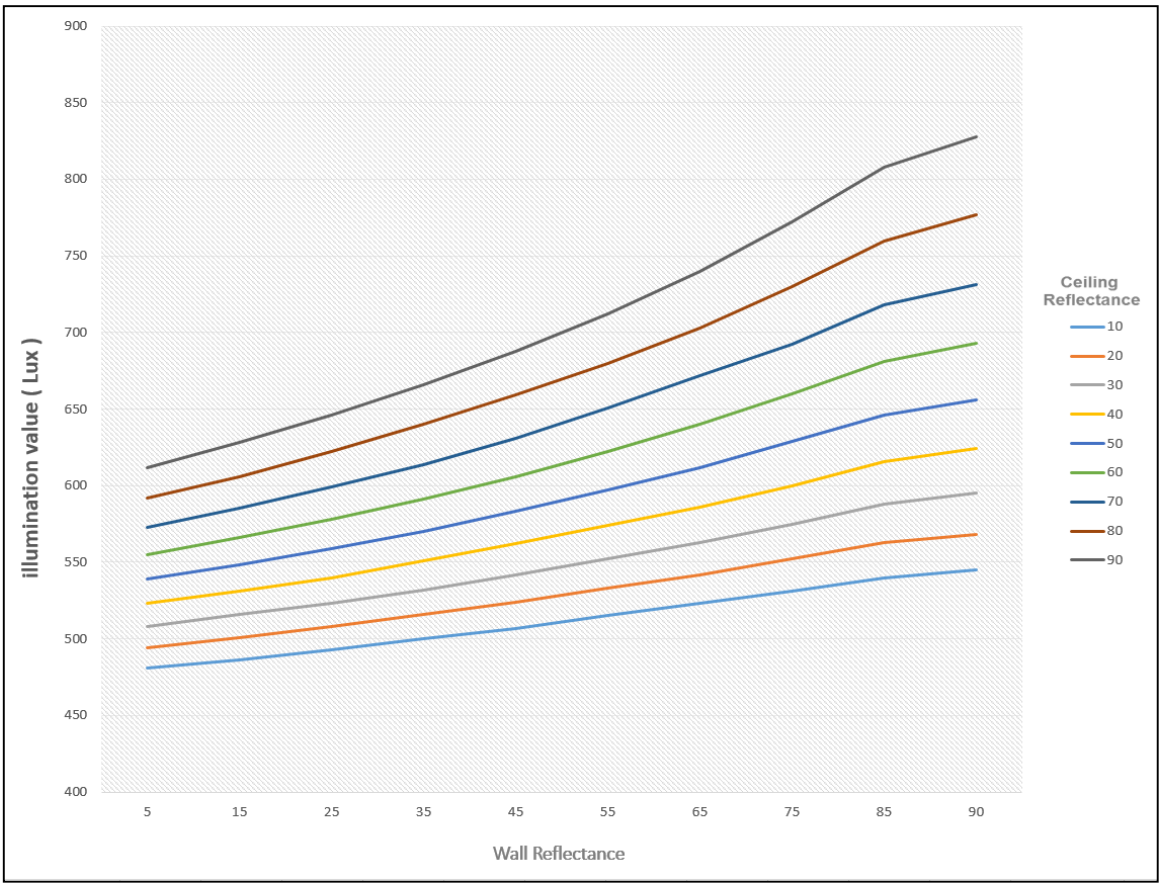


Figure 5.17 : Excel Chart for Dialux model with constant floor reflectance of 45%

(Source: Author through Excel software, 2018)

At the floor reflectance 45% ,and by increasing each 10 % in ceiling reflectance with a constant reflectance of wall , the illumination level at the work plan is increased between 13 to 51 lx , while in the wall reflectance each increase of 10 % (with a constant ceiling reflectance percentage) is maximize the level of illumination only from 5 to 20 lx , as shown the ceiling reflectance in this case has the larger impact on the illumination than the wall .

The researcher has divided all the values in table 5.28 by the lowest result, which is 481 lx to show the amount of illumination increasing in clear way.

