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DEVELOPMENT OF AN OPTIMIZED LIGHTING MODEL THROUGH THE APPLICATION OF A PARAMETRIC APPROACH TO A MIXED-USE CASE STUDY

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SVILUPPO DI UN MODELLO DI OTTIMIZZAZIONE ILLUMINOTECNICA ATTRAVERSO L'APPLICAZIONE DI UN APPROCCIO PARAMETRICO AD UN CASO DI STUDIO

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Parole chiave: *Luce naturale, Efficienza energetica, Approccio parametrico, Sistema di oscuramento, Prestazione d'involucro, Benessere umano*

ABSTRACT (IT)

L'obiettivo principale della tesi è la redazione, attraverso un approccio di tipo parametrico, di un processo di ottimizzazione illuminotecnica per ambienti interni, elaborato tramite un caso di studio. Un'adeguata progettazione della luce è indice di qualità degli ambienti, benessere e comfort dell'utenza. In particolare, la luce naturale sta guadagnando una sempre maggiore importanza nell'ambiente delle costruzioni, in quanto consente di minimizzare l'utilizzo di energia elettrica a carico del sistema di illuminazione; sono infatti sempre maggiori i progettisti che fanno di questo un elemento fondamentale, sia dal punto di vista architettonico sia dal punto di vista del benessere degli occupanti. La luce naturale, essendo stagionale, consente inoltre una più semplice acclimatazione luminosa da parte degli utenti, diminuendo la differenza tra la qualità della luce all'esterno e all'interno dell'edificio.

É stato quindi realizzato un modello illuminotecnico con l'ausilio del software DIALux, dal quale sono stati estrapolati i dati di partenza relativi allo stato di fatto del caso di studio. Una volta individuati i valori iniziali, ha avuto inizio il processo di ottimizzazione, che parte dalla definizione dei requisiti minimi individuati all'interno della Normativa UNI-EN 12464-1. Il processo di seguito presentato prenderà in considerazione un fattore alla volta, associando ad ogni valore i paramentri ottici in grado di interagire direttamente col fattore desiderato. Il progressivo sviluppo delle simulazioni ha portato quindi alle possibili scelte future da parte del progettista.

Nello svolgimento delle analisi sono stati considerati anche fattori pratici quali semplicità d'installazione dei sistemi proposti, piani manutentivi di pulizia o sostituzione di elementi ed infine anche studi di carattere economico, al fine di avere una visuale non solo basata su valutazioni fisiche del comportamento dell'edificio, ma anche su aspetti di fattibilità materiale di realizzazione.

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Key words: *Natural light, Energy efficiency, Parametric approach, Shading devices, Envelope performance, Human Comfort*

ABSTRACT (ENG)

The aim of the thesis is to provide, through a parametric approach, a lighting optimization process for indoor environments, through a case study. Proper lighting design is in fact an index of quality of environment, health and user comfort. Natural light is therefore gaining even greater importance in the construction environment, as it minimizes the use of electric energy to the lighting system; the designers/architects who make this a fundamental element, both architecturally and from the point of view of occupant well-being, are becoming more and more. The natural light, being seasonal, also allows a simpler light acclimatization by users, decreasing the difference between the quality of the light outside and inside the building.

A lighting model was then realized by using the software DIALux, from which the starting data were extrapolated to the current layout of the case study. Once identified the initial values, the optimization process began, starting from the definition of the minimum requirements identified in UNI-EN 12464-1. The process presented below takes into consideration one factor at a time, associating with each value, the optical parameters capable of interacting directly with the desired factor.

During the analysis were also considered practical issue such as simplicity of installation of the proposed systems, maintenance plans for cleaning or elements replacement, and finally also economic studies, in order to have a global vision based not only on physical evaluations but also on construction feasibility.

INTRODUCTION

Nowadays, the need to bring global attention to a more careful and aware control of the energy consumption of the various areas of daily life is becoming increasingly stringent. One of the areas which we are aiming at and trying to sensitize the population is the housing sector. This need for reduction that is often heard is an important act in response to the climate changes the planet is undergoing over the years[1].

> The atmospheric concentrations of carbon dioxide (CO2), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. CO2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuels and secondary from net land use change emissions. […]. Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiating forcing, observed warming and understanding of the climate system.

(IPCC-Intergovernmental panel on climate change- Headline statement from the summary for policymakers- Climate change 201, the physical science basis.)

Therefore it is ever more obvious how much this excessive production of greenhouse gases can be reduced by proper planning or requalification of housing[2].

The interventions which can be carried out to improve the consumption performances of building are many. One of these solutions is a careful study of the façade performances casing, an element through which the principle thermal exchanges, entry of air, ventilation occur. It is also the means by which it is possible to exploit and/or control solar input according to seasonal needs of the place where the building is situated[3].

Other benefits which proper planning of the building's facing can bring about are proper control of the natural internal lighting that brings conditions of internal comfort and increased livability and productivity for those who live or work within.

Therefore it is necessary to have an overall vision of these aspects such as to be able to have a final solution that respects the interactions that are created in the involved parameters.

The following thesis will basically involve in natural lighting and the analysis of multiple internal layouts, both residential and public. The tool used for the simulations is the software DIALux, thanks to which it was possible to carry out extremely accurate analyses, punctual and seasonally. It will then start from the current layout, from which input data will be taken, following the analysis and implementation of the different parameters involved in the lighting engineering study.

The analysis will therefore be divided into PHASES in which each parameter will be varied singularly, specifically:

- Reflection factor of the internal partition
- Dimensions of the glass surfaces

Following these first stages a possible shading system will be hypothesized and their use in different configurations will be analyzed.

The building under investigation is a 5-level mix-used building, with public areas on the mezzanine floor and residential in later levels.

REFERENCE CONTEX

THE BUILT ENVIROMENT

The proposed site for the project is located in the area called "Ponte Lambro", located to the southeast of Milan. It is bordered to the North by undeveloped area, to the South with San Donato, to the East with the historic district of Ponte Lambro and its river from which it takes its name, and with the A4 ring road to the West.

Image 1 – Fly view of the lot - https://www.google.com/maps/ (background)

The project is part of an urban redevelopment of the neighbourhood, so it cannot be separated from a preliminary analysis of the existing context.

Image 1 - Built context (yellow) and context of Intervention (purple) https://www.google.com/maps/ (background)

The elements that characterize the built up area of Ponte Lambro have been identified and described in the following images:

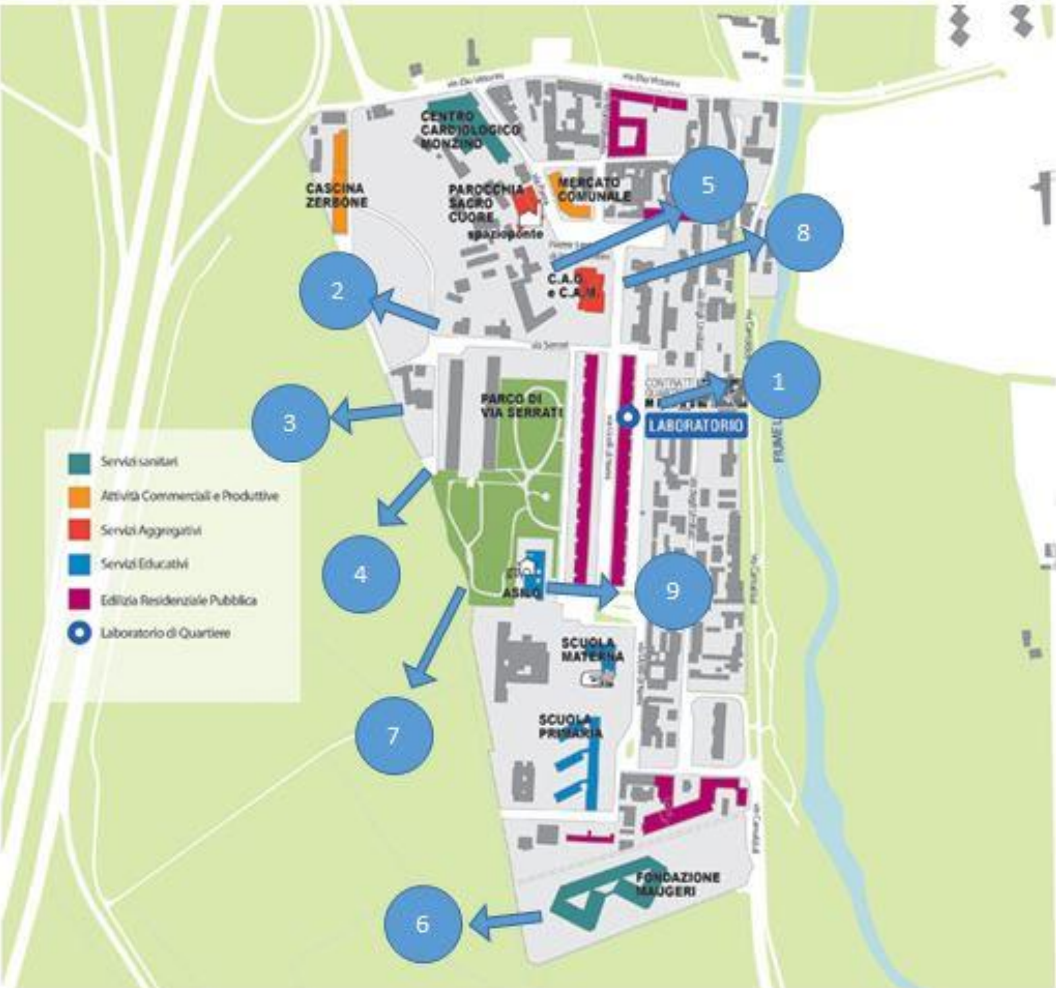


Image 2 - Ponte Lambro Map

Image 3.1 – Renzo Piano laboratory

Image 4.1 – Residential building


Image 5.2 – Residential building


Image 6.3 – Farmstead


Image 7.4 – Residential building


Image 8.4 – Residential building


Image 9.5 – Residential building


Image 10.6 – Fondazione Naugeri


Image 11.7 – Public green area


Image 12.7 – Civic center

From the site visit it can be noticed that there is a significant presence of public housing complexes built "slat buildings" with predominant structural technology in reinforced concrete frames and closing walls in bricks; many buildings are currently undergoing upgrading works from time to reduce energy consumption, particularly through thermal insulation works in the perimeter walls coat.

The most significant architectural element found in the area is the lab walkway, still under construction, designed by Renzo Piano. The idea of a connecting walkway between two residential slats will be one of the features of the design of the residential complex.

Image 13 - Renzo Piano Labortory – ODB & Partners con Lamberto Rossi

THE ENVIRONMENT

The intervention of the redevelopment of Ponte Lambro is informed by the principles of eco-sustainability and eco-compatibility as well as defined in the draft of the new building code of the City of Milan.

The project of a residential complex in equilibrium with the environment starts from the knowledge of the microclimate of the area and the urban boundary conditions, which results can be translate in inputs to the definition of volumes, collective and private spaces, for the project of the building envelope.

The built environment affects the characteristics of the urban fabric, the location and density of surrounding buildings for their influence on the shadows, on the winds and on local temperatures.

Based on these principles, the project in its totality, intends to propose an answer to land consumption by promoting a different balance between settlement density and green areas.

The main targets of the project, according to the general redevelopment objectives of Ponte Lambro, are:

- Inclusion in the batch to facilitate the penetration of direct sunlight
- Optimizing the use of solar energy
- Energy consumption limited
- High usage of renewable energy sources

The project hypothesis thus involves the construction of an integrated residential neighbourhood to a set of other features and services to people:

- A big equipped park of about 800 m^2
- A farming area for residents;
- A series of private services for the residents in the complex (meeting rooms, multipurpose room, workshop, children's play room, reading room) and a public service gym;
- A pedestrian walkway (about 18 m) between the two housing bodies;
- A bowling green-field

Image 5 – Mezzanine floor - Functions

The entire residential area is elevated, with a vertical drop of about one meter due to the presence of the ground water at height of -2 m from ground level[4]. So the garage will be underground and therefore it will be covered above, in the parts with clear sky, with a green roof, by pedestrian pavements to use as a small square, and by a paved space used for parking. A series of grate openings above the lane of the basement will allow the ventilation of the garage, in compliance with fire regulations.

DESIGN CHOISES

WINDS ANALYSIS

The North-South orientation of the urban park, as established by the redevelopment project, is aimed at encouraging the flow of prevailing winds with positive results in the cooling of the surface in Summer. In general, the park and the new buildings of the area of Ponte Lambro are addressed to comply with an overall design of this strip of land at East of the city that arises not only as a green lung area as well as mitigation of the effects of temperatures, with positive results in terms of reduction of these ones, due to the concentrations of built-up urban areas.

The project forms of the residential complex "WOODEN HINT" and its inclusion in the master plan aims to follow the guidelines outlined in the study of the entire urban renewal project, through the decision to create two opposing slats with North-South orientation, and divided by a green area mainly with longitudinal development, in order to maximize the use of the prevailing winds and thus ensure additional natural ventilation to the one that is already guaranteed by the "green lungs"

This choice is in contrast, from the point of view of the shape and orientation, to the project of the complex compared to the other buildings included in the masterplan, but it leads in a direct way to the direction and the prevalent form of the buildings that were already presented in the area of Ponte Lambro.

Image 14 - Insertion into the Map

STUDY OF THE SHADOWS AND SOLAR ANALYSIS

The study of the shadows of buildings course is the premise for the control of radiation phenomena due to the ground and to the outer surfaces of buildings.
The proximity of the buildings between them and the presence of large shielding surfaces constitute an obstacle to direct radiation, which is the main responsible of the overheating of the ground surfaces.
The choice of the inclusion complex in the master plan is thus carried out in order to facilitate shielding conditions and shading of fronts in summer mode and optimize the system of free solar gains in winter conditions. This positive effect is obtained through the choice of positioning faces with longitudinal development (on which you have the balconies, and then the main inputs and predominantly the living areas) opposing each other and at distance of about 18 meters, in front of an overall height of each carton of about 23 meters, and to place the south side of the building facing away from the building in which promote the natural radiation in winter conditions.
The north side, being the least affected by the radiation and shading phenomena, does not provide for the presence of balconies and loggias, looking out over an area free from obstacles and required to green. This choice allows to avoid, in winter conditions (less inclination of the solar rays) to create shading the adjacent buildings.
Below we represent studies of lights and shadows conducted relatively insertion of the housing complex in the master plan, in the most significant days in the calendar year:

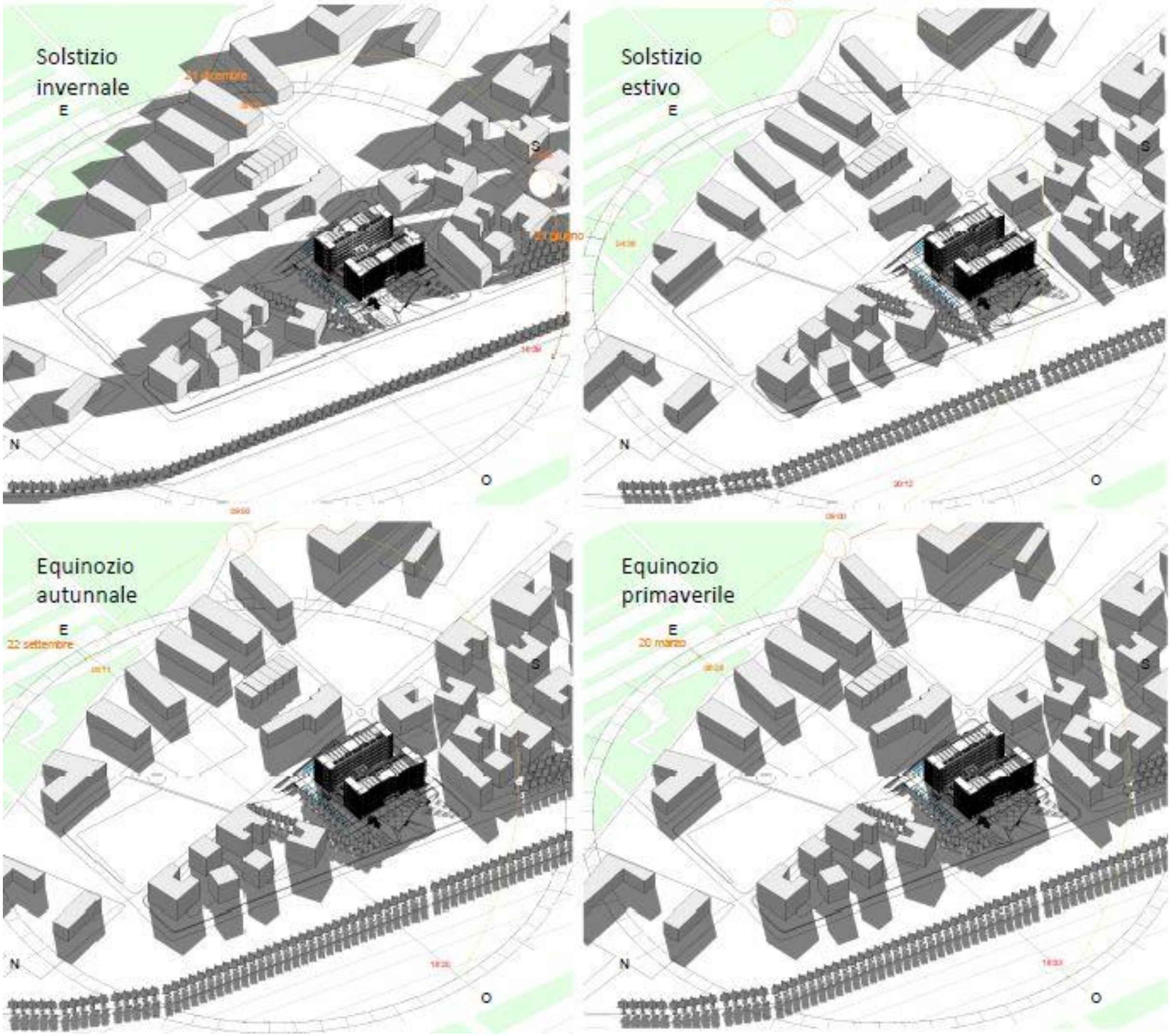


Image 15 - Study of the shadows an Solar analysis – Autodesk Revit visualisation

ACUSTIC ANALYSIS

Another factor in the choice was to facilitate the fulfilment of the acoustic comfort.

The sources of disturbance that directly affect the area are the High Way of the West ring road and the landing lanes of the Forlanini airport at East.

The design of the masterplan according to these sources of disturbance involves the formation of dispersion and dissipation ways through the creation of an acoustic barrier made up of an artificial parked hill, which houses the interior parking system of the residence.

The height and the net thickness of the acoustic barrier allow for a 15-20 dB noise reduction in the building areas.

The acoustic protection finds an additional attenuation factor in the planimetric configuration of the residential complex, characterized by a private green area protected by sources of disturbance from the two East and West slats, and the choice of wall-mounted shutter ventilated facade solutions, which, in addition to favouring thermal performance, ventilation, and protection of the building envelope, are also an important protection for low wavelength waves (high energy) coming from the West ring road and from the East airport. The choice of shielding enclosures, however, does not disturb the permeability, however guaranteed, not only on the North-South axis, but also on the East-West, in order to create a system of connections between the interior and exterior of the building complex, so that it can be integrated in all its components.

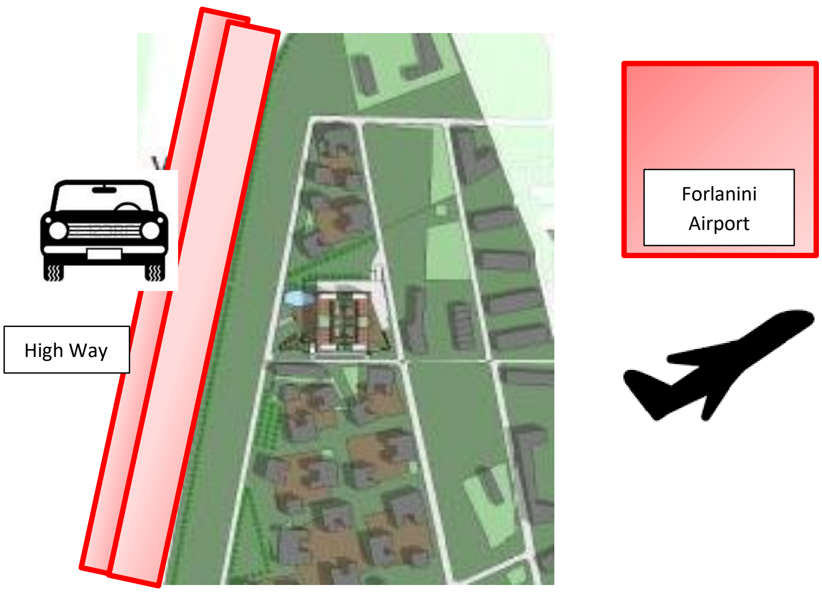


Image 16 - Masterplan Ponte Lambro: sources of acoustic disturb

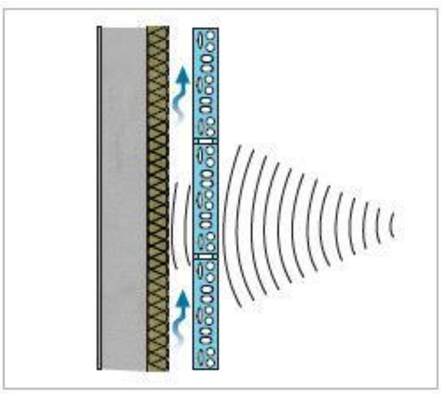


Image 17 - Wall-mounted shutter ventilated façade solution – Acoustic behaviour

ROAD AXIS ANALYSIS

From the point of view of the viability, the Ponte Lambro area is at the center of a vast infrastructural system that makes it in a strategic location: the well-developed road and motorway system, the railway and the metropolitan system are in full swing and it is important to capture the growth lines in order to adequately plan the accessibility to the new settlement being analyzed.