Table 5.29 : calculation with constant floor reflectance of 45% - values divided by lowest value (Source: Author through Excel software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
45%		10	20	30	40	50	60	70	80	90
	5	1.00	1.03	1.06	1.09	1.12	1.15	1.19	1.23	1.27
	15	1.01	1.04	1.07	1.10	1.14	1.18	1.22	1.26	1.31
	25	1.02	1.06	1.09	1.12	1.16	1.20	1.25	1.29	1.34
	35	1.04	1.07	1.11	1.15	1.19	1.23	1.28	1.33	1.38
	45	1.05	1.09	1.13	1.17	1.21	1.26	1.31	1.37	1.43
	55	1.07	1.11	1.15	1.19	1.24	1.29	1.35	1.41	1.48
	65	1.09	1.13	1.17	1.22	1.27	1.33	1.40	1.46	1.54
	75	1.10	1.15	1.20	1.25	1.31	1.37	1.44	1.52	1.60
	85	1.12	1.17	1.22	1.28	1.34	1.42	1.49	1.58	1.68
	90	1.13	1.18	1.24	1.30	1.36	1.44	1.52	1.62	1.72

By dividing the highest result in table 5.28 by the lowest result (828 ÷ 481), it resulted with a 1.72 versus 1.0 for the lowest value , which means that the changing in surface reflectance's for the walls and ceiling when they reached 90% percentage of surface reflectance is increased the illumination by 72 % , based on the lowest value (481 lx) which occurred when the ceiling reflectance is 10% and walls reflectance is 5% .

Table 5.30: Dialux calculation with constant floor reflectance of 45% divided by the base case value (70%,50%,20%), (Source: Author through Dialux software, 2018)

Floor Reflectance	Wall reflectance	Ceiling reflectance								
45%		10	20	30	40	50	60	70	80	90
	5	0.87	0.90	0.92	0.95	0.98	1.01	1.04	1.07	1.11
	15	0.88	0.91	0.94	0.96	0.99	1.03	1.06	1.10	1.14
	25	0.89	0.92	0.95	0.98	1.01	1.05	1.09	1.13	1.17
	35	0.91	0.94	0.97	1.00	1.03	1.07	1.11	1.16	1.21
	45	0.92	0.95	0.98	1.02	1.06	1.10	1.15	1.20	1.25
	55	0.93	0.97	1.00	1.04	1.08	1.13	1.18	1.23	1.29
	65	0.95	0.98	1.02	1.06	1.11	1.16	1.22	1.28	1.34
	75	0.96	1.00	1.04	1.09	1.14	1.20	1.26	1.32	1.40
	85	0.98	1.02	1.07	1.12	1.17	1.24	1.30	1.38	1.47
	90	0.99	1.03	1.08	1.13	1.19	1.26	1.33	1.41	1.50

The results in the table above are divided by three categories which are :

-Category (1) is between 0 < 1, which means that the lux values in certain reflectances are less that the value of lux in base case (less than 551 lux) .

- Category (2) is = 1, that means the resulted value of lux at some reflectances is equal and near to the base case value (equal 551 lux).

- Category (3) is > 1, which means that the resulted value of lux at some reflectances is greater than the base case value (more than 551 Lux), which was addressed in some percentages in the table from 1 to 50 % as an increasing in illumination.

Chapter 6: Research Conclusion

6.1 Final Results and discussion

The tested scenarios were taken to identify the relationship between the work plane illumination and the surface reflectance parameter.

- the resulted scenario for model A which is a small office space (Length 3 x Width 5 x Height 2.8 meters) gave 450 different simulated result, those results have addressed a high illumination value on the work plane in the case of high wall reflectance .

- added to that, the test of applying coat with certain reflectance has an impact on the illumination, as it increased by 4 lux by using a material with reflectance factor of 34% , and coat reflectance of 15% for material (1) .

By using material (2) which has surface reflectance value of 16% , and coat reflectance factor of 98% , the illuminance has been increased by 34 lux .

- The model (B) which is a large office space (Length 30 x Width 15 x Height 3.2 meters) shows increasing in the illumination by having a high reflectance values for the walls and ceiling .

- The result for the small office space (model A) showed that the maximum illuminance increasing by wall reflectance is in the ranges between 16 – 89 lux, while the illuminance levels after raising ceiling reflectance are between 4 – 61 lux as an increasing , which is clearly state that the wall reflectance parameter has the largest impact on increasing the illumination of the work plane zone in the small office .

- The result for the large office space (model B) showed that the maximum illuminance increasing by wall reflectance is in the ranges between 5 – 20 lux, while the illuminance levels after raising ceiling reflectance are between 13 – 51 lux as an increasing , which is clearly state that the ceiling reflectance parameter has the largest impact on increasing the illumination of the work plane zone in the large office

6.2 Conclusion

The design of indoor lighting mainly focuses on illuminance for the work plane and pays little attention to variation of reflection factor of room surfaces on the final outcome . Recently, the importance of indirect illuminance is been raised due to its criticality to be designed based on the functions and to ensure a high visual task performance. Especially, the prospect application of well lighting design for the offices in the built environment sets a challenging requirement on the level of direct illuminance within the daytime.

Lighting system with a good design just provides the right light amount for its proposed application, as the less light levels produce poor performance and productivity, but more light levels resulted with wasted energy.

As a starting point, the lighting designers utilize photometric information of the proposed fixtures. For the stage of calculation, they concentrate on the location of the project, outdoor or indoor, and the environmental situations as a dirt and temperature.

The lighting calculation purpose is to reach and investigate a proper level of illuminance for the desired functions and application . The illuminance concept characterizes the delivered lighting per unit of the area, it is measured typically in foot-candles (lumens per each square foot) or lux (lumens per each square meter)

The objective of this work is to develop easy-to-use methods to guide work plane lighting design and explore new important approach to enhance indirect work plane illuminance effectively. By summarizing the most significant contributions they are as follows:

● It is proved that the reflectance of surfaces has a large impact on the illuminance of the space ,which clearly answers the research question 1: Is there a strong relationship between surface reflectance and illumination in the interior space ?

● Improving of the surface reflectance approach has noteworthy preferences over different techniques like the initial increasing in flux from the luminaire (artificial lighting) , without the need of additional cost of energy or a serious re-construction (expanding the area of the window , ceiling lightings fixing).

The relationship between surface reflectance and illuminance is strong since the reflectance of surfaces plays a role in increasing the illuminance level within the space . Thus , it must be attention for this parameter to be used as a guide line if the increasing of the lighting level is necessary .

6.3 Future work

This research produces a base and foundation for studies in the future that covers the same topic in nemours areas within the office spaces and work places,

Suggestions for studies and researches in the future include:

1. Conducting similar studies and researches on other offices types which have similar problems that have been identified, as listed in this study
2. Scouting the establishing possibility of a unified office lighting design code which includes the previous tested parameters .
3. Investigating an alternative system of lighting which can offer sustainability superior features in terms of provide comfortable work lighting with energy saving .
4. Study indirect lighting .
5. Study surface specularity for its importance as a light diffuser or absorber .
6. It will be important to study the non uniform wall reflectance to address the impacts on the illumination .

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Appendix (A)

Appendix (A): Model (A) documentation for different surface reflectance simulations .

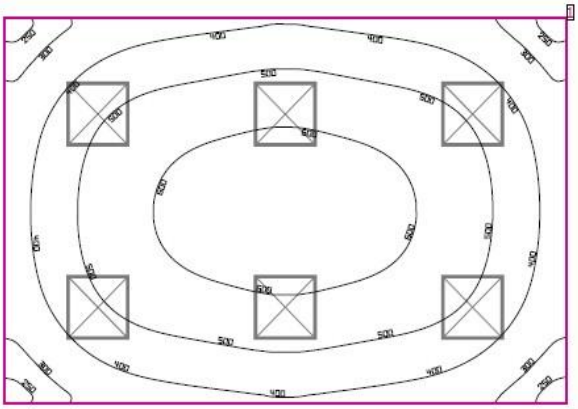
(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 5.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	479 (≥ 500)	227	650	0.47	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.45 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

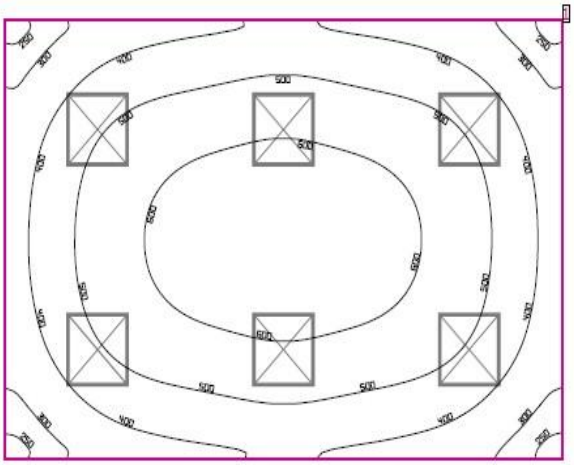
Figure A.1 : Model A simulation c90-w5-f5

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 15.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	485 (≥ 500)	231	657	0.48	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.42 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.2 : Model A simulation c90-w5-f15

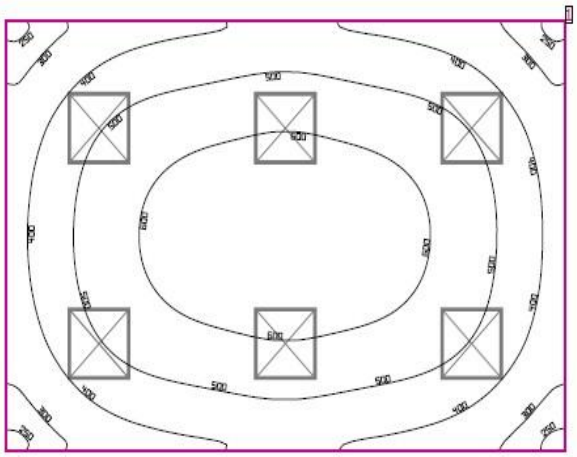
(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 25.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	490 (≥ 500)	235	665	0.48	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.39 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.3 : Model A simulation c90-w5-f25