The choice of the location of the intervention lot into the masterplan of the area is, therefore, also derived from considerations of the viability studies carried out in the project for the redevelopment of the area, and therefore to the infrastructures within the area envisaged in the study general.

The redevelopment project involves the implementation of a main road access road to the neighbourhood, with a South access from via Marignano, an access from via Camaldoli and another one from the North with an intersection with traffic lights; it is also planned to carry out an internal road system, transversal to the main one, used only by vehicles.

It is also planned to carry out a secure tramway, parallel to the main road.

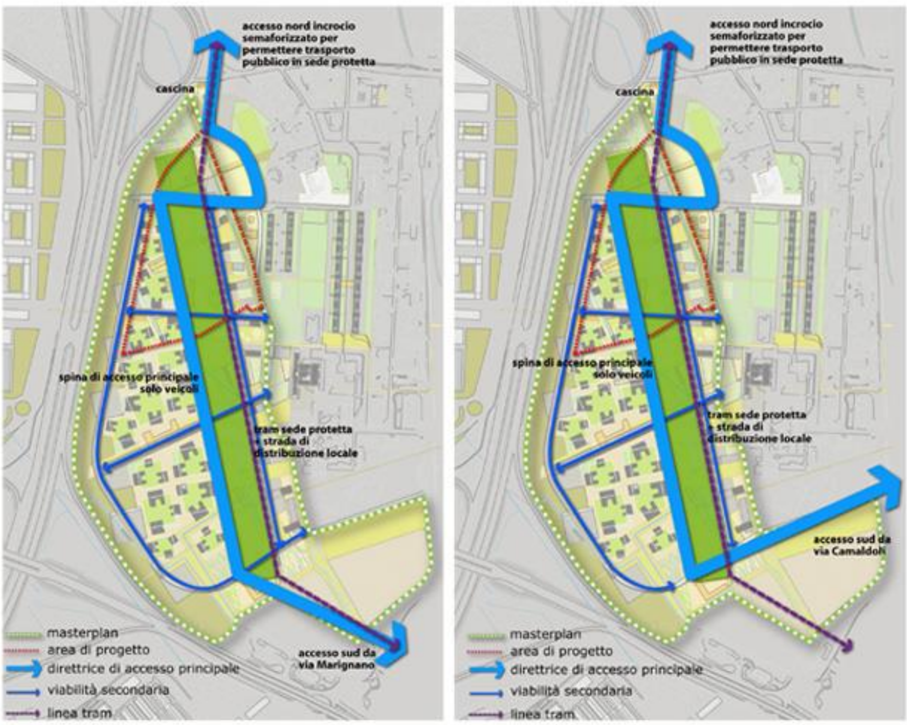


Image 18 - Masterplan Ponte Lambro: Road axis

The choice of the location of the lot was therefore guided by the need to easily serve the residential complex with the infrastructures envisaged in the masterplan and for this reason it was decided to place it near a cross between the main road and a secondary one.

So this area is easy to be accessed by vehicles and in addition this location also favours the view of the green lungs.

CLIMATE CONTEXT

In Milan the weather is warm and temperate, with significant rainfalls during the course of the whole year. The climate is classified Cfa (humid temperate climate with a hot summer) according to the Köppen and Geiger climate classification. Here the average temperature is equal to 13.1 °C, while the average yearly rainfall is 1,013mm.

TABELLA CLIMATICA MILANO

	Gennaio	Febbraio	Marzo	Aprile	Maggio	Giugno	Luglio	Agosto	Settembre	Ottobre	Novembre	Dicembre
Temperatura media (°C)	1.9	4.3	8.7	13	17.6	21.1	23.8	22.8	19.3	13.4	7.7	3.3
Temperatura minima (°C)	-0.8	0.9	4.3	7.9	12.1	15.8	18.3	17.8	14.7	9.5	4.6	0.6
Temperatura massima (°C)	4.7	7.8	13.1	18.2	23.1	26.5	29.3	27.8	24	17.4	10.8	6
Temperatura media (°F)	35.4	39.7	47.7	55.4	63.7	70.0	74.8	73.0	66.7	56.1	45.9	37.9
Temperatura minima (°F)	30.6	33.6	39.7	46.2	53.8	60.4	64.9	64.0	58.5	49.1	40.3	33.1
Temperatura massima (°F)	40.5	46.0	55.6	64.8	73.6	79.7	84.7	82.0	75.2	63.3	51.4	42.8
Precipitazioni (mm)	55	62	79	92	94	97	67	90	78	118	110	71

Table 1 - Milan Climate chart - https://it.climate-data.org/location/1094/

The average temperature in July, the hottest month of the year, is 23.8 ° C, while in January, the coldest month, is 1.9 ° C. 55 mm is the precipitation of January, which is the driest month. With an average of 118 mm in October is the one with the highest precipitation.

Summarizing the driest month has a difference of precipitation of 63 mm compared to the rainiest month and the average temperature during the year, ranging from 21.9 ° C.

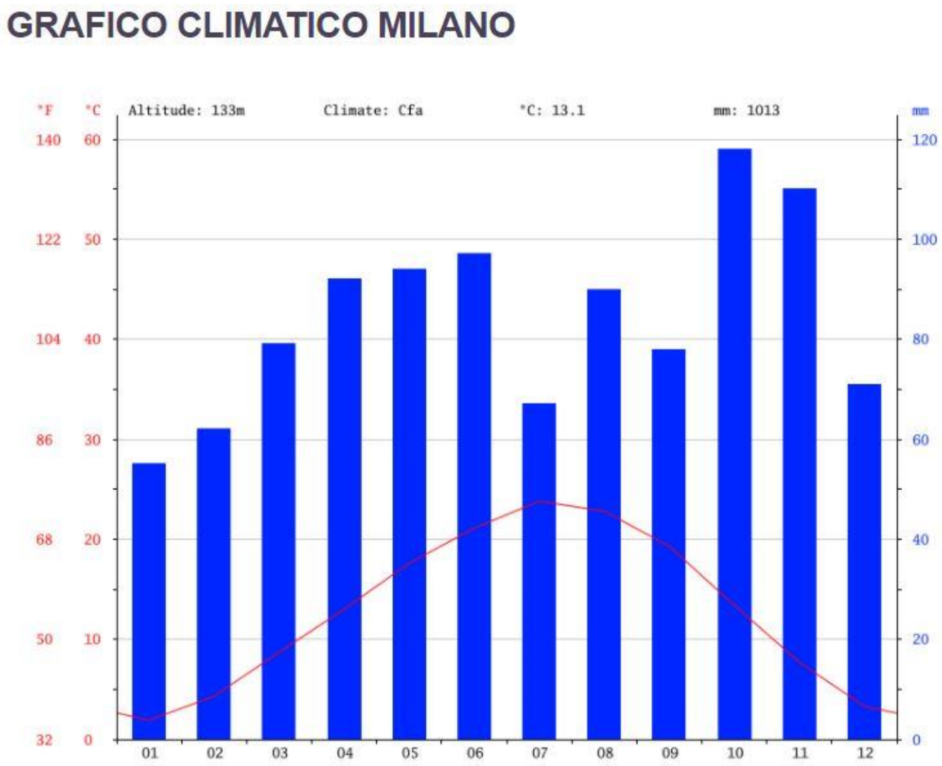


Diagram 1 - Milan Climate chart - https://it.climate-data.org/location/1094/

IDENTIFICATION OF THE AREAS ANALYSED

In order to draw up a process that is as repeatable as possible, at least in the geographical areas similar to the one under examination, it was decided to conduct the analysis of three types of lodgings, for the residential section, and of two common spaces for the public section.

The building under analysis is a gallery type and, as already described, is made up of two mains bodies connected by a walkway. Therefore at least one residence and one common area per body were chosen (A and B).

For yardstick A, located in the EAST, we will propose the lighting optimization of a three roomed apartment of 73.9sq.m (designated as "Apartment A" in the simulations) situated on the fifth floor and for two common spaces, one used as an atelier (71.1sq.m) and one as a reading room (103.5sq.m.) situated on the ground floor (designated in the simulations as "Common Space A").

For yardstick B, located in the WEST, we will propose the lighting optimization of a two room apartment of 52.9sq.m. (designated in the simulations as "Apartment B"), a three room apartment of 67.4.sq.m.(designated in the simulations as "Apartment C"), both situated in the fifth floor and two common areas, one used as a kids area (83.6sq,m) and the other as a meeting room (107.6sq.m.) situated on the ground floor (designated in the simulations as "Common Space B").

Below is a general view of the plans concerning the areas involved in the analyses which will be described in detail later on:

Image 11 - 5th floor plan

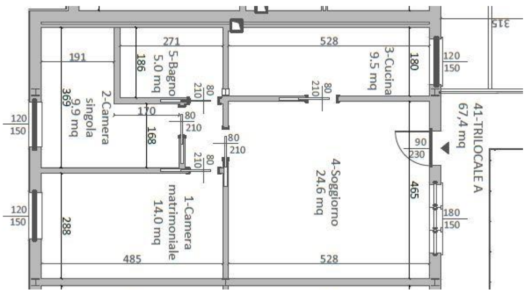


Image 12 - Apartment C-Plan

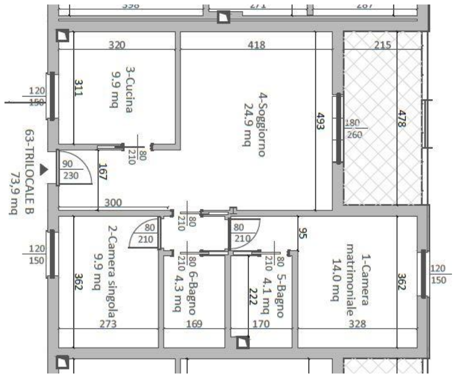


Image 13- Apartment A-Plan

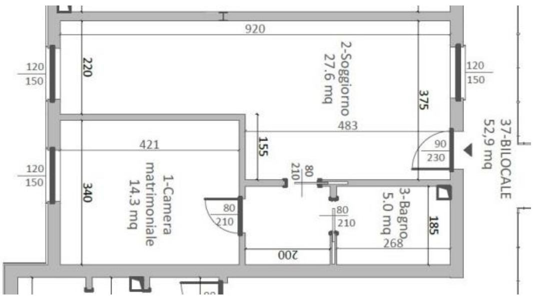


Image 14 - Apartment B-Pan

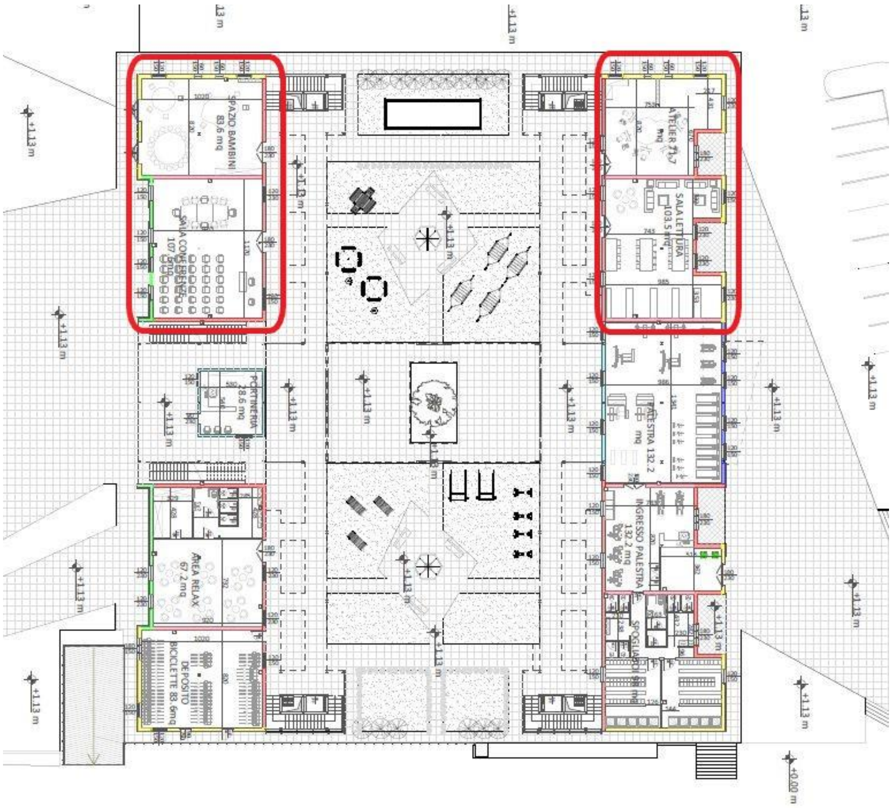


Image 15 - Mezzanine floor - Plan

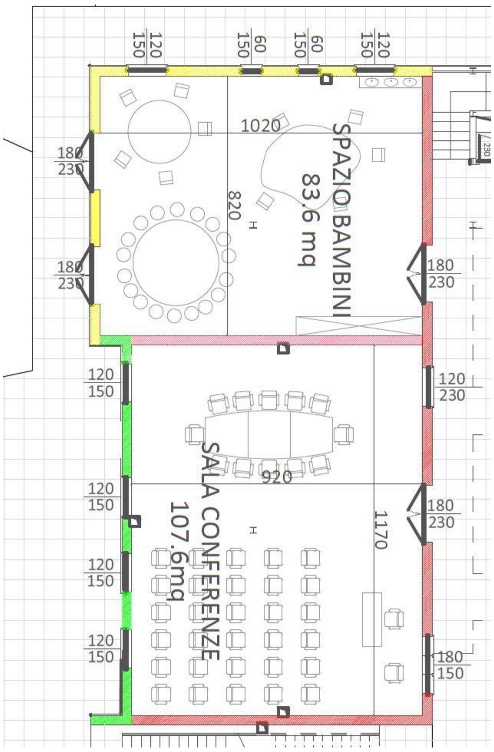


Image 16 - Public Space B-Plan

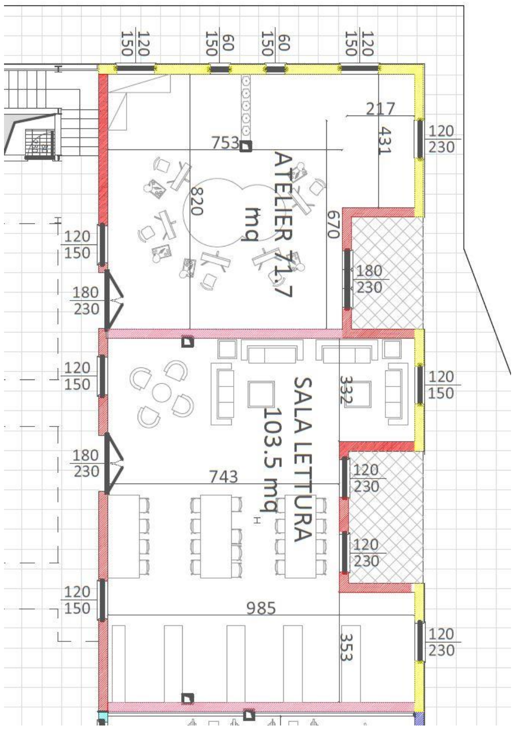


Image 17 - Public Space A-Plan

DESCRIPTION OF THE AREAS ANALYSED

RESIDENTIAL:

Regarding to the residential areas, it was decided to focus special attention on places of daily life in which natural light assumes a major role, the day zone, particularly the Living room and the kitchen. Starting with the current layout, after having therefore defined the internal distribution, the optimization of lighting engineering will be undertaken in the spaces with fixed internal partition. The aim is to identify the many devices to be used to maximize the use of natural light. In the following analyses the calculation surfaces were imposed in the apartment spaces, specifically in the lounge room the area calculated in general and includes an area within which the architect can plan increased use by the users. Instead in the kitchen the area is more specific and this was carried out in the work area.

PUBLIC SPACES

As for the common spaces, the surface areas calculated include all the surface area useful for the purpose, guaranteeing maximum flexibility to subsequent changes of internal layout or destination of use. Therefore, following the analyses the zones within said ambiance with different levels of natural light will be indicated thus allowing the identification of the areas more suitable for various types of activities, such as reading (which needs higher light levels) or the storage of books (where the need for light is less).

DESIGN TOOLS:

The software used to carry out the analyses and elaborations were:

AUTOCAD: used to create the plans set as background on DIALux

DIALux: With this free software you can design, calculate and visualize light professionally – single rooms, whole floors, buildings and outdoor scenes[5]. This software, can run daylight simulation, setting up the geographical position and the orientation of your project. It is possible to modify the single parameters which affect the light distribution. Additionally it has a very big catalogue full of different lighting company products, this allows to use the specific photometric files for the design.

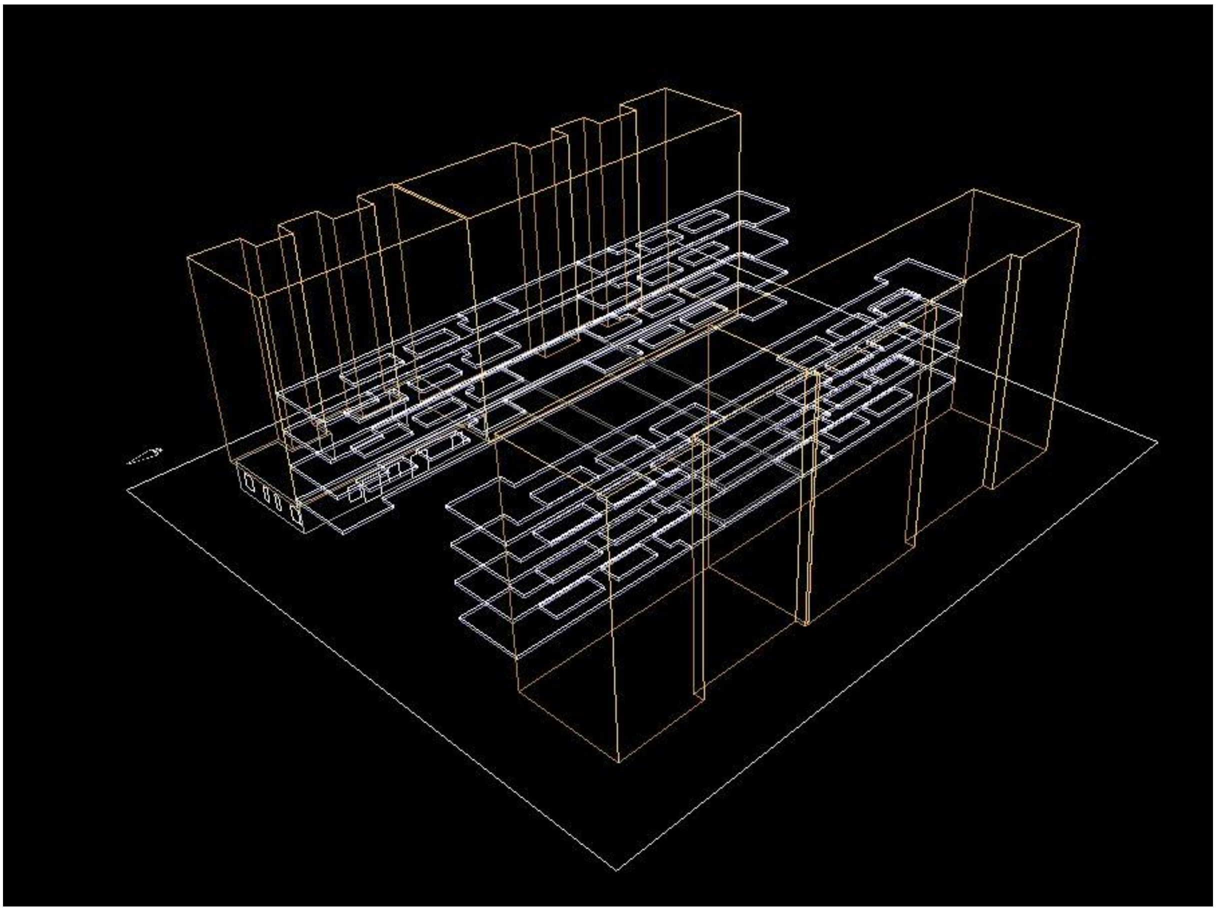


Image 18 - DIALux 3D modeling

Before starting the lighting engineering study it is necessary to undertake an analysis of the of the current layout of the building under examination, in terms of the construction technology and materials used, for the purpose of inserting the corresponding information into the software.

DIALux distinguishes the internal and external scenes of the simulations and allows, once the internal scene has been modelled, to model the obstructions present outside the area under examination, taking into account their reflections and shading during the simulation.

In the modelling phase the whole building was assimilated only for its volume, setting the optical characteristics of the materials used for the external cladding of the facades. As for the interior of the spaces being studied it is possible to reach a very high level of detail since the software used, allows the setting of optical parameters of individual elements such as windows, internal partitions, paved surfaces or ceilings with a variation of 0.1%.