(Source : Author through DIALux evo , 2018)

Project 1 6/22/2018

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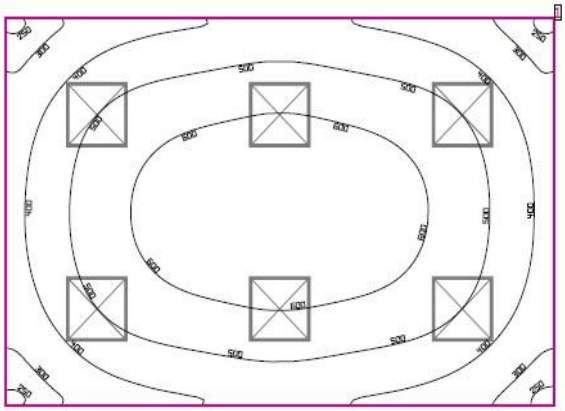
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 35.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	495 (≥ 500)	235	672	0.47	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.37 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.4 : Model A simulation c90-w5-f35

(Source : Author through DIALux evo , 2018)

Project 1 6/22/2018

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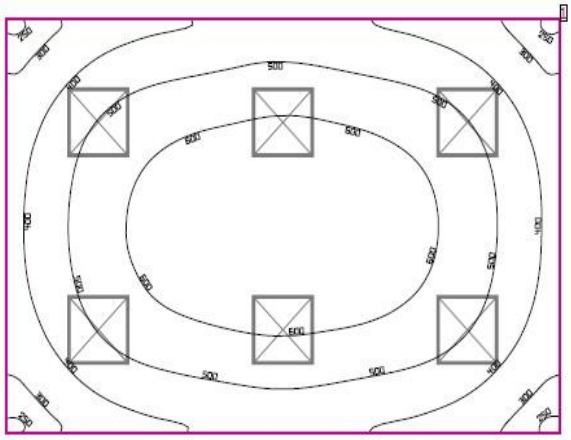
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 45.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	501 (≥ 500)	239	679	0.48	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.34 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.5 : Model A simulation c90-w5-f45

(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

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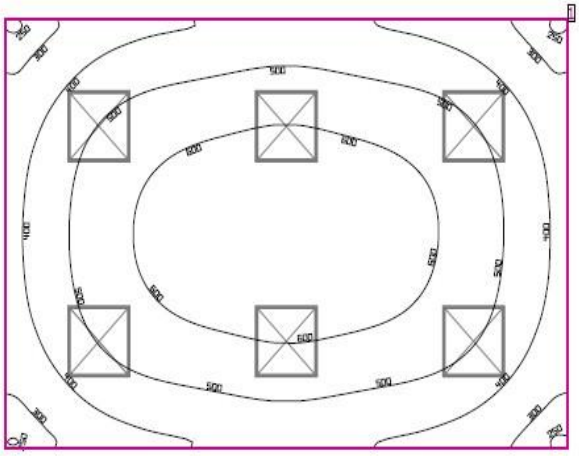
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 5.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	499 (≥ 500)	243	667	0.49	0.36

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.35 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.6 : Model A simulation c90-w15-f 5

(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

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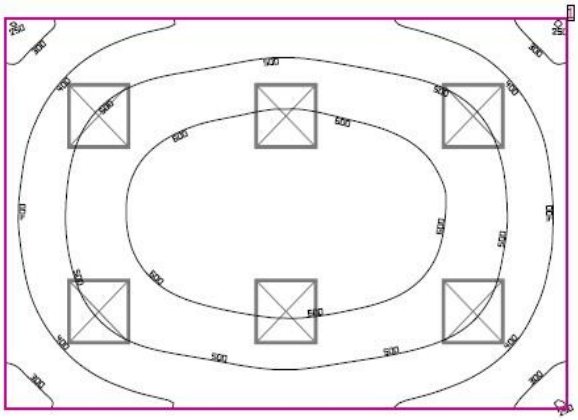
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 15.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	506 (≥ 500)	248	676	0.49	0.37

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.32 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.7 : Model A simulation c90-w15-f 15

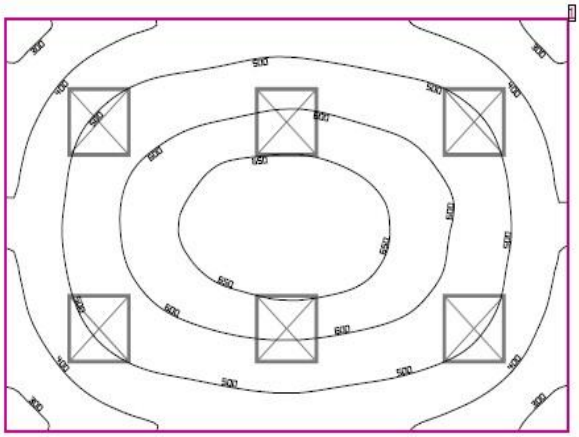
(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 25.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	512 (≥ 500)	253	684	0.49	0.37

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.29 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.8 : Model A simulation c90-w15-f 25

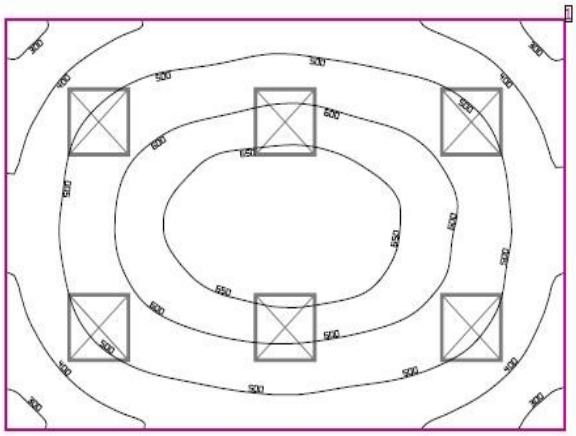
(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 35.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	519 (≥ 500)	258	692	0.50	0.37

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.26 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.9 : Model A simulation c90-w15-f 35

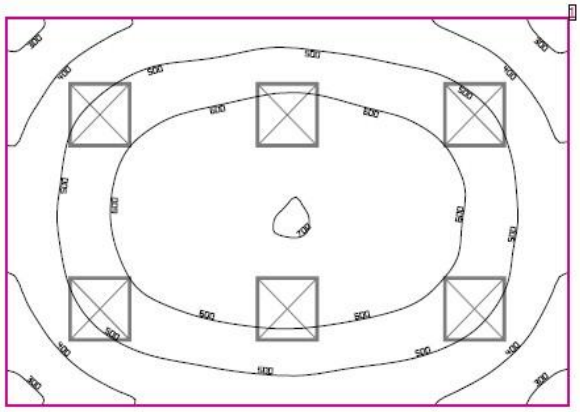
(Source : Author through DIALux evo , 2018)

Project 1 6/22/2018

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

DIALux

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 45.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	526 (≥ 500)	262	701	0.50	0.37

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.23 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.10 : Model A simulation c90-w15-f 45

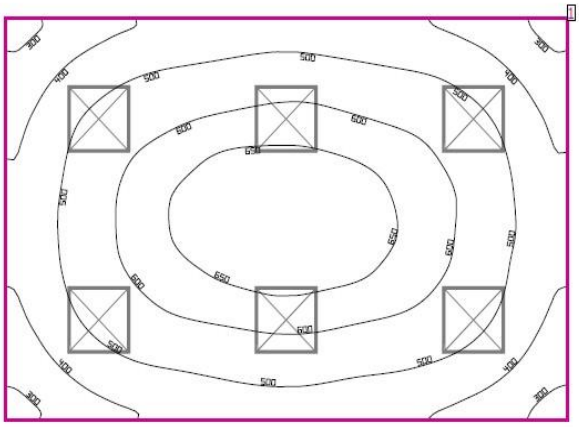
(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 5.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	521 (≥ 500)	265	686	0.51	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.25 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.11 : Model A simulation c90-w25-f 5

(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

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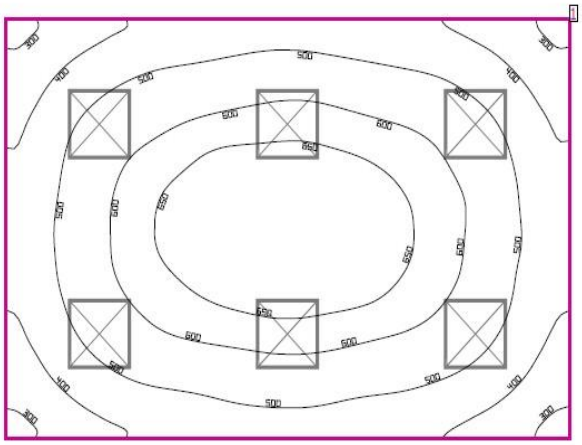
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 15.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	529 (≥ 500)	272	696	0.51	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.22 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.12 : Model A simulation c90-w25-f 15