Before beginning the lighting optimization we present the calculations of the area-lighting ration of the rooms under study:

PIANO	ALLOGGIO	LOCALE	SUPERFICIE CALPESTABILE [mq]	SUPERFICIE VETRATA [mq]	R.A.I. (>0,1)	VERIFICA
5	63-Trilocale B (Apartment A)	1-camera matrimoniale	14	1,8	0,129	SI
		2-camera singola	9,9	1,8	0,182	SI
		3-cucina	9,9	1,8	0,182	SI
		4-soggiorno	24,9	4,68	0,188	SI
	33-Bilocale (Apartment B)	1-camera matrimoniale	14,3	1,8	0,126	SI
		2-soggiorno	27,6	3,6	0,13	SI
	41-Trilocale A (Apartment C)	1-camera matrimoniale	14	1,8	0,129	SI
		2-camera singola	9,9	1,8	0,182	SI
		3-cucina	9,5	1,8	0,189	SI
		4-soggiorno	24,6	2,7	0,11	SI

Table 2 - R.A.I. Chart – 5th floor

ANALYSIS AND OPTIMIZATION OF THE LIGHTING PERFORMANCE

INTRODUCTION

We will now give a brief introduction which will present the specific factors that influence the lighting engineering behavior of a building:

NATURAL ILLUMINATION

The satisfaction of the natural light conditions is a fundamental requirement for guaranteeing the completion of the activities, acceptance of space, mental and physical wellbeing and also allows the reduction of energy use for lighting. Therefore the use of natural lighting is the index of quality for environments and for this reason requires an adequate study.

The calculation of lighting wellbeing is regulated by specific laws dictated by European, Italian and local council standards. The quality of natural light can be evaluated according to various factors and methods which make analysis more or less detailed according to needs.

The indicator parameters which dictate the minimum and recommended limits of lighting are AIR (area illuminated ratio) and DF (daylight factor). During planning the spaces that did not satisfy the minimum lighting requirements cannot be included in the calculations of minimum habitable floor spaces for residences.

Building an environment in such a way as to make best use of this free and clean resource through careful planning and dimensions, position and type of glass openings can significantly reduce the use of electricity and, at the same time, assist in winter heating costs. On the other hand oversized glass surfaces could cause an excessive cost for the summer air-conditioning system.

INFLUENCING FACTORS AND PRINCIPLE PARAMETERS

THE SKY

Even though on its own it is not able to emit radiations, the sky is usually considered as a real source of light since the atmospheric gases and fine dust redistribute the solar radiation in the celestial vault and so it appears luminous.

Normally the sky is considered a primary source for the calculation of lighting within environments.

The distribution of light from the celestial vault is not uniform and constant due to atmospheric and meteorological disturbances and therefore simplified models are used according to the needs of the calculation:

- *sky with uniform light*: the sky is treated as an extended source of constant and uniform light. This type of distribution can be considered valid for cloudy skies when there is an atmosphere rich with vapour such as happens in winter in the plains of the Po River. Usually its luminance is equal to1600nit [cd/m²], in other words an average external illumination of about 5,000lux;

- *international covered sky*: (CIE standard overcast) is the most used model for calculations since it makes a good approximation for conditions of a covered sky. The distribution of luminous luminance LP is carried out on the basis of the angle of elevation ϑ in respect to the horizontal plane and the luminance of the zenith Lz according to the formula: $Lp=Lz((1+2\cos\vartheta)/3)$ while the luminance of the zenith is tied to the horizontal external lighting through the relation $Lz=(9/7)(E0/\pi)$. The sky's luminance is variable according to the time and its minimum horizon from one moment to another and has its maximum value at the zenith and its minimum on the horizon where the luminance is about a third of that of the zenith. ;

- *analytical models*: these schemes take into account, in the distribution of luminance of the celestial vault and also the concentrated component due to the presence of the sun. In addition, they simulate various meteorological conditions that make the result more applicable to the real behaviour of the celestial vault.

DAYLIGHT FACTOR (DF)

This is the immediate parameter of reference for evaluating the proper use of natural light within an environment. It is defined as the value of the relationship between illumination at a point within the environment under consideration (E_{in}) and the contextual illumination on an external horizontal with no obstructions (buildings or the presence of glass) and shielded from direct solar radiation (E_{ext}).

$DF = E_{in}/E_{ext}$

While, point by point, the sky's luminance and internal lighting are variable in the course of the day and the passing of months, the daylight factor remains constant since it is the relationship between the values of internal and external illumination, basically dependent on geometry, optical properties and the topographical position of the spaces under consideration.

The luminous radiation within an environment is due principally to the radiation coming from the celestial vault and also the effects of reflection, both internally and externally, of the environment and externally by the presence of buildings and obstructions that reduce or reinforce the direct light.

The following components are usually distinguished:

- *sky factor*, D_s, which indicates the percentage of which the external luminous flux is responsible for internal illumination;

- *internally reflected component*, D_i, this expresses the percentage of light due to reflections from surfaces within the environment;

- *externally reflected component*, D_e, this expresses the percentage of light that comes from within the environment under consideration due to reflection from external surfaces (such as buildings, the ground, water reflections, walls, etc.).

To verify that the daylight factor is sufficient for the needs of the environment, three components are added together, unless there are corrective factors deriving from the model of calculation used for the determination of these variables.

$$DF = D_s + D_i + D_e$$

For DF factors greater than 2% the natural lighting of the environment is generally considered satisfactory. In any case, it is necessary to verify the information through the table of values recommended by the coefficient of lighting according to the environment under consideration which often supplies values less than 4%.

In order to achieve a good uniformity of light distribution within the environments, it is recommended to compare the minimum value of the daylight factor DF_{min} and the average value DF_{med} in such a way that their relationship is greater than 0.400 (UNI 10840 e EN 12464-1).

There are a number of ways to calculate the coefficient of daylight. In literature it is possible to obtain tabular methods, graphic methods and through the use of specific software. We will deal with this in this explanation.

PROJECT REQUIREMENTS

In order to better define the performance objectives, reference is made to specific regulations which offer values of reference (in terms of illumination and uniformity) for achieving correct visual comfort according to the desired use. Specifically, the regulations taken into consideration are UNI 10380, DIN 5035, EN 12464-1 and Milan Local Council's Health Regulation which impose "premises for office use, open to the public and for any public activity or open to the public" that the width of the windows is such as to provide an average daylight factor of not less than 2%.

Below are shown the value set up at target for the analysis, divided into residential and public:

RESIDENTIAL:

ILLUMINATION:

Living Room: average Lux level Eav ≥ 200 Lux

Kitchen (general): average Lux level Eav ≥ 200 Lux (only for Apartment A)

Kitchen (Work Plane): average Lux level Eav ≥ 300 Lux

Uniformity for all residential spaces u0=Emin/Eav: ≥ 0.4

DAYLIGHT FACTOR

Percentage of DF for all residential spaces: Dav [%] ≥ 2%

Uniformity for all residential spaces Dmin/Dav: ≥ 0.4

PUBLIC SPACE:

ILLUMINATION:

General Surfaces and Kids Area: average Lux level Eav ≥ 300 Lux

Specific Work Area: average Lux level Eav ≥ 500 Lux

Uniformity for all public space u0=Emin/Eav: ≥ 0.5 (acceptable by low)

Uniformity for all public space u0=Emin/Eav: ≥ 0.6 (ideal by low)

DAYLIGHT FACTOR

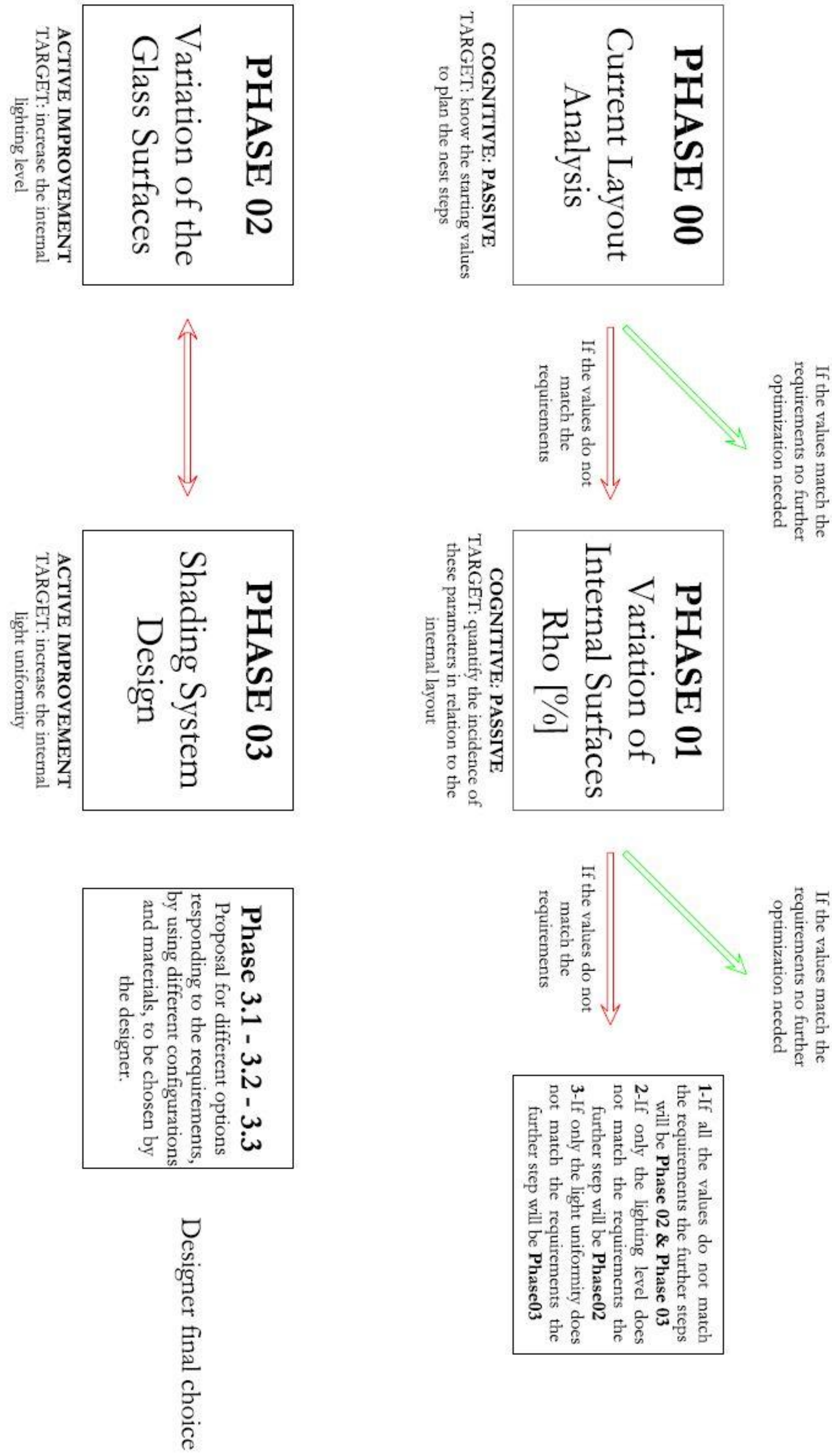
Percentage of DF for General Surfaces and Kids Area: Dav [%] ≥ 3%

Percentage of DF for Specific Work Area: Dav [%] ≥ 4%

Uniformity for all public space Dmin/Dav: ≥ 0.5 (acceptable by low)

Uniformity for all public space Dmin/Dav: ≥ 0.6 (ideal by low)

DEVELOPMENT OF THE OPTIMIZATION PROCESS



The optimization sought is based on graduated variations, one parameter at a time, progressively discovering all the cases possible between parameters with a cascade effect. The results obtained in each variation were extrapolated in the form of graphics so as to make recording of the variations and analysing their behaviour more immediate. The process being presented will therefore be divided into PHASES that start with the analysis of the current layout to progressively reach the best configuration possible using the lowest number of modifications possible, all while considering one parameter at a time. For each of the phases presented the analyses were carried out at on the 15th day of each month at 3.00pm in conditions of Overcast Sky.

The PHASES will be made up as follows:

00- PHASE 00, CURRENT LAYOUT: installing the project data into the software such as the dimensions of internal spaces, glass surfaces and external blocking objects, orientation and geographical position of the project area. During this phase the reflective values of the vertical and horizontal partitions and the glass surface are considered like the software's default equal to the values of visual transparency and transmission of the glass surfaces. This first phase is useful for knowing the values at the starting point and for planning the subsequent actions to be carried out.

01- PHASE 01: The factor to be varied in the first phase is the reflectance of the horizontal and vertical internal partitions according to the values recommended in the standard EN 12464-1 shown in the table above. Specifically values equal to 0.8 for the ceiling, 0.7 for the walls and 0.3 for the floor were set. These results can be obtained by using standard finishing materials such as white plaster and stoneware.

Tipo di superficie	Fattore di riflessione consigliato (EN 12464-1)
Soffitto	Da 0,7 a 0,9
Pareti	Da 0,5 a 0,8
Pavimento	Da 0,2 a 0,4

Tabella 6 – Intervalli consigliati per i fattori di riflessione di un locale

Table 3 – Suggested Rho (%) values – EN 12464-1

02- PHASE 2: In this PHASE the target to be set is reaching the requested value for the average Eav lighting. For this purpose only the glass surfaces of the environments under examination will be varied, maintaining the commercials cuts of the windows and taking into account the structural technologies present.

03- PHASE 3: In this case the parameter that will be set as target is the uniformity of light distribution u0 (Emin/Eav). For this purpose an easily installed and controlled system of light obscuration of fixed aluminium slats was designed. This system allows better diffusion of the environments' internal light, reducing the gap between the highest and lowest level in both the illumination level in lux and the value of the daylight factor. This phase will be divided in sub-phases (Phases 3.1-3.2-3.3 within which the reflection coefficient of the slats, specifically with values of 0.8 (high reflection), 0.6 (medium reflection) and 0.3 (low reflection) will be varied.

Phases 00-01 both the residential and the public areas will be presented simultaneously as they are part of the preliminary analyses of the environments under consideration.

For each of these phases a Maintenance factor of 0.8 was considered as it simulates a condition of ordinary use of the opaque and glass surfaces.

ANALYSIS OF THE CURRENT LAYOUT: PHASE 00

It will now present the current layout of the project which is useful for understanding the starting point of the levels present. For each of the environments analysed a table will be presented showing all the values that it is possible to extract from the software a diagram showing the only parameter that fluctuate during the year, the average illumination. There will also be extrapolated two false colour images that show the distribution of light inside the various spaces; in particular, it has been chosen to show the months of June and December that represent the extremes in terms of light provision.

APARTMENT A: FASE 00

Summary data on entry:

Reflection factor:

Walls: 0.5

Floors: 0.2

Ceiling: 0.7

Maintenance factor: 0.8

Glass surface Living Room: 4.68mq

Glass surface kitchen: 1.8mq

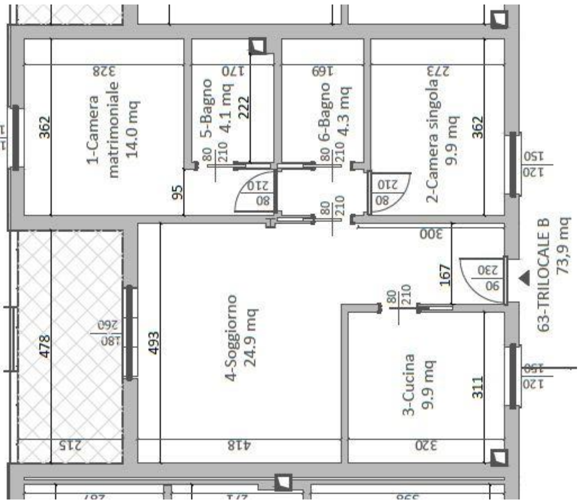


Image 13- Apartment A-Plan

LOCATION	Building A - 5th Floor											
PROJECT NAME	Apartment A - PHASE 00											
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane				Kitchen			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	240	0,37	2,83%	0,372	461	0,273	5%	0,283	168	0,554	1,98%	0,551
FEBRUARY	317	0,37	2,83%	0,372	610	0,273	5%	0,283	223	0,554	1,98%	0,551
MARCH	403	0,37	2,83%	0,372	776	0,273	5%	0,283	283	0,554	1,98%	0,551
APRIL	487	0,37	2,83%	0,372	936	0,273	5%	0,283	342	0,554	1,98%	0,551
MAY	537	0,37	2,83%	0,372	1032	0,273	5%	0,283	377	0,554	1,98%	0,551
JUNE	556	0,37	2,83%	0,372	1069	0,273	5%	0,283	390	0,554	1,98%	0,551
JULY	548	0,37	2,83%	0,372	1054	0,273	5%	0,283	385	0,554	1,98%	0,551
AUGUST	513	0,37	2,83%	0,372	986	0,273	5%	0,283	360	0,554	1,98%	0,551
SEPTEMBER	447	0,37	2,83%	0,372	859	0,273	5%	0,283	314	0,554	1,98%	0,551
OCTOBER	359	0,37	2,83%	0,372	690	0,273	5%	0,283	252	0,554	1,98%	0,551
NOVEMBER	260	0,37	2,83%	0,372	500	0,273	5%	0,283	183	0,554	1,98%	0,551
DECEMBER	218	0,37	2,83%	0,372	418	0,273	5%	0,283	153	0,554	1,98%	0,551

Table 4 – Apartment A, PHASE 00 - Calculation Surfaces – Results Overview

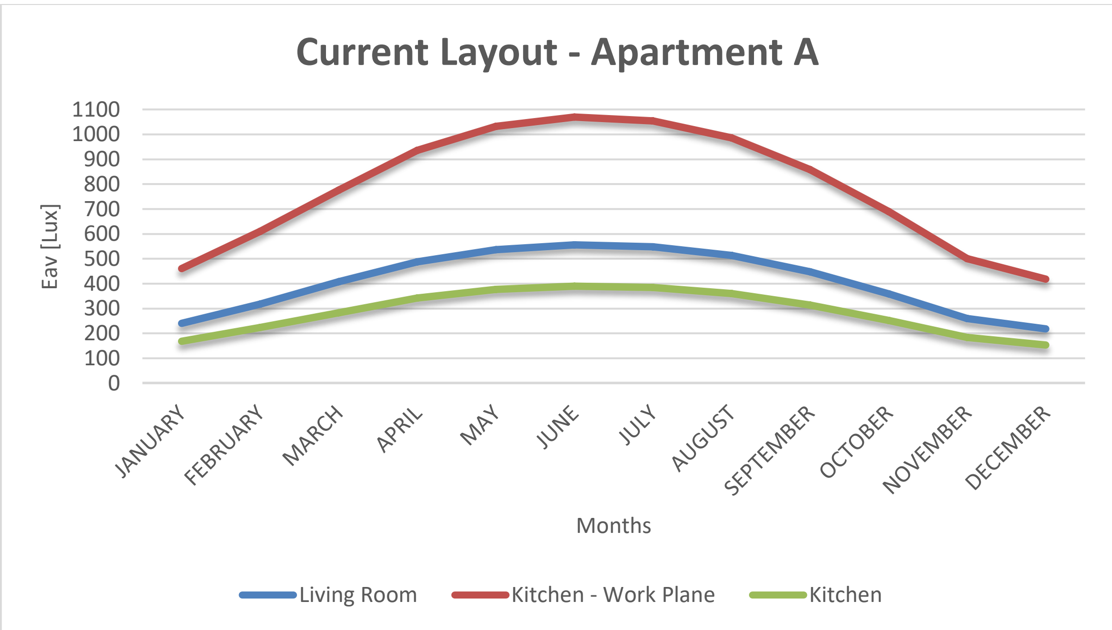


Diagram 2 – Apartment A, PHASE 00 - Calculation Surfaces – Results Overvie

June December

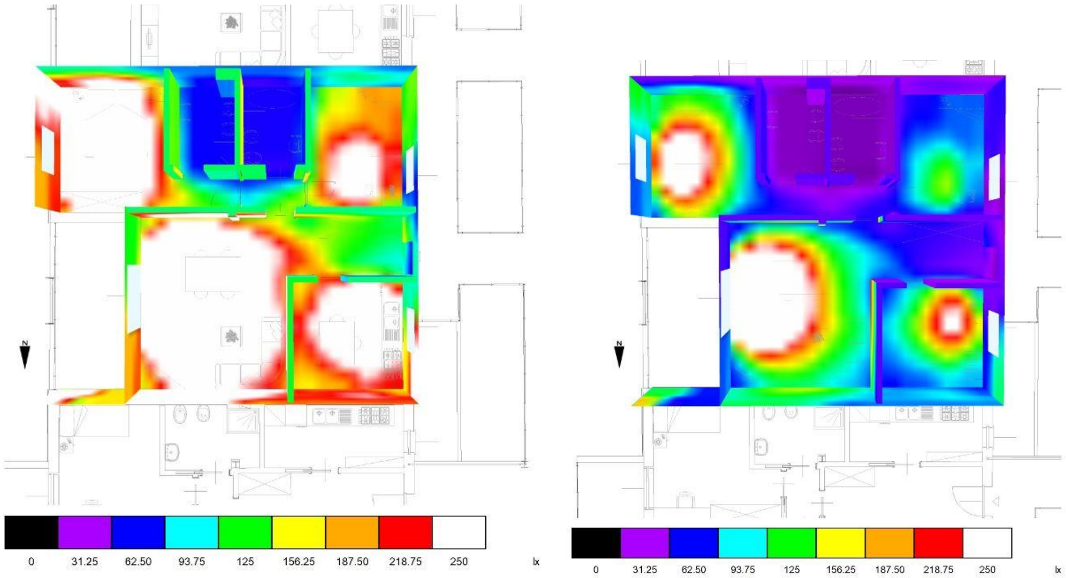


Image 19 – Apartment A, PHASE 00 – False Colour Rendering – June & December

As can be seen from the values shown in the table, the levels of both illumination and the Daylight factor for all three surfaces calculated do not deviate by much from the targets set. Only the general area set for the kitchen did not correspond to the values requested in the months of January, November and December. As for uniformity, the other two surfaces were the ones that created problems of visual discomfort as the value was well below 0.4 which had been set as the target and for both the level of illumination and the Daylight factor. Therefore this shows the need for optimization in this direction to improve the inhabitants' comfort.