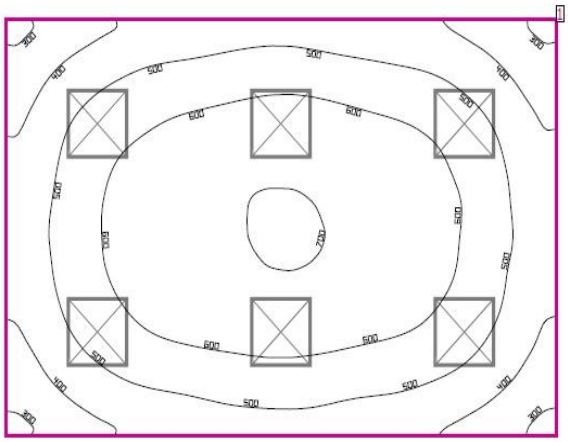
(Source : Author through DIALux evo , 2018)

Project 1 5/19/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 25.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	537 (≥ 500)	278	707	0.52	0.39

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.18 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.13 : Model A simulation c90-w25-f 25

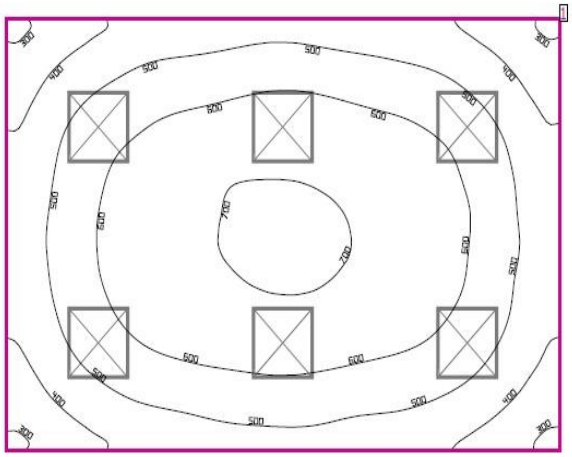
(Source : Author through DIALux evo , 2018)

Project 1 6/22/2018

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

DIALux

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 35.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	546 (≥ 500)	284	717	0.52	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.15 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.14 : Model A simulation c90-w25-f 35

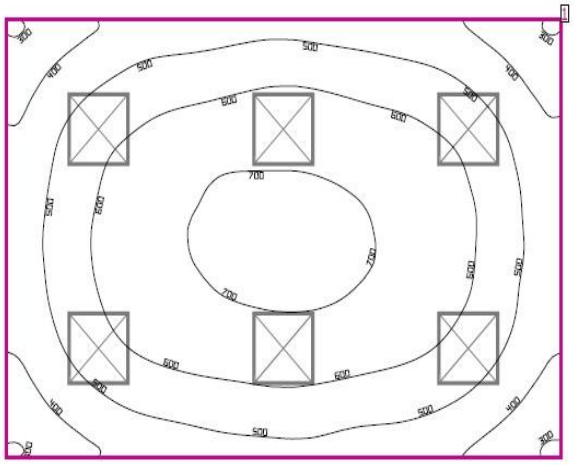
(Source : Author through DIALux evo , 2018)

Project 1 6/22/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 2.800 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 45.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	556 (≥ 500)	291	728	0.52	0.40

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
6	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	20418	228.0	89.6

Lighting power density: 11.73 W/m² = 2.11 W/m²/100 lx (Floor area of room 19.44 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 630 kWh/a of maximum 700 kWh/a

Figure A.15 : Model A simulation c90-w25-f 45

(Source : Author through DIALux evo , 2018)

Appendix (B)

Appendix (B): Model (B) documentation for different surface reflectance simulations .

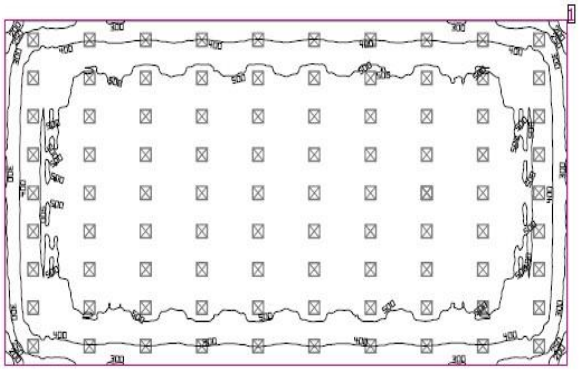
(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 5.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	481 (≥ 500)	172	564	0.36	0.30