APARTMENT B: FASE 00

Summary data on entry:

Reflection factor:

Walls: 0.5

Floors: 0.2

Ceiling: 0.7

Maintenance factor: 0.8

Glass surface Living Room: 1.8mq

Glass surface kitchen: 1.8mq

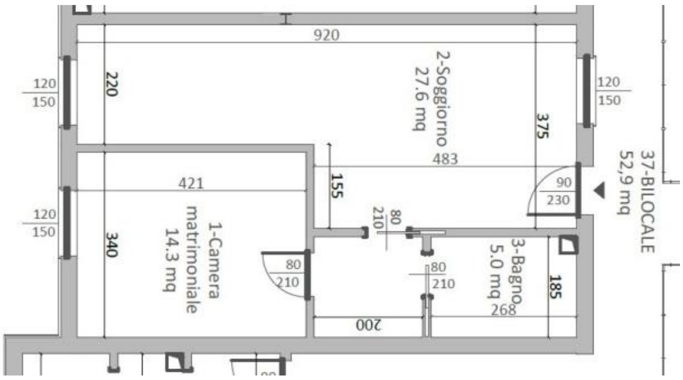


Image 14- Apartment B-Plan

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment B - PHASE 00							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	117	0,452	1,37%	0,452	210	0,377	2,45%	0,379
FEBRUARY	155	0,452	1,37%	0,452	278	0,377	2,45%	0,379
MARCH	197	0,452	1,37%	0,452	353	0,377	2,45%	0,379
APRIL	237	0,452	1,37%	0,452	426	0,377	2,45%	0,379
MAY	262	0,452	1,37%	0,452	470	0,377	2,45%	0,379
JUNE	271	0,452	1,37%	0,452	487	0,377	2,45%	0,379
JULY	267	0,452	1,37%	0,452	480	0,377	2,45%	0,379
AUGUST	250	0,452	1,37%	0,452	449	0,377	2,45%	0,379
SEPTEMBER	218	0,452	1,37%	0,452	391	0,377	2,45%	0,379
OCTOBER	175	0,452	1,37%	0,452	314	0,377	2,45%	0,379
NOVEMBER	127	0,452	1,37%	0,452	228	0,377	2,45%	0,379
DECEMBER	106	0,452	1,37%	0,452	191	0,377	2,45%	0,379

Table 5 – Apartment B, PHASE 00 - Calculation Surfaces – Results Overview

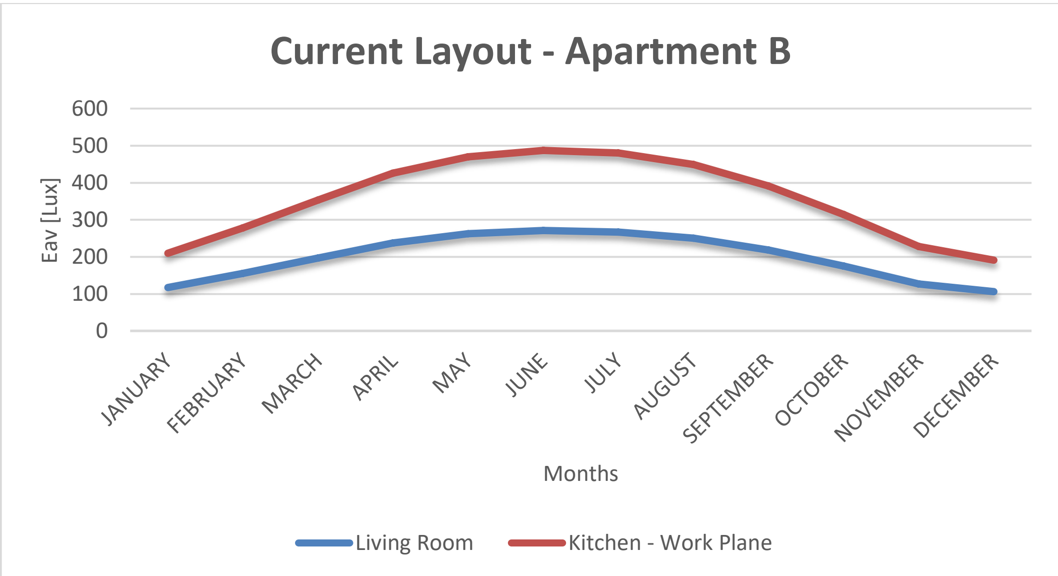


Diagram 3 – Apartment B, PHASE 00 - Calculation Surfaces – Results Overview

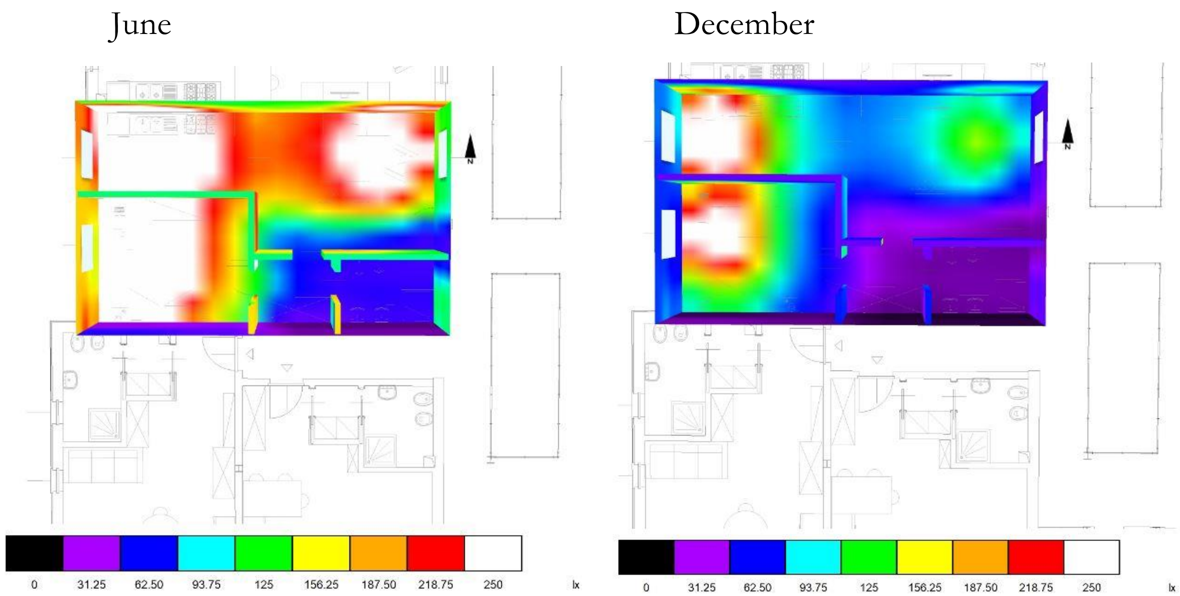


Image 20 – Apartment B, PHASE 00 – False Colour Rendering – June & December

The situation in this case is decidedly worse as the only acceptable values are the Daylight factor in the kitchen and the uniformity of the lighting in the Living room. In fact, the average lighting levels were not sufficient for 6 months of the year in the Living room and for 4 months in the kitchen. This light distribution is due to the great length of the room which includes both the living room and the kitchen with only one window for each of the extremities. In this case too proper optimization to relieve the user's discomfort is needed.

APARTMENT C: FASE 00

Summary data on entry:

Reflection factor:

Walls: 0.5

Floors: 0.2

Ceiling: 0.7

Maintenance factor: 0.8

Glass surface Living Room: 2.7mq

Glass surface kitchen: 1.8mq

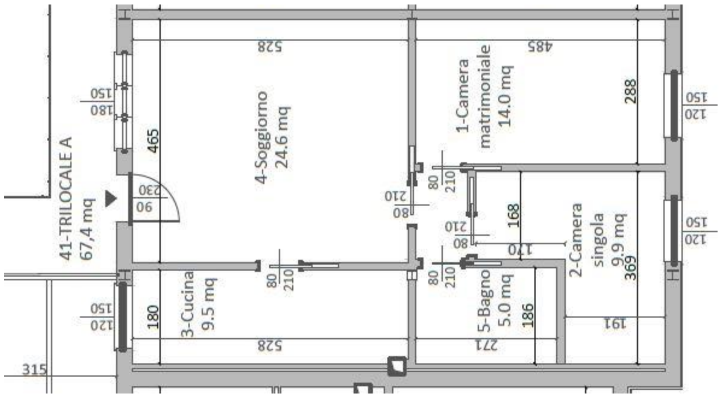


Image 12 - Apartment C-Plan

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment C - PHASE 00							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	105	0,378	1,24%	0,373	185	0,216	2,08%	0,219
FEBRUARY	139	0,378	1,24%	0,373	244	0,216	2,08%	0,219
MARCH	176	0,378	1,24%	0,373	310	0,216	2,08%	0,219
APRIL	213	0,378	1,24%	0,373	375	0,216	2,08%	0,219
MAY	235	0,378	1,24%	0,373	413	0,216	2,08%	0,219
JUNE	243	0,378	1,24%	0,373	428	0,216	2,08%	0,219
JULY	240	0,378	1,24%	0,373	422	0,216	2,08%	0,219
AUGUST	224	0,378	1,24%	0,373	395	0,216	2,08%	0,219
SEPTEMBER	195	0,378	1,24%	0,373	344	0,216	2,08%	0,219
OCTOBER	157	0,378	1,24%	0,373	276	0,216	2,08%	0,219
NOVEMBER	114	0,378	1,24%	0,373	200	0,216	2,08%	0,219
DECEMBER	95	0,378	1,24%	0,373	167	0,216	2,08%	0,219

Table 6 – Apartment C, PHASE 00 - Calculation Surfaces – Results Overview

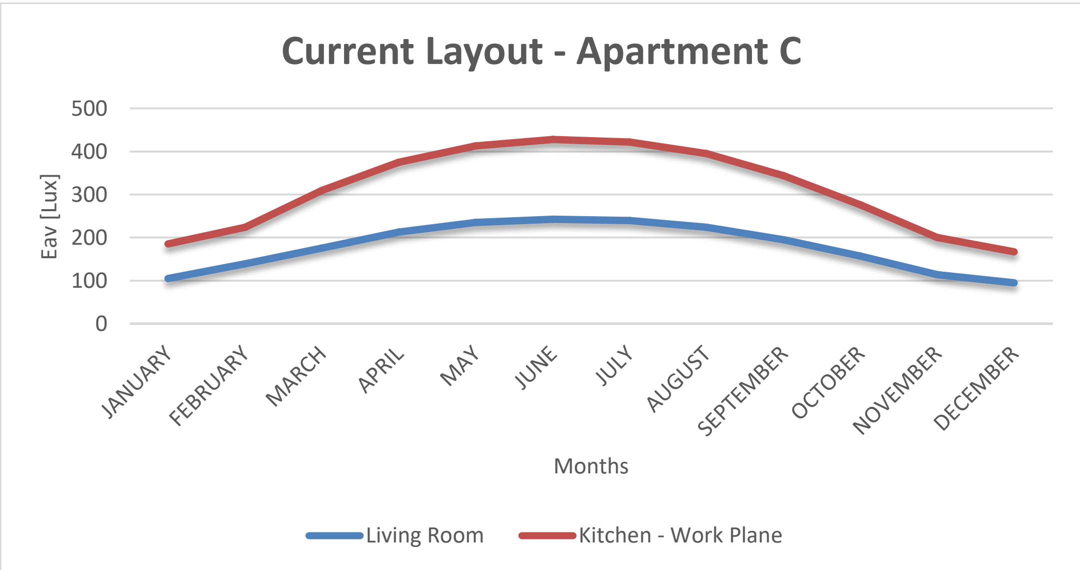


Diagram 4 – Apartment C, PHASE 00 - Calculation Surfaces – Results Overview

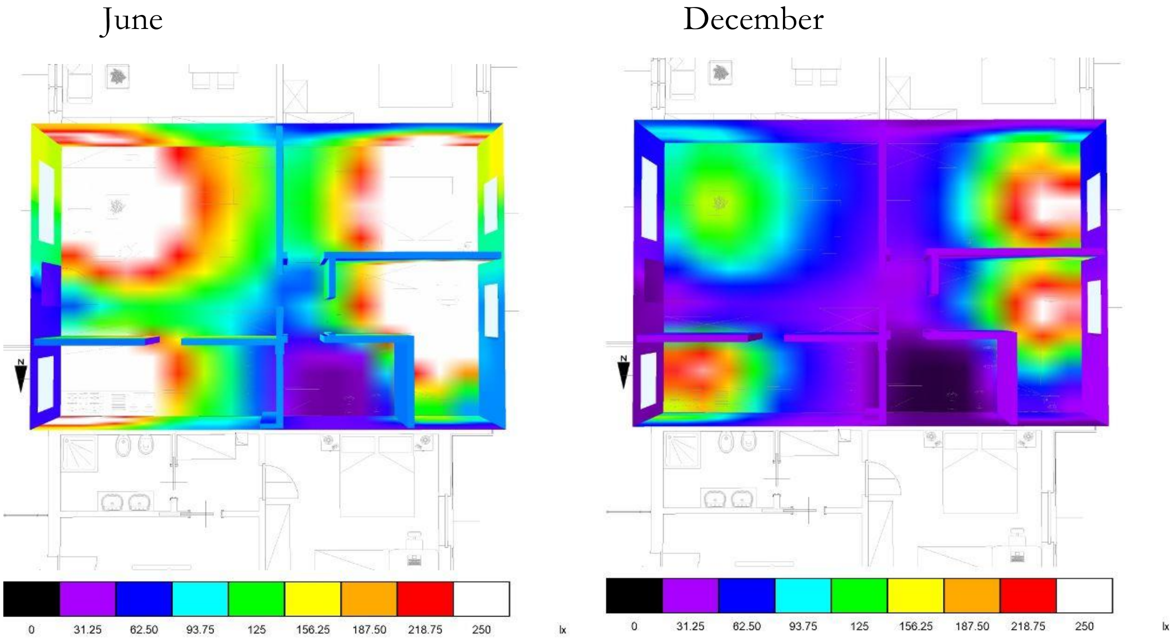


Image 21 – Apartment C, PHASE 00 – False Colour Rendering – June & December

In this third case the only acceptable level was the Daylight factor in the kitchen, none of the other values conformed to the standards set. In particular, the lighting level was sufficient only from April to August in the Living room and from March to September for the kitchen. Also the uniformities are very low and this too needs to be increased. The main problem in this case is the tight layout and depth of the kitchen that does not allow the light to reach the opposite side from the window.

PUBLIC SPACE A: FASE 00

Summary data on entry:

Reflection factor:

Walls: 0.5

Floors: 0.2

Ceiling: 0.7

Maintenance factor: 0.8

Glass surface Room 1: 17.82mq (Reading room)

Glass surface Room 2: 18.24mq (Atelier)

Image 17 - Public Space A-Plan

LOCATION	Building A - Mezzanine							
PROJECT NAME	Public Space A - PHASE 00							
CALCULATION SURFACE - NAME	Room 1				Room 2			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	119	0,473	1,41%	0,465	223	0,412	2,63%	0,411
FEBRUARY	157	0,473	1,41%	0,465	295	0,412	2,63%	0,411
MARCH	200	0,473	1,41%	0,465	374	0,412	2,63%	0,411
APRIL	241	0,473	1,41%	0,465	452	0,412	2,63%	0,411
MAY	266	0,473	1,41%	0,465	498	0,412	2,63%	0,411
JUNE	276	0,473	1,41%	0,465	516	0,412	2,63%	0,411
JULY	272	0,473	1,41%	0,465	509	0,412	2,63%	0,411
AUGUST	254	0,473	1,41%	0,465	476	0,412	2,63%	0,411
SEPTEMBER	222	0,473	1,41%	0,465	415	0,412	2,63%	0,411
OCTOBER	178	0,473	1,41%	0,465	333	0,412	2,63%	0,411
NOVEMBER	129	0,473	1,41%	0,465	241	0,412	2,63%	0,411
DECEMBER	108	0,473	1,41%	0,465	202	0,412	2,63%	0,411

Table 7 – Public Space A, PHASE 00 - Calculation Surfaces – Results Overview

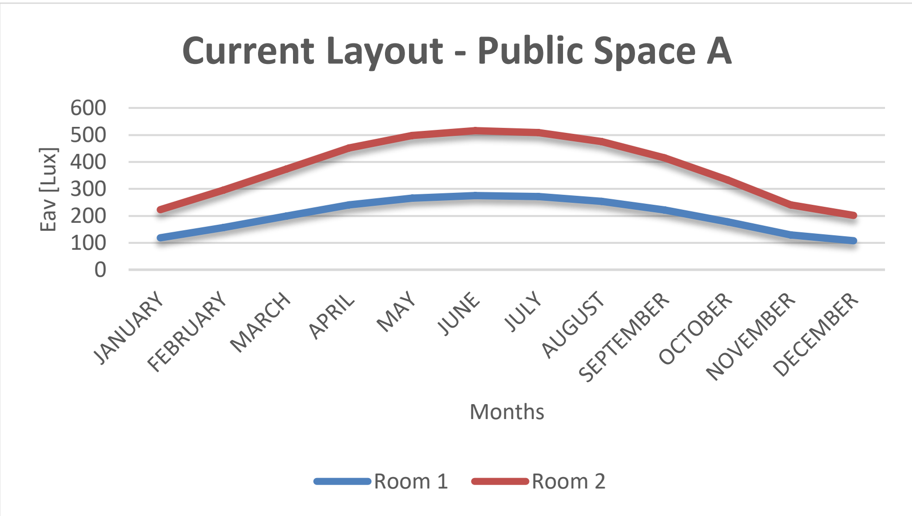


Diagram 5 – Public Space A, PHASE 00 - Calculation Surfaces – Results Overview

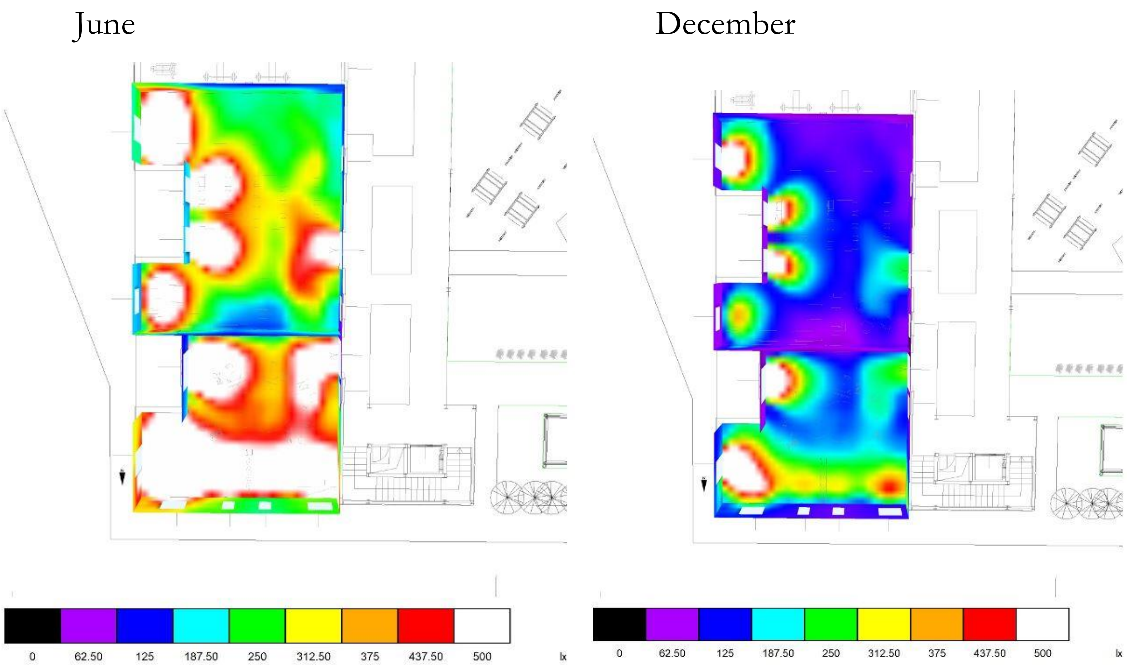


Image 22 – Public Space A, PHASE 00 – False Colour Rendering – June & December

Despite the more stringent regulatory requirements, the initial analysis of the public spaces was the same as the residential areas, in other words a single calculation surface that covers all the rooms under examination. Thus initial passage is useful for knowing the internal light distribution and to then to verify if the choice of internal furnishing reflects the best layout possible to take advantage of the natural light. This same surface of calculation, single for each one of the rooms, will be presented once more in PHASE 1. On the other hand, two different control surfaces will be set, one for the specific work area and the other as a general area within which it is recommended placing furniture that does not have a fixed place for work.

Analyzing the details of the current layout we can quickly notice how all the parameters extrapolated by the software are far from the target values. In these areas therefore, even more so for the residential areas, we find the need for lighting optimization which leads to proper use of the internal spaces divided into areas of competency.

In addition to the parameters considered for the residential part, it was decided to consider the glare factor since in these areas the work places are fixed and the users' orientation in regards to the glass surfaces is unavoidable. In this area three monitoring posts were considered, positioned just as the real users, with a visual sector of 360°, a slope of 5° and placed at a height of 1.5m. At the end of the simulations the maximum value of the glare factor was < 10 and was therefore well within the limits set by the standard of reference which recommends a value of < 20 for public spaces for long stays such as offices.