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.58 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.1 : Model B simulation c90-w 5-f 5

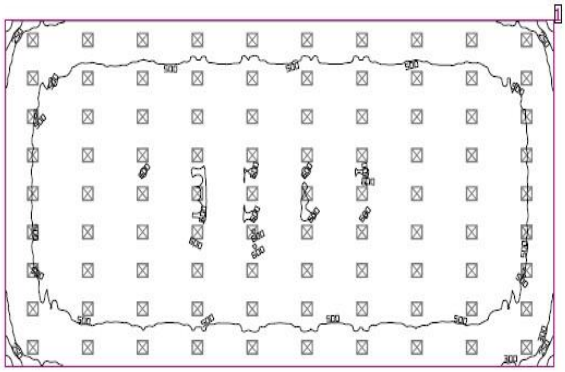
(Source : Author through DIALux evo , 2018)

Project 2 4/21/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 15.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	508 (≥ 500)	180	605	0.35	0.30

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.50 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.2 : Model B simulation c90-w 5-f 15

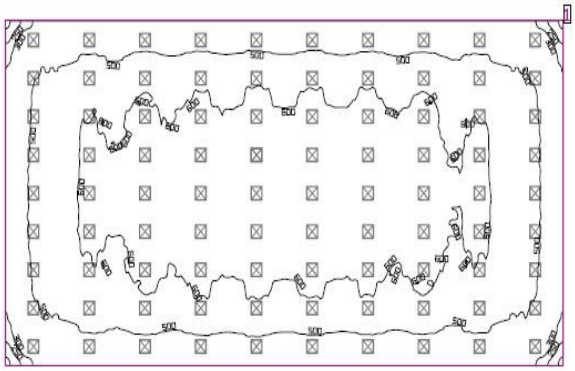
(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 25.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	538 (≥ 500)	190	649	0.35	0.29

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.41 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.3 : Model B simulation c90-w 5-f 25

(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

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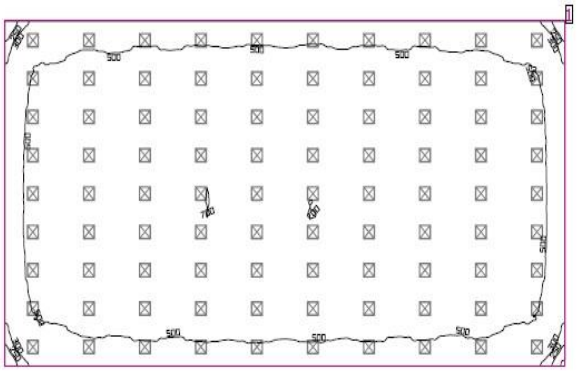
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 35.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	573 (≥ 500)	189	703	0.33	0.27

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.33 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.4 : Model B simulation c90-w 5-f 35

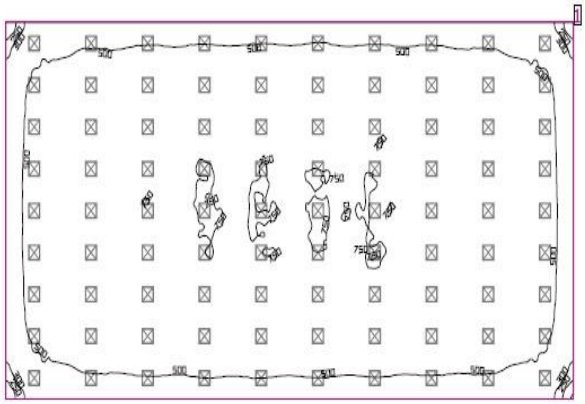
(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

DIALux

Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 5.0%, Floor 45.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	612 (≥ 500)	197	778	0.32	0.25

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.24 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.5 : Model B simulation c90-w 5-f 45

(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

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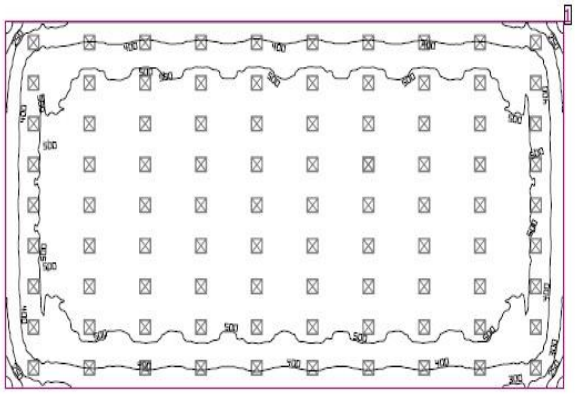
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 5.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	487 (≥ 500)	182	568	0.37	0.32

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.56 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.6 : Model B simulation c90-w 15-f 5

(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

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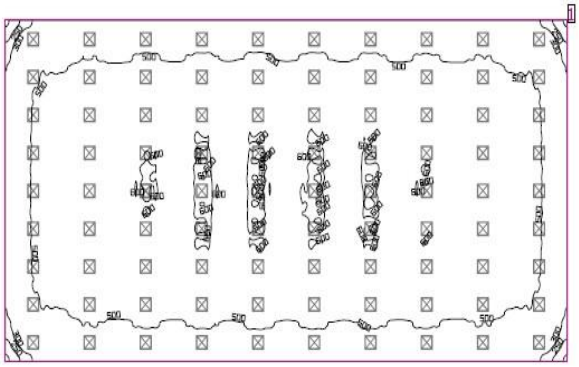
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 15.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	517 (≥ 500)	194	610	0.38	0.32

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.47 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.7 : Model B simulation c90-w 15-f 15

(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

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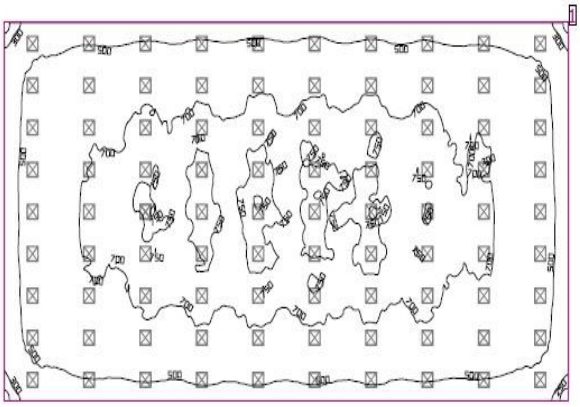
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 15.0%, Floor 45.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	628 (≥ 500)	217	790	0.35	0.27

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.21 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.8 : Model B simulation c90-w 15-f 45

(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

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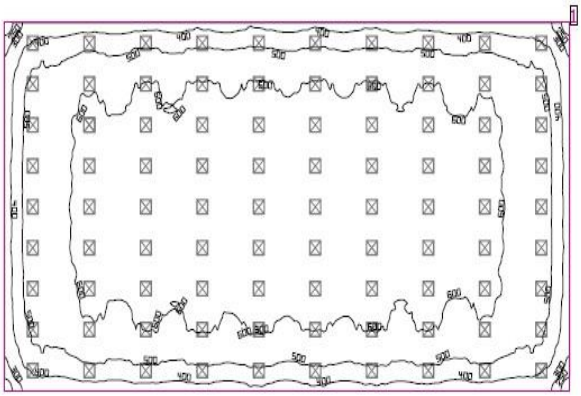
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 25.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	560 (≥ 500)	223	661	0.40	0.34

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.36 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.9 : Model B simulation c90-w 25-f 25

(Source : Author through DIALux evo , 2018)

Project 2 9/13/2018

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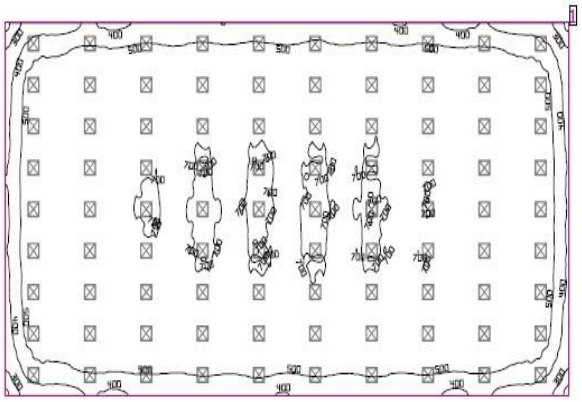
Site 1 / Building 1 / Storey 1 / Room 1 / Room summary

Room 1



Clearance height: 3.200 m, Reflection factors: Ceiling 90.0%, Walls 25.0%, Floor 35.0%, Maintenance factor: 0.80

Workplane

	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Workplane 1	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.000 m	600 (≥ 500)	239	717	0.40	0.33

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
90	iGuzzini illuminazione - P180 iPlan LED 38W	3403	38.0	89.6
	Total via all luminaires	306270	3420.0	89.6

Lighting power density: 7.60 W/m² = 1.27 W/m²/100 lx (Floor area of room 450.00 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 9400 kWh/a of maximum 15800 kWh/a

Figure B.10 : Model B simulation c90-w 25-f 35

(Source : Author through DIALux evo , 2018)