PUBLIC SPACE B: FASE 00

Summary data on entry:

Reflection factor:

Walls: 0.5

Floors: 0.2

Ceiling: 0.7

Maintenance factor: 0.8

Glass surface Room 1: 17.82mq (Kids Area)

Glass surface Room 2: 16.8mq (Conference Room)

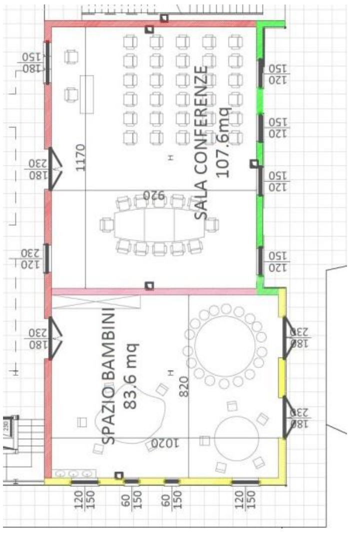


Image 16 - Public Space B-Plan

LOCATION	Building B - Mezzanine							
PROJECT NAME	Public Space B - PHASE 00							
CALCULATION SURFACE - NAME	Room 1				Room 2			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	144	0,282	1,70%	0,283	83	0,363	0,98%	0,365
FEBRUARY	191	0,282	1,70%	0,283	110	0,363	0,98%	0,365
MARCH	243	0,282	1,70%	0,283	140	0,363	0,98%	0,365
APRIL	293	0,282	1,70%	0,283	169	0,363	0,98%	0,365
MAY	323	0,282	1,70%	0,283	186	0,363	0,98%	0,365
JUNE	335	0,282	1,70%	0,283	193	0,363	0,98%	0,365
JULY	330	0,282	1,70%	0,283	190	0,363	0,98%	0,365
AUGUST	309	0,282	1,70%	0,283	178	0,363	0,98%	0,365
SEPTEMBER	269	0,282	1,70%	0,283	155	0,363	0,98%	0,365
OCTOBER	216	0,282	1,70%	0,283	125	0,363	0,98%	0,365
NOVEMBER	157	0,282	1,70%	0,283	90	0,363	0,98%	0,365
DECEMBER	131	0,282	1,70%	0,283	76	0,363	0,98%	0,365

Table 8 – Public Space B, PHASE 00 - Calculation Surfaces – Results Overview

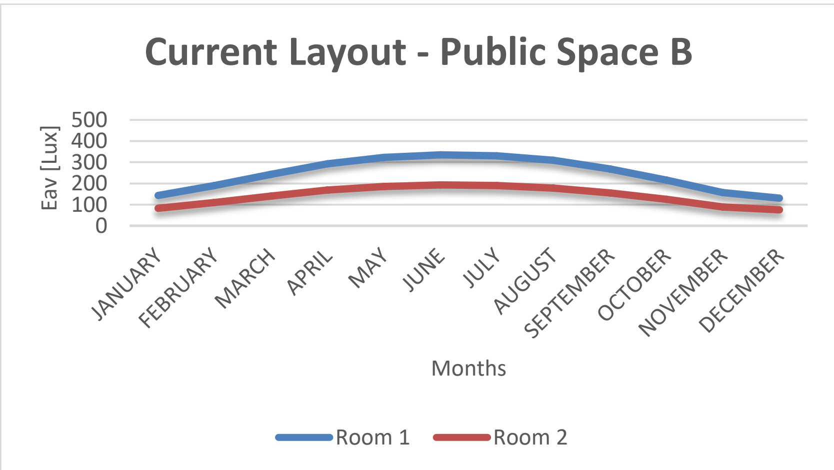


Diagram 6 – Public Space B, PHASE 00 - Calculation Surfaces – Results Overvie

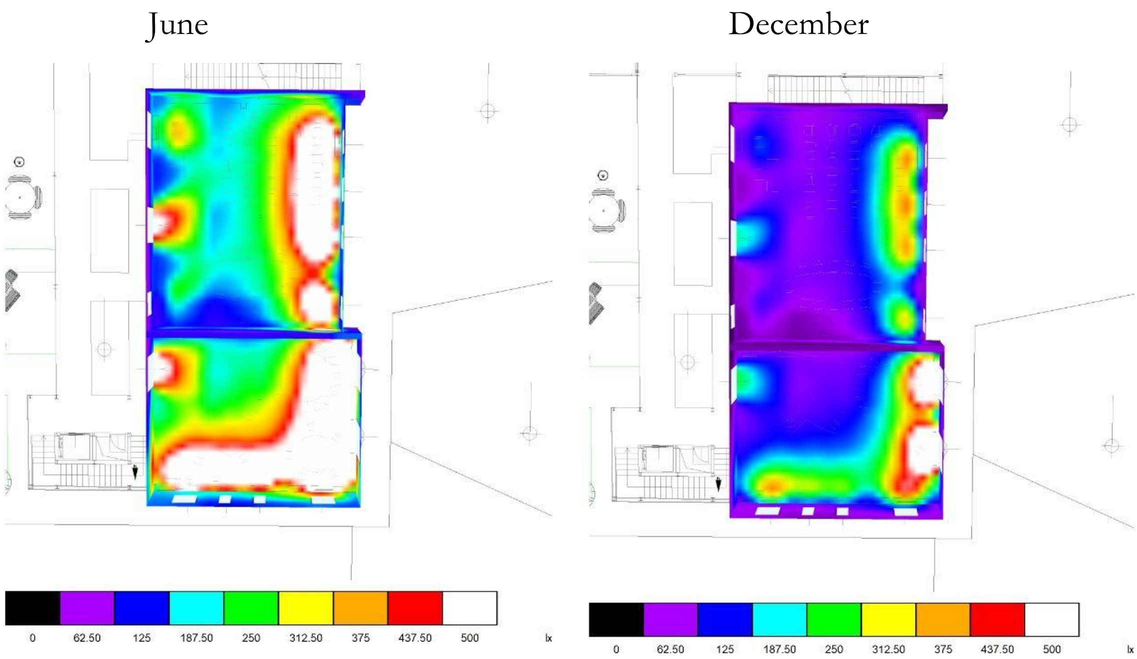


Image 23 – Public Space B, PHASE 00 – False Colour Rendering – June & December

As for the previous area, the calculation surfaces set for Public Space B cover the totality of the two rooms under examination in such a manner as to show the internal light distribution. Going on to the analysis of the data following the first simulation, we can see a great lack of light and Daylight factor, as well as a marked disparity of its distribution. Also in this case the successive analyses will have as an aim the identification of the two main areas into which divide the internal environment, in other words one specifically for work activities and the other for storage or for archives. In this area too monitoring posts were inserted into the model with the same characteristics as the previous case with a visual sector of 360°, a slope of 5° and placed at a height of 1.5m. As in the previous case the values extrapolated from the software show levels < 10 in all the cases and therefore there is currently no need for any particular action in this direction.

VARIATION OF INTERNAL SURFACES REFLECTION FACTOR PHASE 01

As explained previously, in this phase the reflection factor of the internal partitions will be varied, bringing them to the levels recommended in standard EN 12464-1. This passage is useful for understanding when this parameter is fundamental in planning such as the choice of one material compared to another has implications only esthetic or costs, but it also has powerful implications in the internal light distribution of an environment. All the other parameters won't change.

APARTMENT A: FASE 01

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 4.68mq

Glass surface kitchen: 1.8mq

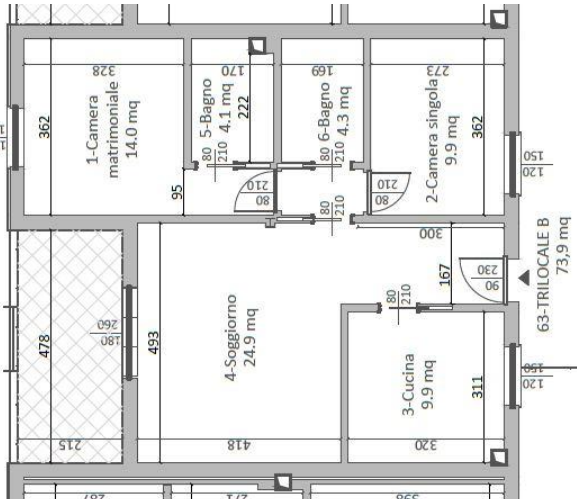


Image 13- Apartment A-Plan

LOCATION	Building A - 5th Floor											
PROJECT NAME	Apartment A - PHASE 01											
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane				Kitchen			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	255	0,428	3,00%	0,429	483	0,312	5,69%	0,320	192	0,618	2,26%	0,615
FEBRUARY	337	0,428	3,00%	0,429	638	0,312	5,69%	0,320	255	0,618	2,26%	0,615
MARCH	428	0,428	3,00%	0,429	811	0,312	5,69%	0,320	324	0,618	2,26%	0,615
APRIL	516	0,428	3,00%	0,429	979	0,312	5,69%	0,320	390	0,618	2,26%	0,615
MAY	570	0,428	3,00%	0,429	1080	0,312	5,69%	0,320	431	0,618	2,26%	0,615
JUNE	590	0,428	3,00%	0,429	1118	0,312	5,69%	0,320	446	0,618	2,26%	0,615
JULY	582	0,428	3,00%	0,429	1103	0,312	5,69%	0,320	440	0,618	2,26%	0,615
AUGUST	544	0,428	3,00%	0,429	1032	0,312	5,69%	0,320	411	0,618	2,26%	0,615
SEPTEMBER	474	0,428	3,00%	0,429	899	0,312	5,69%	0,320	358	0,618	2,26%	0,615
OCTOBER	381	0,428	3,00%	0,429	722	0,312	5,69%	0,320	288	0,618	2,26%	0,615
NOVEMBER	276	0,428	3,00%	0,429	523	0,312	5,69%	0,320	209	0,618	2,26%	0,615
DECEMBER	231	0,428	3,00%	0,429	438	0,312	5,69%	0,320	175	0,618	2,26%	0,615

Table 8 – Apartment A, PHASE 01 - Calculation Surfaces – Results Overview

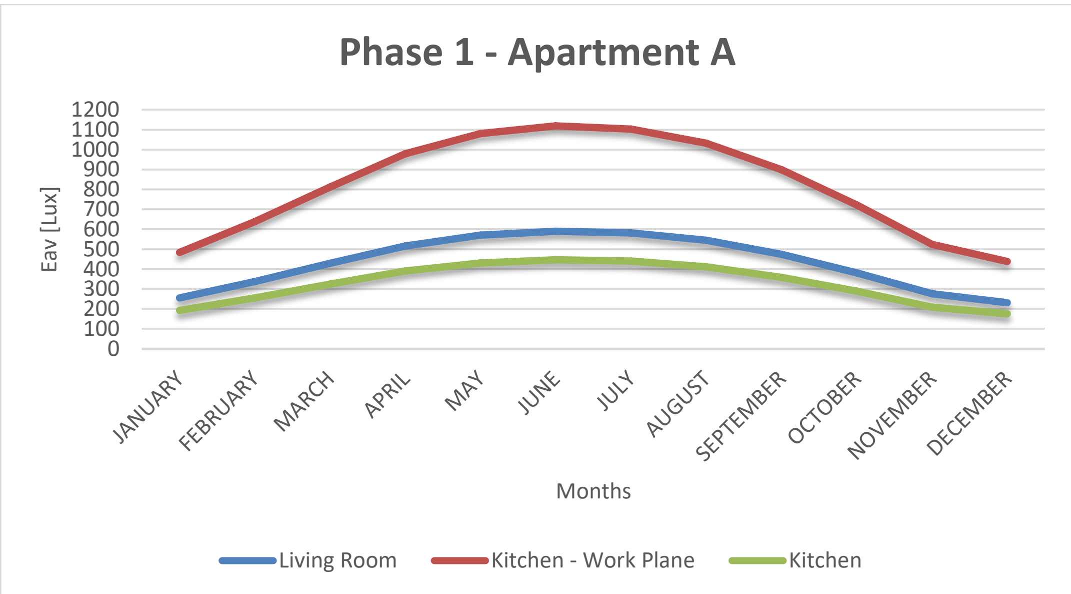


Diagram 7 – Apartment A, PHASE 01 - Calculation Surfaces – Results Overview

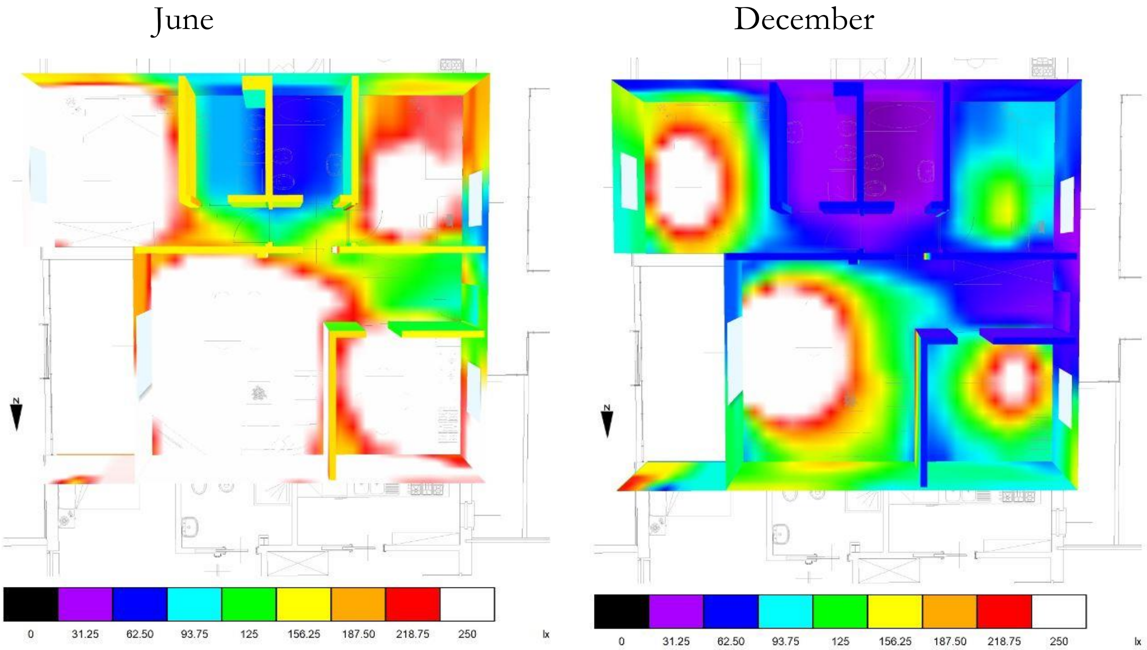


Image 25 – Apartment A, PHASE 01 – False Colour Rendering – June & December

As can be seen in the values shown in the table the levels of both lighting and Daylight factor for all three surfaces calculated have improved, particularly the Living room which now corresponds completely with the values requested. On the other hand the kitchen still requires another slight increase of the light levels for the general surfaces and uniformity in the work area. The procedure presented in this case, divided into phases allows the architect to concentrate on one parameter at a time, improving the efficiency of the planning since at every step the output of the software clearly shows where to bring about improvements and which parameters are to be modified.

APARTMENT B: FASE 01

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 1.8mq

Glass surface kitchen: 1.8mq

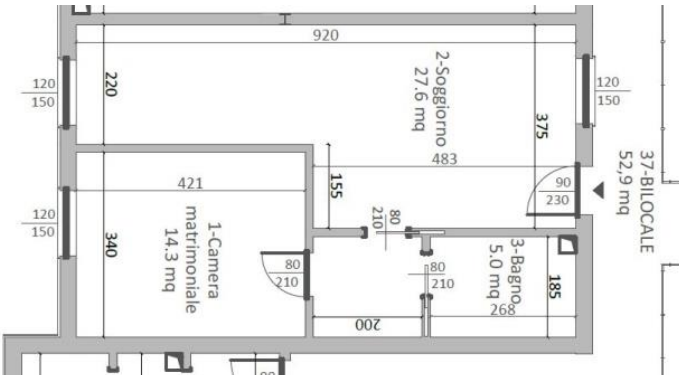


Image 14- Apartment B-Plan

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment B - PHASE 01							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	135	0,524	1,59%	0,524	236	0,435	2,76%	0,440
FEBRUARY	179	0,524	1,59%	0,524	313	0,435	2,76%	0,440
MARCH	228	0,524	1,59%	0,524	397	0,435	2,76%	0,440
APRIL	275	0,524	1,59%	0,524	479	0,435	2,76%	0,440
MAY	303	0,524	1,59%	0,524	529	0,435	2,76%	0,440
JUNE	314	0,524	1,59%	0,524	548	0,435	2,76%	0,440
JULY	309	0,524	1,59%	0,524	540	0,435	2,76%	0,440
AUGUST	290	0,524	1,59%	0,524	505	0,435	2,76%	0,440
SEPTEMBER	252	0,524	1,59%	0,524	440	0,435	2,76%	0,440
OCTOBER	203	0,524	1,59%	0,524	354	0,435	2,76%	0,440
NOVEMBER	147	0,524	1,59%	0,524	256	0,435	2,76%	0,440
DECEMBER	123	0,524	1,59%	0,524	214	0,435	2,76%	0,440

Table 9 – Apartment B, PHASE 01 - Calculation Surfaces – Results Overview

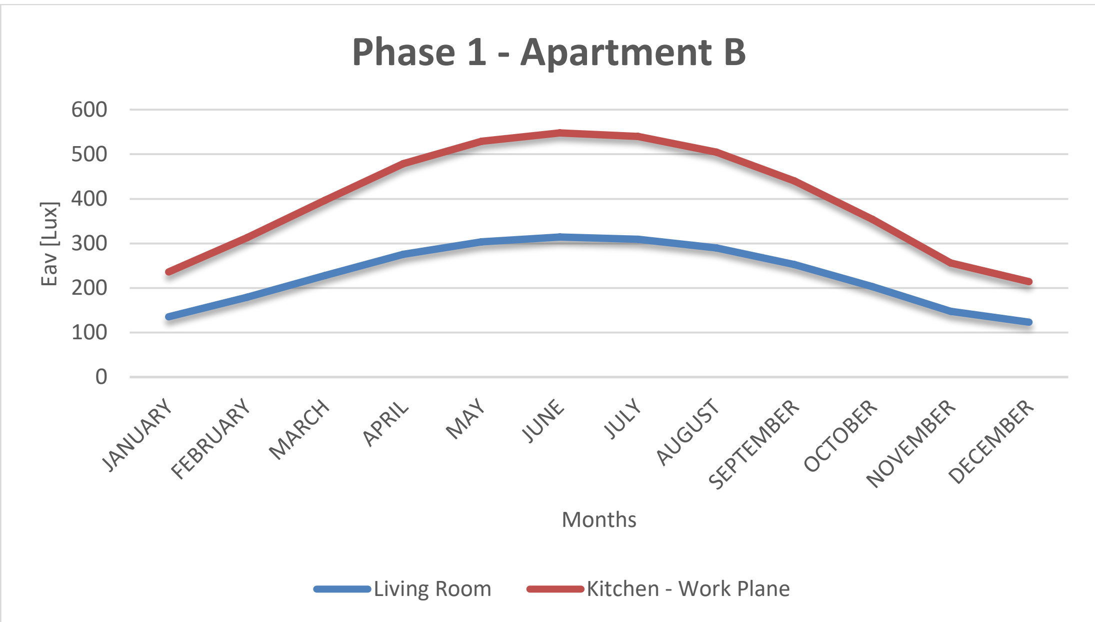


Diagram 8 – Apartment B, PHASE 01 - Calculation Surfaces – Results Overview

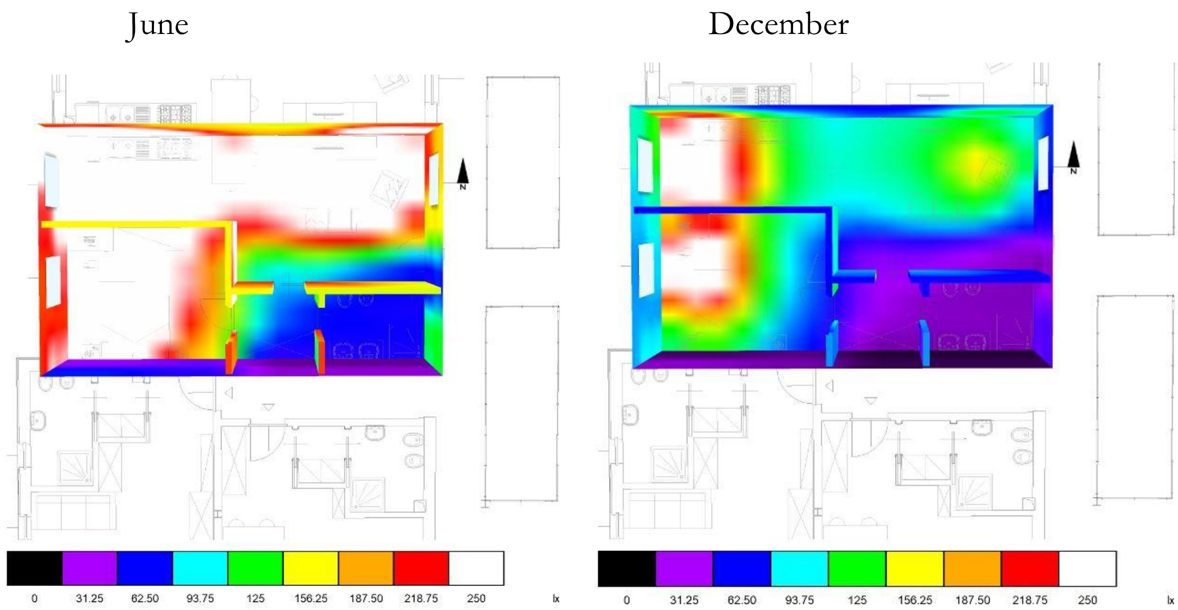


Image 26 – Apartment B, PHASE 01 – False Colour Rendering – June & December

Also in this case the increase in the reflective coefficient of the internal surfaces gave a general improvement, both in the in the quality of light and its uniformity. Specifically this apartment's need is to increase the light level in the months from November to February (for 4 months against the 6 in the previous phase), obviously the least favored from this point of view. Therefore in the subsequent phases action will be taken on the glass surfaces to reach the levels set as targets.

APARTMENT C: FASE 01

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 2.7mq

Glass surface kitchen: 1.8mq

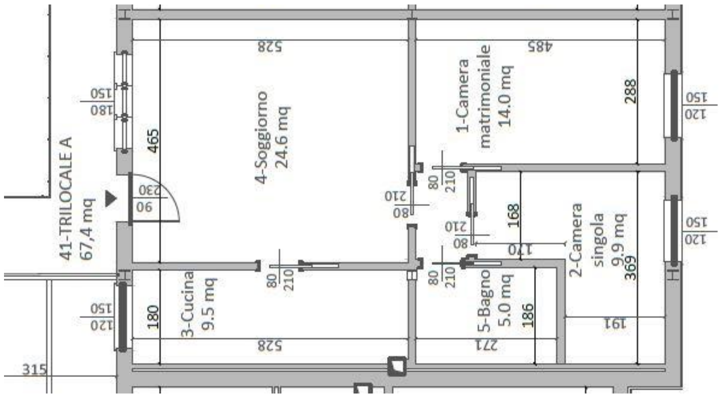


Image 12 - Apartment C-Plan

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment C - PHASE 01							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	127	0,484	1,50%	0,479	209	0,292	2,36%	0,307
FEBRUARY	168	0,484	1,50%	0,479	277	0,292	2,36%	0,307
MARCH	213	0,484	1,50%	0,479	352	0,292	2,36%	0,307
APRIL	257	0,484	1,50%	0,479	424	0,292	2,36%	0,307
MAY	283	0,484	1,50%	0,479	468	0,292	2,36%	0,307
JUNE	293	0,484	1,50%	0,479	484	0,292	2,36%	0,307
JULY	289	0,484	1,50%	0,479	478	0,292	2,36%	0,307
AUGUST	271	0,484	1,50%	0,479	447	0,292	2,36%	0,307
SEPTEMBER	236	0,484	1,50%	0,479	389	0,292	2,36%	0,307
OCTOBER	190	0,484	1,50%	0,479	313	0,292	2,36%	0,307
NOVEMBER	137	0,484	1,50%	0,479	227	0,292	2,36%	0,307
DECEMBER	115	0,484	1,50%	0,479	190	0,292	2,36%	0,307

Table 10 – Apartment C, PHASE 01 - Calculation Surfaces – Results Overview

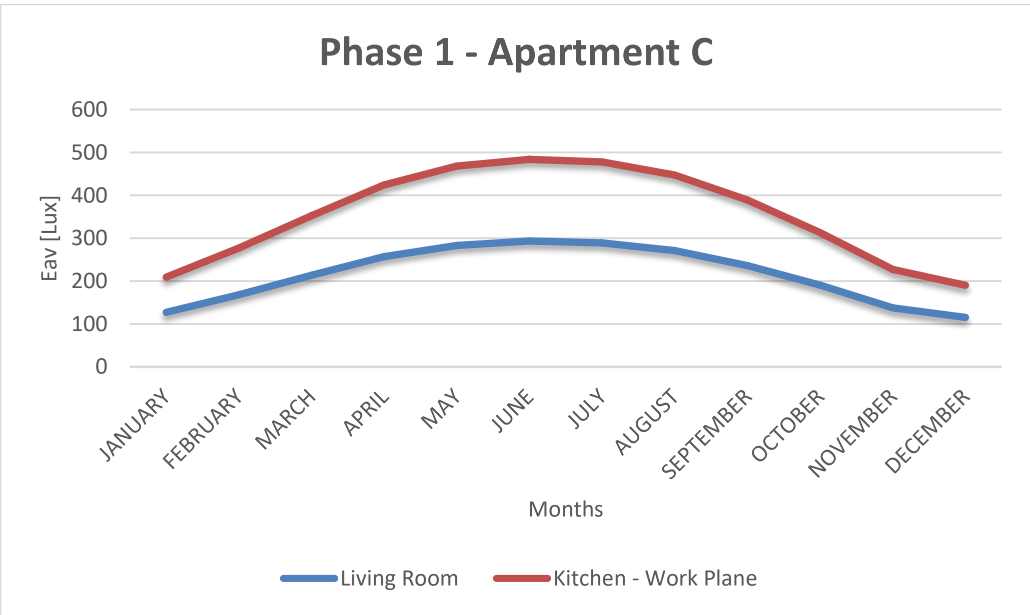


Diagram 9 – Apartment C, PHASE 01 - Calculation Surfaces – Results Overview

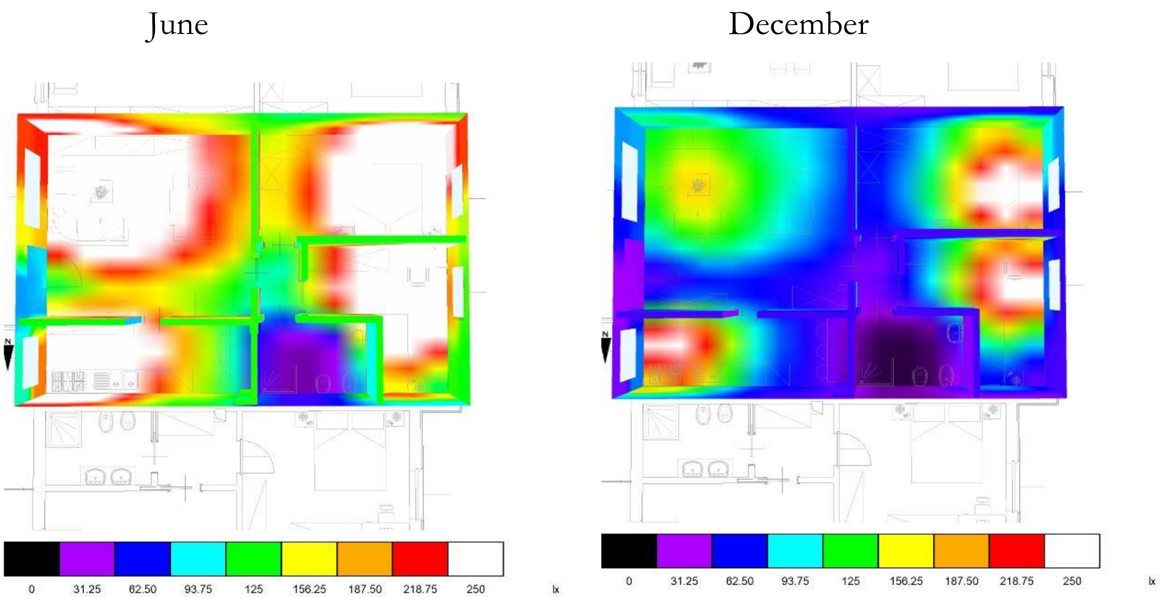


Image 27 – Apartment C, PHASE 01 – False Colour Rendering – June & December

The trend for improvement is present also in this case, but in any case it remains the least favored of the three residential environments analyzed. Therefore both spaces will require further optimization for both the quality of light and its distribution.

PUBLIC SPACE A: FASE 01

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Room 1: 17.82mq (Reading room)

Glass surface Room 2: 18.24mq (Atelier)

Image 17 - Public Space A-Plan

LOCATION	Building A - Mezzanine							
PROJECT NAME	Public Space A - PHASE 01							
CALCULATION SURFACE - NAME	Room 1				Room 2			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	130	0,529	1,54%	0,526	242	0,462	2,86%	0,461
FEBRUARY	172	0,529	1,54%	0,526	321	0,462	2,86%	0,461
MARCH	219	0,529	1,54%	0,526	408	0,462	2,86%	0,461
APRIL	264	0,529	1,54%	0,526	492	0,462	2,86%	0,461
MAY	292	0,529	1,54%	0,526	542	0,462	2,86%	0,461
JUNE	302	0,529	1,54%	0,526	562	0,462	2,86%	0,461
JULY	298	0,529	1,54%	0,526	554	0,462	2,86%	0,461
AUGUST	279	0,529	1,54%	0,526	518	0,462	2,86%	0,461
SEPTEMBER	243	0,529	1,54%	0,526	451	0,462	2,86%	0,461
OCTOBER	195	0,529	1,54%	0,526	363	0,462	2,86%	0,461
NOVEMBER	141	0,529	1,54%	0,526	263	0,462	2,86%	0,461
DECEMBER	118	0,529	1,54%	0,526	220	0,462	2,86%	0,461

Table 11 – Public Space A, PHASE 01 - Calculation Surfaces – Results Overview

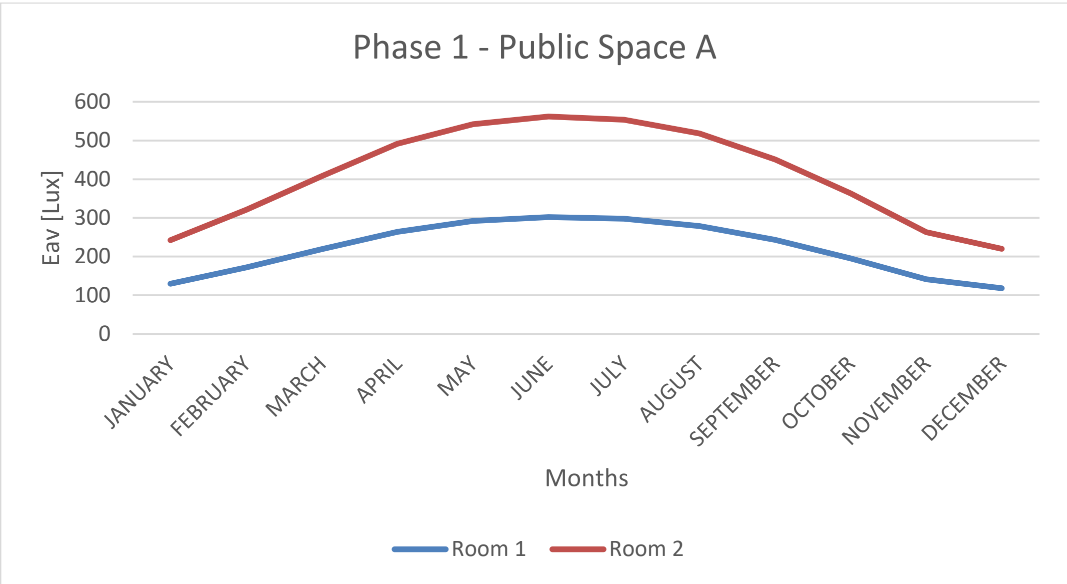


Diagram 10 – Public Space A, PHASE 01 - Calculation Surfaces – Results Overview

June December

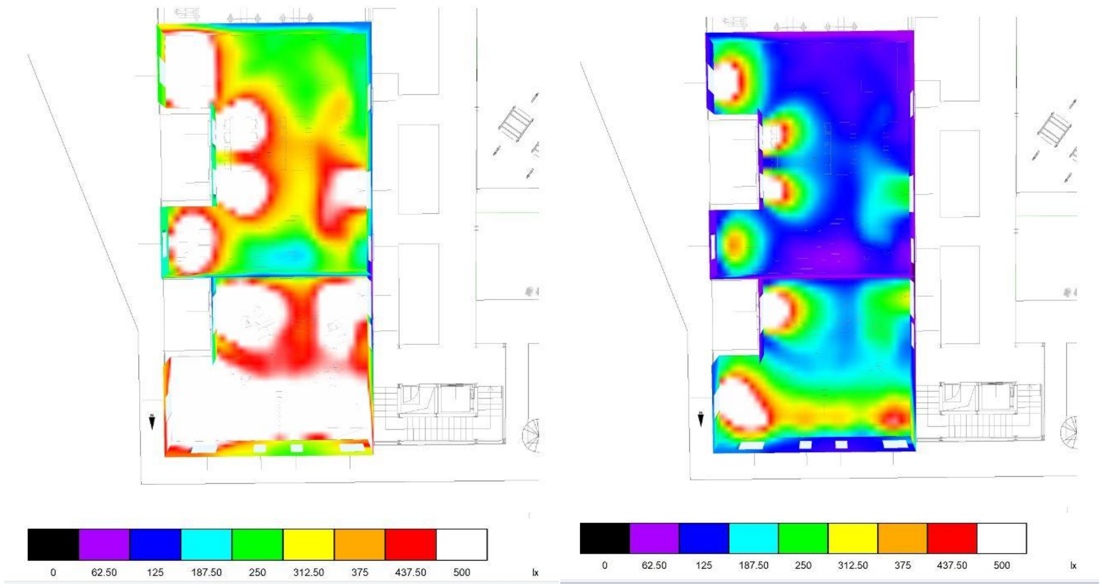


Image 27 – Public Space A, PHASE 01 – False Colour Rendering – June & December

As previously stated, the surfaces calculated also for PHASE 1 are unique to each room, from the subsequent phase to this phase and continuing on they will be doubled and we will seek to improve the internal distributive configuration to allow the proper use of the natural light source. Up to now it has been possible to identify the areas with the greatest contribution of light and where the light is distributed more uniformly. This will make the choice of the future position for the calculation of surfaces easier. Nonetheless, the critical points of these environments are still very high as the spaces are very extensive and deep. In addition, the glass surfaces are screened on one side by the structure of the balconies. Another critical element is the limit of the double view of the reading room which in fact is the one that is least luminous. As far as the glare is concerned, no increases of note were recorded since each one of the monitoring posts within the rooms registered values greater than 10.

PUBLIC SPACE B: FASE 01

Summery data on entry:

Reflection factor:

Wall: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Room 1: 17.82mq (Kids Area)

Glass surface Room 2: 16.8mq (Conference Room)

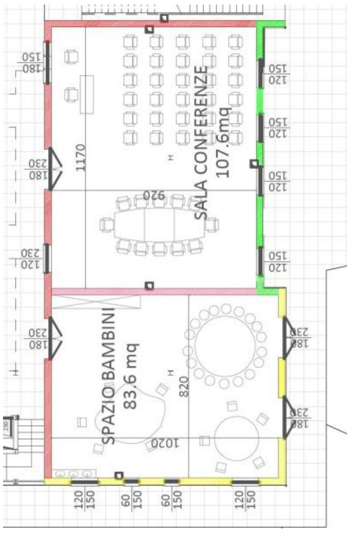


Image 16 - Public Space B-Plan

LOCATION	Building B - Mezzanine							
PROJECT NAME	Public Space B - PHASE 01							
CALCULATION SURFACE - NAME	Room 1				Room 2			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	161	0,342	1,89%	0,342	93	0,432	1,10%	0,434
FEBRUARY	213	0,342	1,89%	0,342	123	0,432	1,10%	0,434
MARCH	270	0,342	1,89%	0,342	157	0,432	1,10%	0,434
APRIL	326	0,342	1,89%	0,342	189	0,432	1,10%	0,434
MAY	360	0,342	1,89%	0,342	209	0,432	1,10%	0,434
JUNE	372	0,342	1,89%	0,342	216	0,432	1,10%	0,434
JULY	367	0,342	1,89%	0,342	213	0,432	1,10%	0,434
AUGUST	344	0,342	1,89%	0,342	199	0,432	1,10%	0,434
SEPTEMBER	299	0,342	1,89%	0,342	174	0,432	1,10%	0,434
OCTOBER	240	0,342	1,89%	0,342	140	0,432	1,10%	0,434
NOVEMBER	174	0,342	1,89%	0,342	101	0,432	1,10%	0,434
DECEMBER	149	0,342	1,89%	0,342	85	0,432	1,10%	0,434

Table 12 – Public Space B, PHASE 01 - Calculation Surfaces – Results Overview

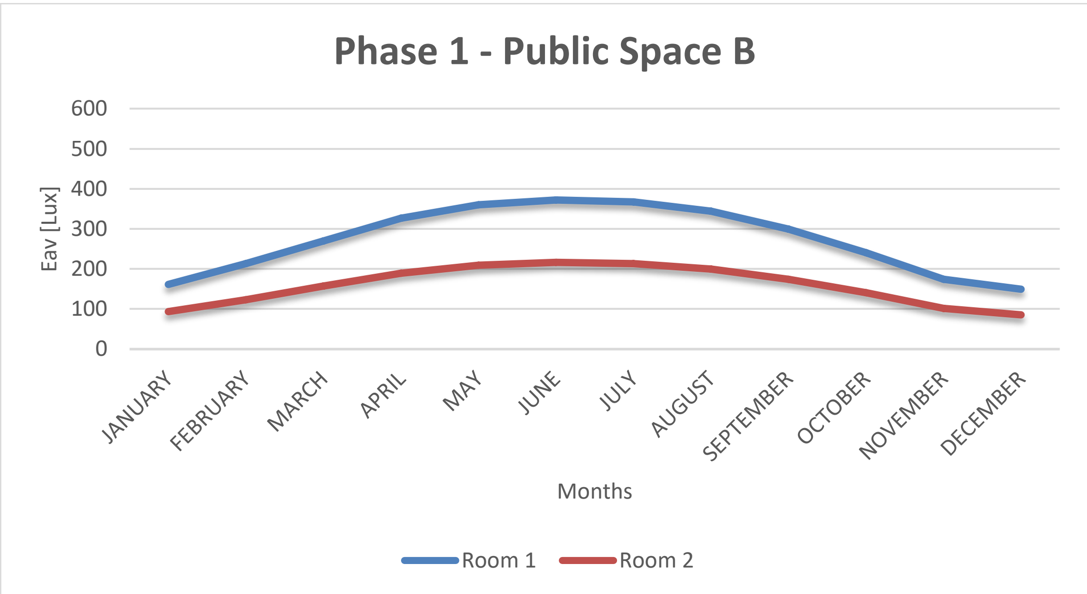


Diagram 11 – Public Space B, PHASE 01 - Calculation Surfaces – Results Overview

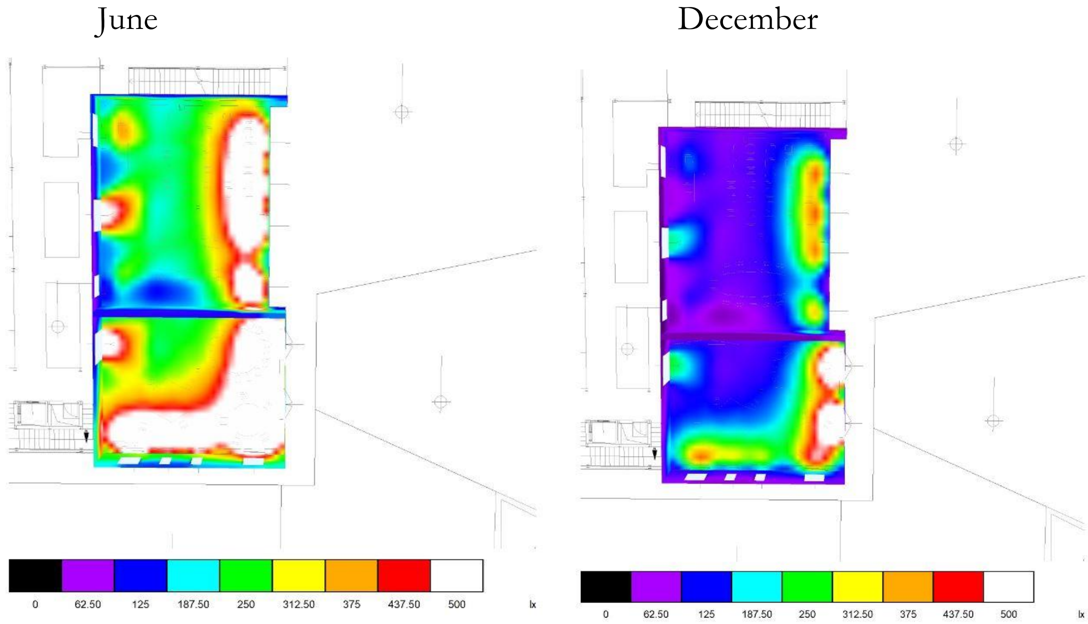


Image 28 – Public Space B, PHASE 01 – False Colour Rendering – June & December

The improvement compared to the previous phase is in the order of 10% for the level of illumination, whereas a greater increase of the uniformity was recorded. As in the previous area (public Space A) the major critical points were the great depth of the environments and the external obstruction due to the balcony. The values of glare remain well within the set limits. In fact, each one of the monitoring posts within the places recorded a level of < 10 and therefore no further action is required. Beginning in the next phase they will be divided in two which will have to correspond to the different objective values shown previously.

VARIATIONS OF THE GLASS SURFACES PHASE 02

This phase marks the passage from the first preliminary phase of analysis to active planning which includes physical modifications of the environments under examination such as the dimensions of the windows or the external application of screening devices. From this point on each area under examination will need specific planning aimed at the improvement of the parameters previously analyzed. In the comments following the presentation of the data therefore the modifications needed for the optimization will be specified. In addition, for the public spaces, the new areas of calculation especially allocated for the different services will be presented.

APARTMENT A: FASE 02

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 4.68mq

Glass surface Kitchen: 2.7mq (150x180cm)

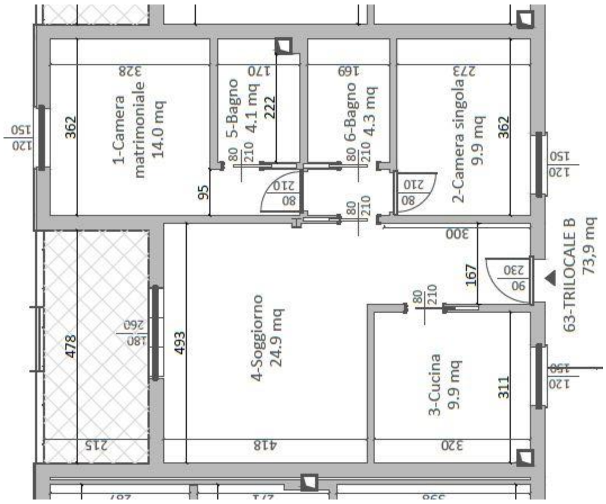


Image 13- Apartment A-Plan

LOCATION	Building A - 5th Floor											
PROJECT NAME	Apartment A - PHASE 02											
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane				Kitchen			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	257	0,435	3,03%	0,436	682	0,325	8,07%	0,319	253	0,596	2,98%	0,599
FEBRUARY	340	0,435	3,03%	0,436	902	0,325	8,07%	0,319	335	0,596	2,98%	0,599
MARCH	432	0,435	3,03%	0,436	1147	0,325	8,07%	0,319	426	0,596	2,98%	0,599
APRIL	521	0,435	3,03%	0,436	1383	0,325	8,07%	0,319	514	0,596	2,98%	0,599
MAY	575	0,435	3,03%	0,436	1526	0,325	8,07%	0,319	567	0,596	2,98%	0,599
JUNE	595	0,435	3,03%	0,436	1580	0,325	8,07%	0,319	587	0,596	2,98%	0,599
JULY	587	0,435	3,03%	0,436	1558	0,325	8,07%	0,319	579	0,596	2,98%	0,599
AUGUST	549	0,435	3,03%	0,436	1458	0,325	8,07%	0,319	542	0,596	2,98%	0,599
SEPTEMBER	478	0,435	3,03%	0,436	1270	0,325	8,07%	0,319	472	0,596	2,98%	0,599
OCTOBER	385	0,435	3,03%	0,436	1021	0,325	8,07%	0,319	379	0,596	2,98%	0,599
NOVEMBER	279	0,435	3,03%	0,436	739	0,325	8,07%	0,319	275	0,596	2,98%	0,599
DECEMBER	233	0,435	3,03%	0,436	619	0,325	8,07%	0,319	230	0,596	2,98%	0,599

Table 13 – Apartment A, PHASE 02 - Calculation Surfaces – Results Overview

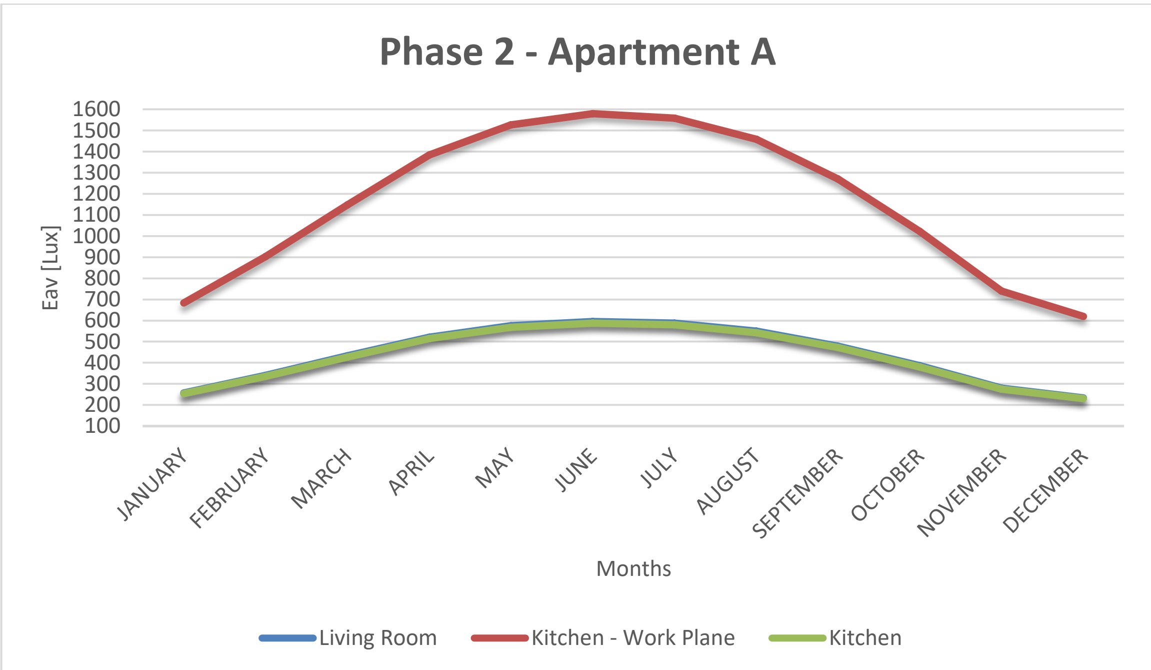


Diagram 12 – Apartment A, PHASE 02 - Calculation Surfaces – Results Overview

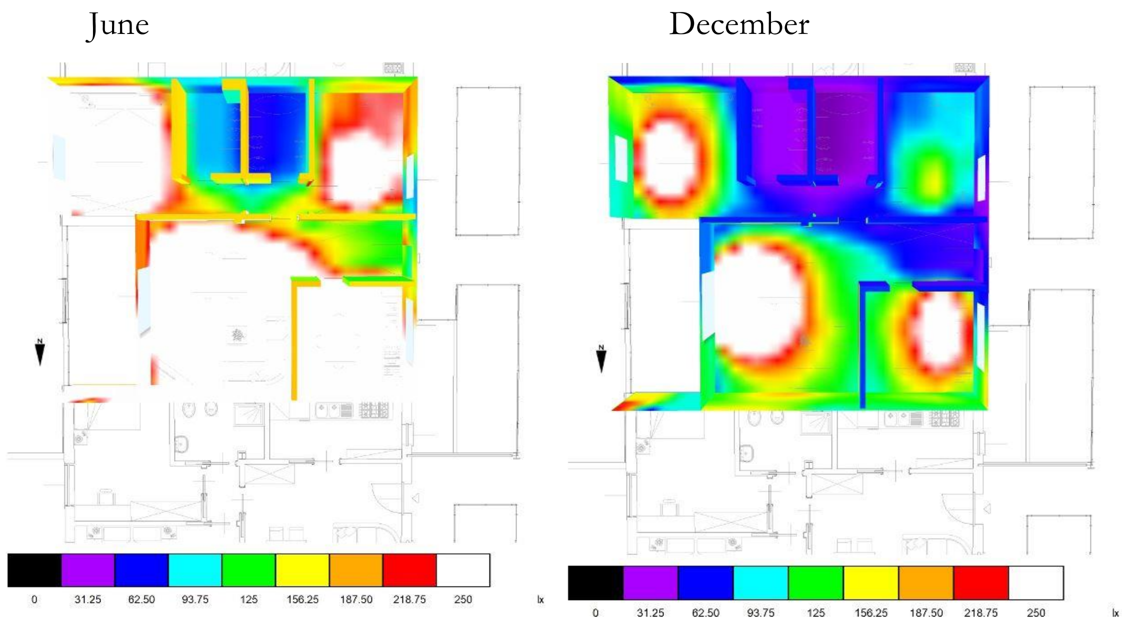


Image 29 – Apartment A, PHASE 02 – False Colour Rendering – June & December

The modifications carried out in this phase concern only the glass surfaces of the rooms which require increases in the level of light, in this case the kitchen. The minimum glass surface needed is equal to 2.7sq.m. The window proposed for this case must be 150 x 180 cm and positioned in the same place as the previous window. In this way it is possible to guarantee an adequate quantity of light which corresponds with the values set for all the year, in terms of both the average level of lighting, and the Daylight factor. The only parameter that remains out from the parameters set is the uniformity on the kitchen work area which shows the need for a shading system which allows the modulation of the entry of natural light and distributing it adequately. In addition, very high average levels of illumination were noted in the summer months, in fact they reached an average 1,580 Lux in the month of June in the kitchen work area. In the successive phases therefore we will try to reduce this value with the use of solar screening.

APARTMENT B: FASE 02

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 3.57mq (210 x 170cm)

Glass surface Kitchen: 2.4mq (150 x 160cm)

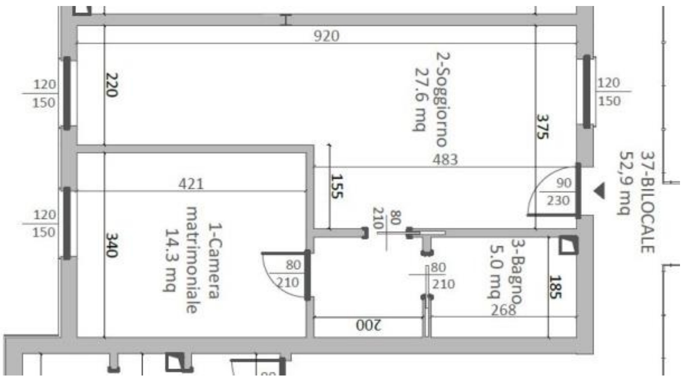


Image 14- Apartment B-Plan

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment B - PHASE 02							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	227	0,467	2,67%	0,471	355	0,363	4,13%	0,367
FEBRUARY	301	0,467	2,67%	0,471	470	0,363	4,13%	0,367
MARCH	382	0,467	2,67%	0,471	597	0,363	4,13%	0,367
APRIL	461	0,467	2,67%	0,471	721	0,363	4,13%	0,367
MAY	509	0,467	2,67%	0,471	795	0,363	4,13%	0,367
JUNE	527	0,467	2,67%	0,471	823	0,363	4,13%	0,367
JULY	519	0,467	2,67%	0,471	812	0,363	4,13%	0,367
AUGUST	486	0,467	2,67%	0,471	759	0,363	4,13%	0,367
SEPTEMBER	423	0,467	2,67%	0,471	661	0,363	4,13%	0,367
OCTOBER	340	0,467	2,67%	0,471	532	0,363	4,13%	0,367
NOVEMBER	246	0,467	2,67%	0,471	385	0,363	4,13%	0,367
DECEMBER	206	0,467	2,67%	0,471	322	0,363	4,13%	0,367

Table 14 – Apartment B, PHASE 02 - Calculation Surfaces – Results Overview

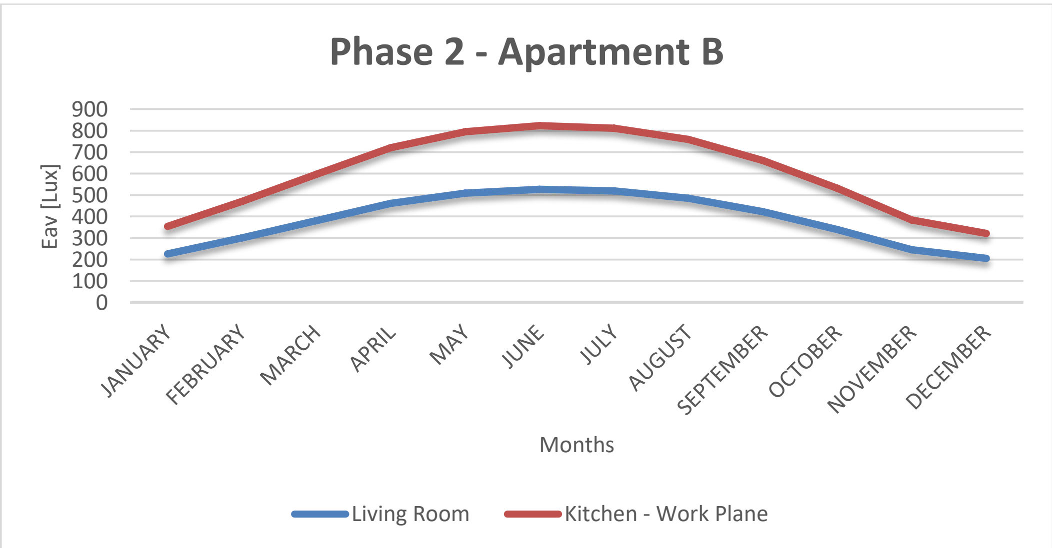


Diagram 13 – Apartment B, PHASE 02 - Calculation Surfaces – Results Overview

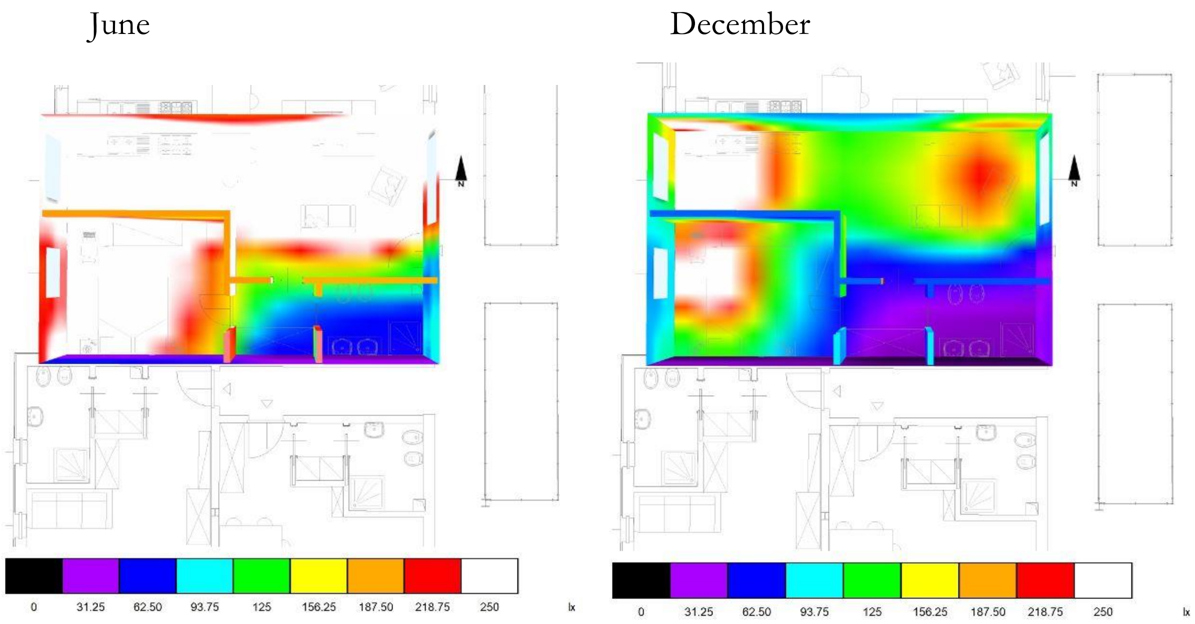


Image 30 – Apartment B, PHASE 02 – False Colour Rendering – June & December

Compared to the previous case it was necessary to increase much more the glass surfaces of both the spaces under examination. In order to reach the suggested dimension a number of different trials were made, increasing each time the dimension of the windows until reaching the minimum dimensions for achieving the illumination required during the whole year. As it is possible to understand from the results shown, in this case the need to study a shading system is also needed to allow a more controlled modulation of the entry of light in order to avoid localized spikes of light, or areas that were too dark.

APARTMENT C: FASE 02

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 3.74mq (220 x 170cm)

Glass surface Kitchen: 2.55mq (150 x 170cm)

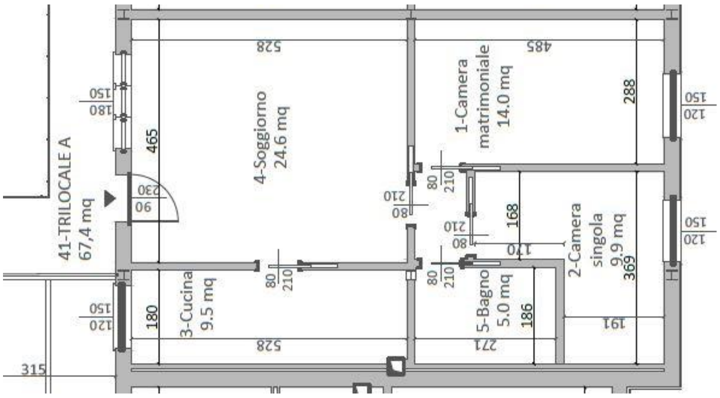


Image 12 - Apartment C-Plan

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment C - PHASE 02							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	221	0,42	2,59%	0,421	341	0,241	4,02%	0,238
FEBRUARY	292	0,42	2,59%	0,421	451	0,241	4,02%	0,238
MARCH	371	0,42	2,59%	0,421	573	0,241	4,02%	0,238
APRIL	447	0,42	2,59%	0,421	691	0,241	4,02%	0,238
MAY	493	0,42	2,59%	0,421	763	0,241	4,02%	0,238
JUNE	511	0,42	2,59%	0,421	790	0,241	4,02%	0,238
JULY	504	0,42	2,59%	0,421	779	0,241	4,02%	0,238
AUGUST	472	0,42	2,59%	0,421	729	0,241	4,02%	0,238
SEPTEMBER	411	0,42	2,59%	0,421	635	0,241	4,02%	0,238
OCTOBER	330	0,42	2,59%	0,421	510	0,241	4,02%	0,238
NOVEMBER	239	0,42	2,59%	0,421	370	0,241	4,02%	0,238
DECEMBER	200	0,42	2,59%	0,421	309	0,241	4,02%	0,238

Table 15 – Apartment C, PHASE 02 - Calculation Surfaces – Results Overview

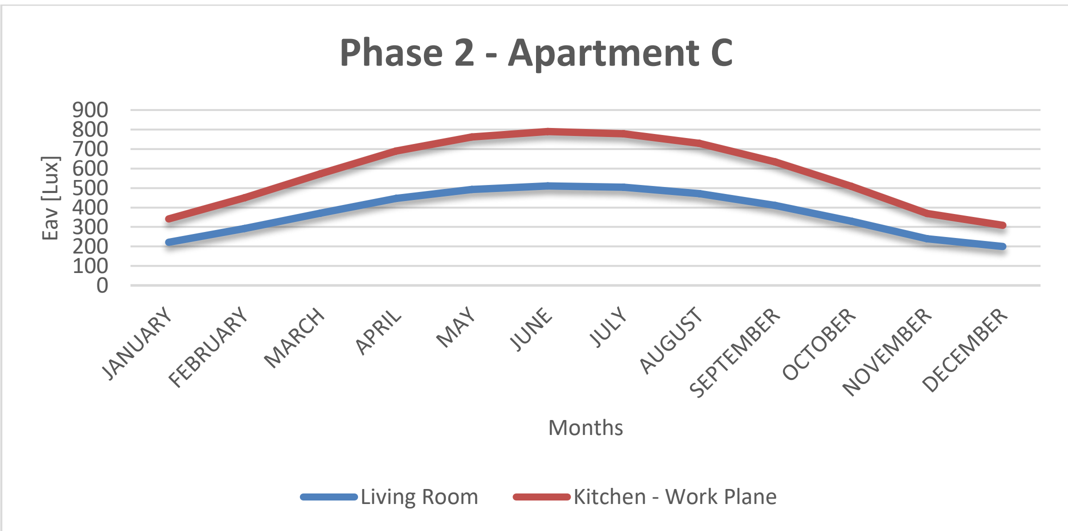
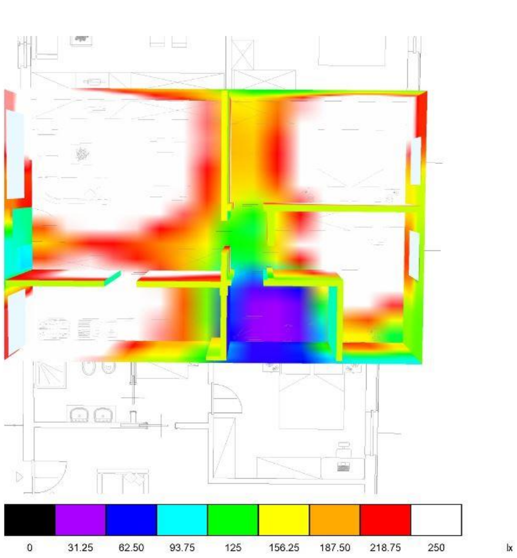


Diagram 14 – Apartment C, PHASE 02 - Calculation Surfaces – Results Overview

June



December

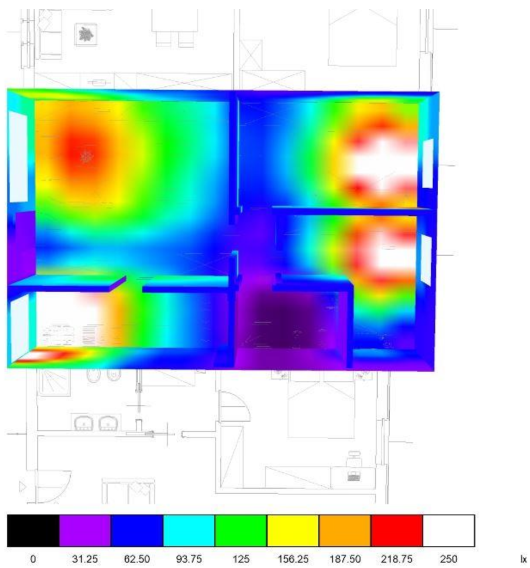


Image 31 – Apartment C, PHASE 02 – False Colour Rendering – June & December

This apartment also needed an increase of the glass surfaces for both the internal spaces. As in the previous cases, the position of the windows did not change. In fact the centerline did not change. From the data presented we note how the Living room did not require further optimization since all the parameters fell within the set limits. As far as the kitchen is concerned, the increase in the glass surfaces brought a big increase in both the level of lighting and the Daylight factor to the detriment of the already insufficient uniformity which resulted even worse than the previous phase. It is already understandable in this stage that it will be very difficult to increase the uniformity in the work area since it is a little more than the half level required. The shading system proposed below will therefore have as its primary aim distributing even more the light from the outside.

It will be now present the analyses undertaken in regards to the common space. As it has already said, from this phase the presentation of the data will be different since these areas had different needs from the others. In the first place the values relating to the calculated surfaces previously will be shown and then it will be displayed the considerations regarding every single environment which could be divided into different areas according to needs.

PUBLIC SPACE A: FASE 02

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Room 1: 43.62mq (Reading room)

Glass surface Room 2: 35.55mq (Atelier)

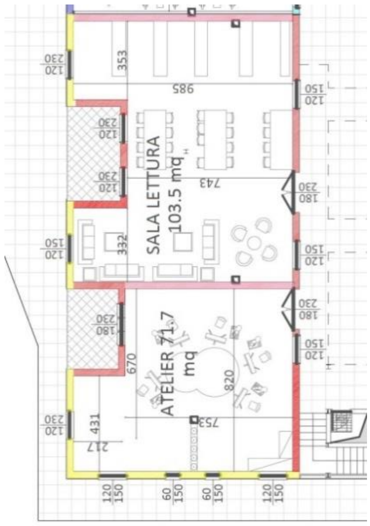


Image 17 - Public Space A-Plan

LOCATION	Building B - Mezzanine							
PROJECT NAME	Public Space A - PHASE 02							
CALCULATION SURFACE - NAME	Room 1 - General				Room 2 - General			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	358	0,529	4,03%	0,55	558	0,484	6,97%	0,465
FEBRUARY	474	0,529	4,03%	0,55	738	0,484	6,97%	0,465
MARCH	602	0,529	4,03%	0,55	938	0,484	6,97%	0,465
APRIL	727	0,529	4,03%	0,55	1132	0,484	6,97%	0,465
MAY	801	0,529	4,03%	0,55	1248	0,484	6,97%	0,465
JUNE	830	0,529	4,03%	0,55	1293	0,484	6,97%	0,465
JULY	819	0,529	4,03%	0,55	1275	0,484	6,97%	0,465
AUGUST	766	0,529	4,03%	0,55	1193	0,484	6,97%	0,465
SEPTEMBER	667	0,529	4,03%	0,55	1039	0,484	6,97%	0,465
OCTOBER	536	0,529	4,03%	0,55	835	0,484	6,97%	0,465
NOVEMBER	388	0,529	4,03%	0,55	605	0,484	6,97%	0,465
DECEMBER	325	0,529	4,03%	0,55	506	0,484	6,97%	0,465

Table 16 – Public Space A, PHASE 02 - Calculation Surfaces – Results Overview

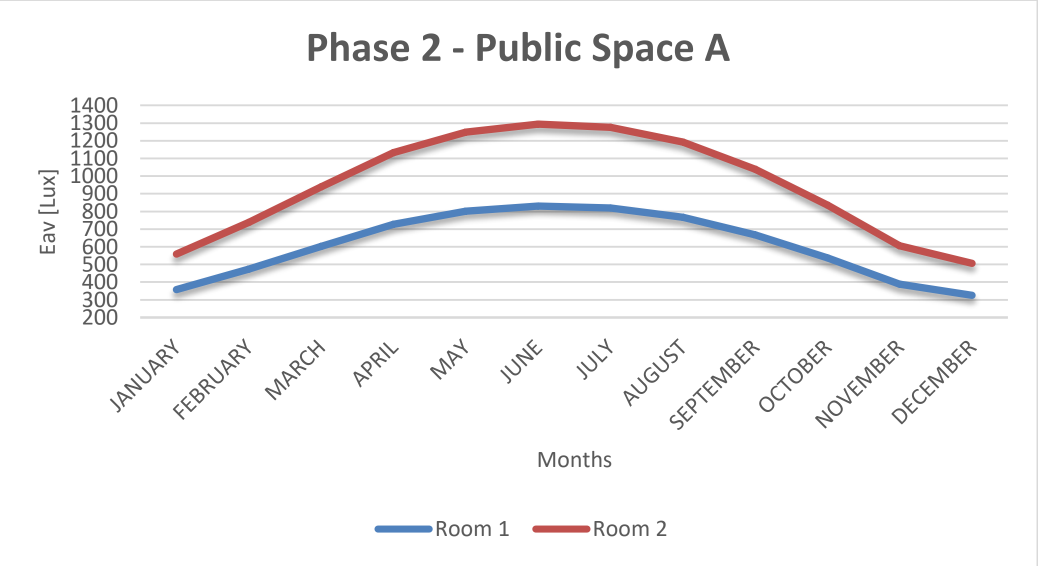


Diagram 15 – Public Space A, PHASE 02 - Calculation Surfaces – Results Overview

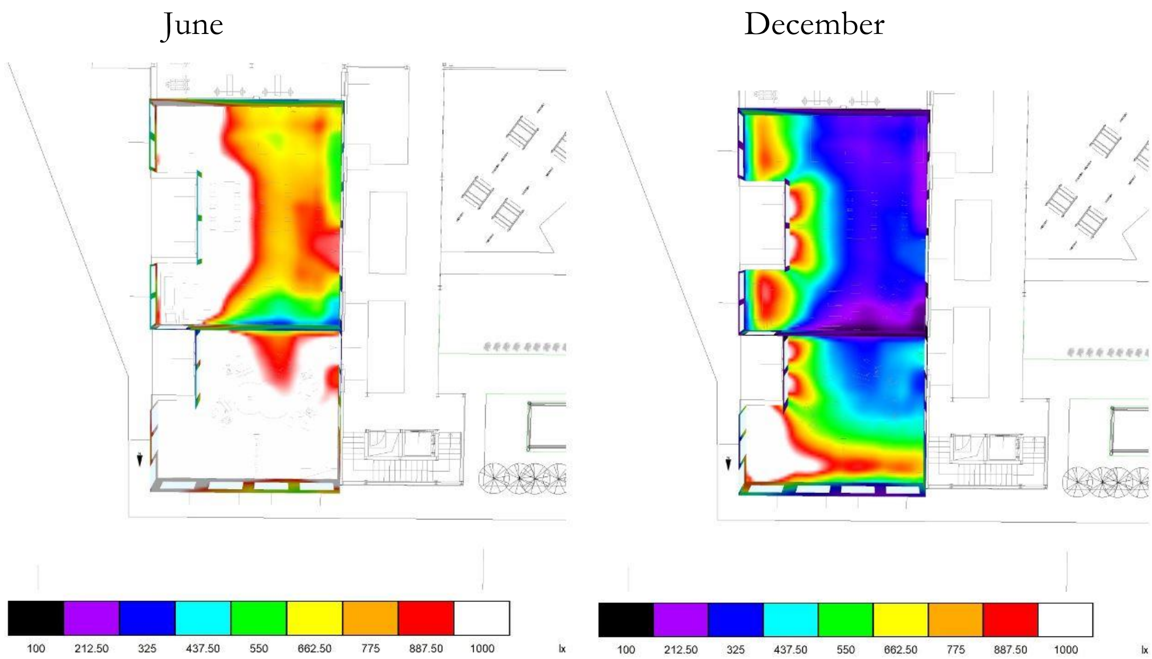
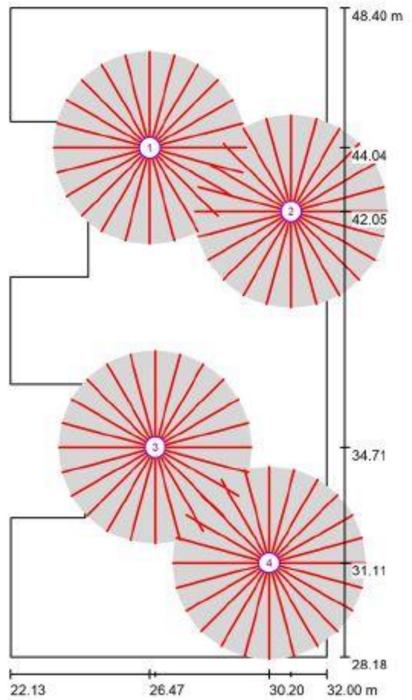


Image 32 – Public Space A, PHASE 02 – False Colour Rendering – June & December

The need for light in public areas is much greater than that for residential environments. In addition, the spaces are wider and deeper which therefore reveals the needs for noticeably increasing the glazed surface. Due to the structural choice for the building, which in this case is Xlam, it is not possible to opt for ribbon windows. Therefore, in PHASE 2 the data presented come from the application of the greatest number of windows possible. In fact, they are placed more than 50cm from each other which allows a discrete discontinuity of the structure which in any case has not been further explained in this thesis.

The first data to consider with big glazed surfaces is the phenomenon of glare which is this case not a problem this case (all the values are <10). The following is a page from the software's output showing the data settled up for the simulation.



Scale 1 : 137

GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	26.468	44.043	1.500	0.0	360.0	15.0	-5.0	<10 1)
2	GR Observer 2	30.881	42.054	1.500	0.0	360.0	15.0	-5.0	<10 1)
3	GR Observer 3	26.637	34.711	1.500	0.0	360.0	15.0	-5.0	<10 1)
4	GR Observer 4	30.196	31.111	1.500	0.0	360.0	15.0	-5.0	<10 1)

1) The equivalent veil luminance of the environment has been calculated precisely.

Page 1

Image 33 – Public Space A, PHASE 02 – GR Observer – Results Overview

Analysing specifically the two rooms, it is evident that the Atelier (Room 2) respects year round the target values in terms of lighting average and therefore does not require a division of the environment into different areas of competence. The entire surface area of the environment corresponds to the minimum requirements concerning the Daylight factor. As far as the Reading room (Room 1) is concerned the values shown are below 500 Lux in the winter months (from November to February), however they are always above 300 Lux and therefore fall within the values recommended by standard EN 12464-1 for different activities such as physical activities, archiving, copying and many others.

There are many possible implications for this observation. We can, for example, change the use of the space by opting for activities that fall within the 300 Lux limits, or we can use the data from the software to identify the areas with different lighting levels (specifically an average of 500 Lux). The first choice could be complicated, particularly if it involves radical changes of use. The second choice allows use of the available space in a different ways as it is possible to simply change the arrangement of the internal furniture, for example by positioning the reading tables in an area this is identified as 500 Lux, while placing the areas for archiving books or the relaxation area in the less lit areas. It will be necessary to propose a different internal distribution, trying to use as much as possible the furniture already present. The identification of the areas with different levels of light is intuitive enough as we only need to consult the false colour diagram which displays the distribution of light and set the cut off for the values shown at a maximum of 500 Lux, specifically in the least favoured period (December) as shown in the image.

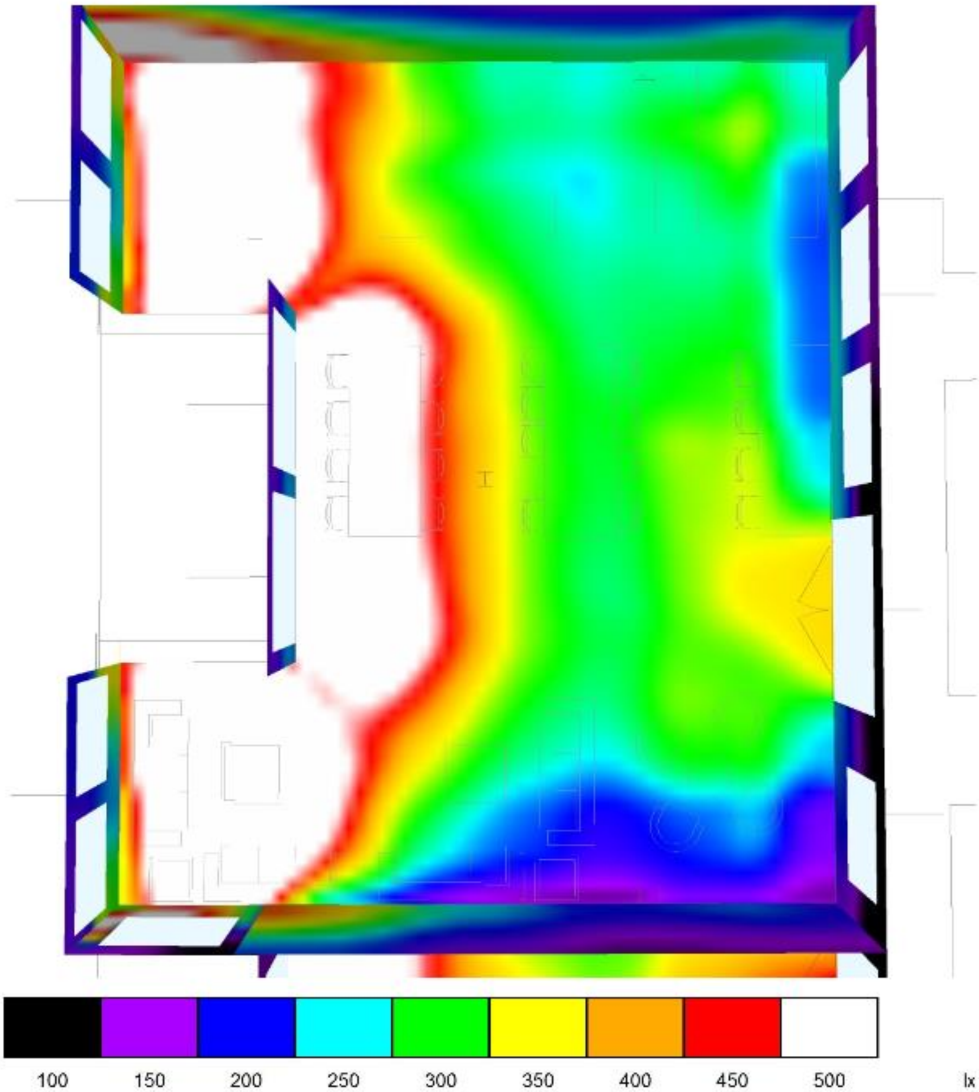


Image 34 – Public Space A, PHASE 02 – False Colour Rendering, December – Room 1 Zoom

In this way it is possible to set new calculation surface within the software by following the profile and the value of 500 Lux (in white in the image). It is worth noting that the required standard requires an average lighting value of 500 Lux which means that it is possible to also include the areas with lower quantities of light within the computing surface. It is possible to understand from this analysis that about half (left in the above image) becomes useful floor space for the Reading room, while the remaining part can be used for other activities. All the considerations just made apply only for the average light level since the value of the Daylight factor is greater than 4% for the whole year.

As far as the level of uniformity in the Reading room (Room 1) is concerned, it falls within the "acceptable" values according to EN 12464-1, while the Atelier (Room 2) does not respect even the minimum requirement. Therefore further optimization is still needed to solve this problem.

In the following PHASE 3 we will therefore show the values of the two general areas already displayed and to this will be added the calculation surface (Room 1 – 500 Lux) corresponding to the characteristics shown above.

PUBLIC SPACE B: FASE 02

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Room 1: 31.8mq (Kids Area)

Glass surface Room 2: 30.9mq (Conference Room)

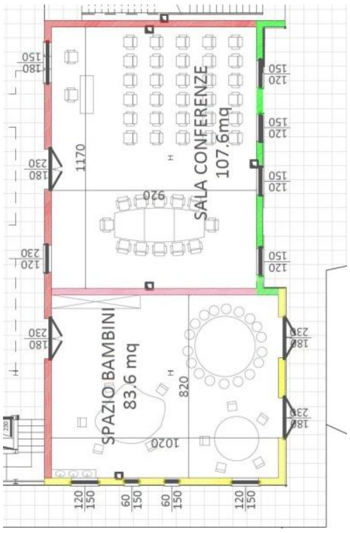


Image 16 - Public Space B-Plan

LOCATION	Building B - Mezzanine							
PROJECT NAME	Public Space B - PHASE 02							
CALCULATION SURFACE - NAME	Room 1 - General				Room 2 - General			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	367	0,469	4,32%	0,472	250	0,486	2,84%	0,514
FEBRUARY	485	0,469	4,32%	0,472	330	0,486	2,84%	0,514
MARCH	616	0,469	4,32%	0,472	420	0,486	2,84%	0,514
APRIL	744	0,469	4,32%	0,472	506	0,486	2,84%	0,514
MAY	820	0,469	4,32%	0,472	559	0,486	2,84%	0,514
JUNE	849	0,469	4,32%	0,472	578	0,486	2,84%	0,514
JULY	837	0,469	4,32%	0,472	570	0,486	2,84%	0,514
AUGUST	784	0,469	4,32%	0,472	534	0,486	2,84%	0,514
SEPTEMBER	682	0,469	4,32%	0,472	465	0,486	2,84%	0,514
OCTOBER	549	0,469	4,32%	0,472	374	0,486	2,84%	0,514
NOVEMBER	397	0,469	4,32%	0,472	271	0,486	2,84%	0,514
DECEMBER	332	0,469	4,32%	0,472	226	0,486	2,84%	0,514

Table 17 – Public Space B, PHASE 02 - Calculation Surfaces – Results Overview

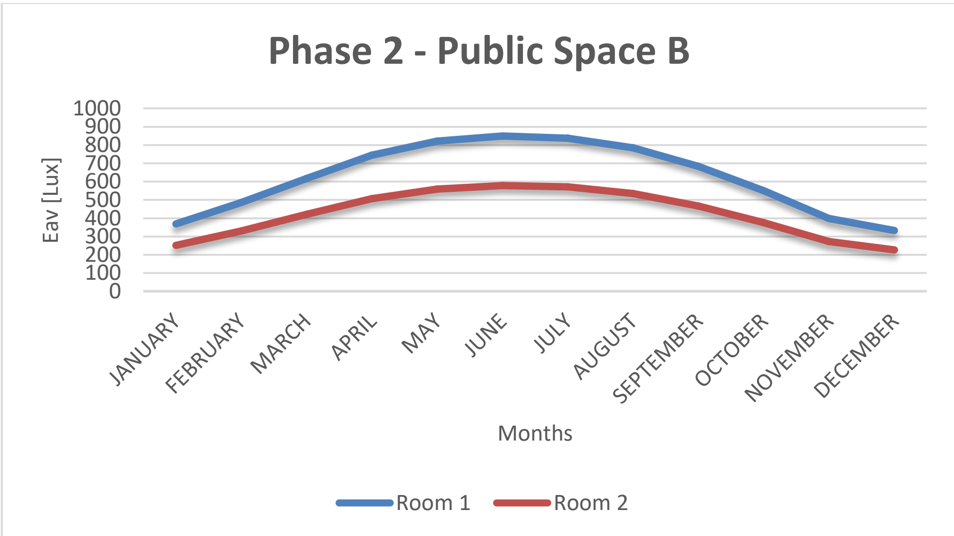


Diagram 16 – Public Space B, PHASE 02 - Calculation Surfaces – Results Overview

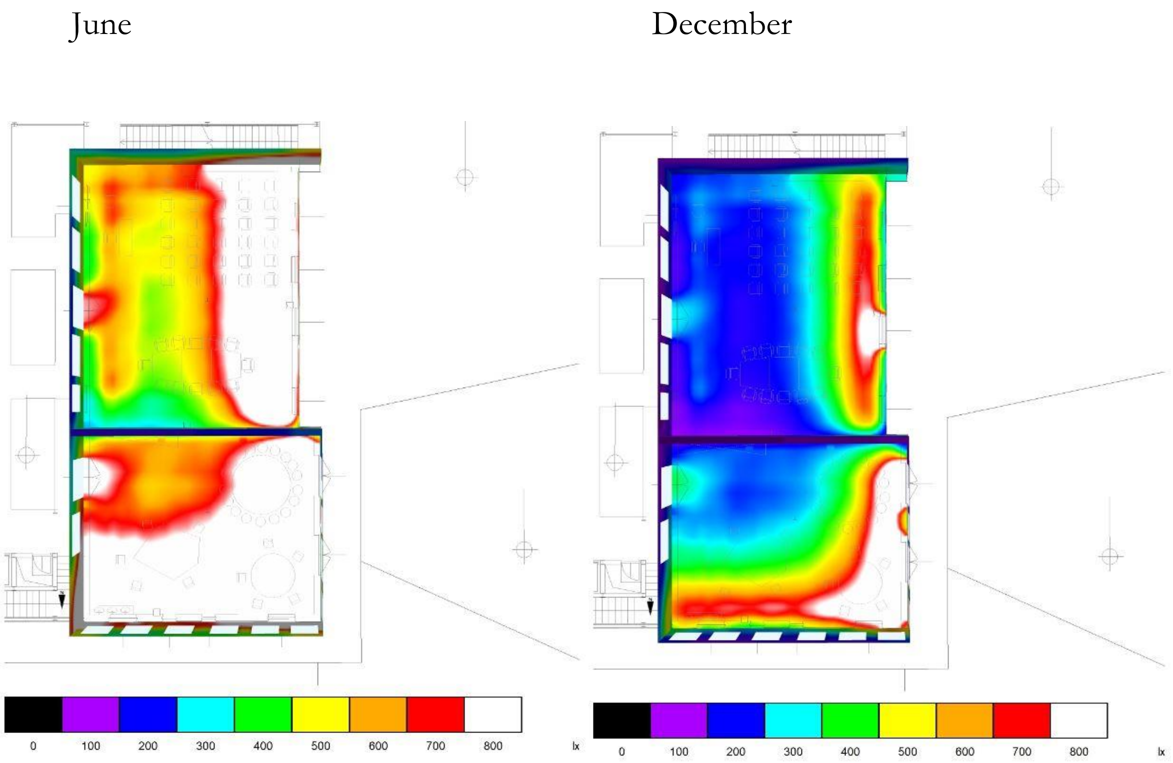


Image 35 – Public Space B, PHASE 02 – False Colour Rendering – June & December

The consideratons made in the previous case can be also apply for this area. As in the previous places, glare is not a problem since each of the monitoring posts within the rooms registered a value of <20. In this case there is the need for further division of the space used as a Conference Room by following the same procedure as the previous case. As far as the Children's area (Room 1) is concerned, the minimum value is an average of 300 lux during full year. it will be now presented the false colour rendering of these two areas which show the distribution of light within the spaces for the month of December:

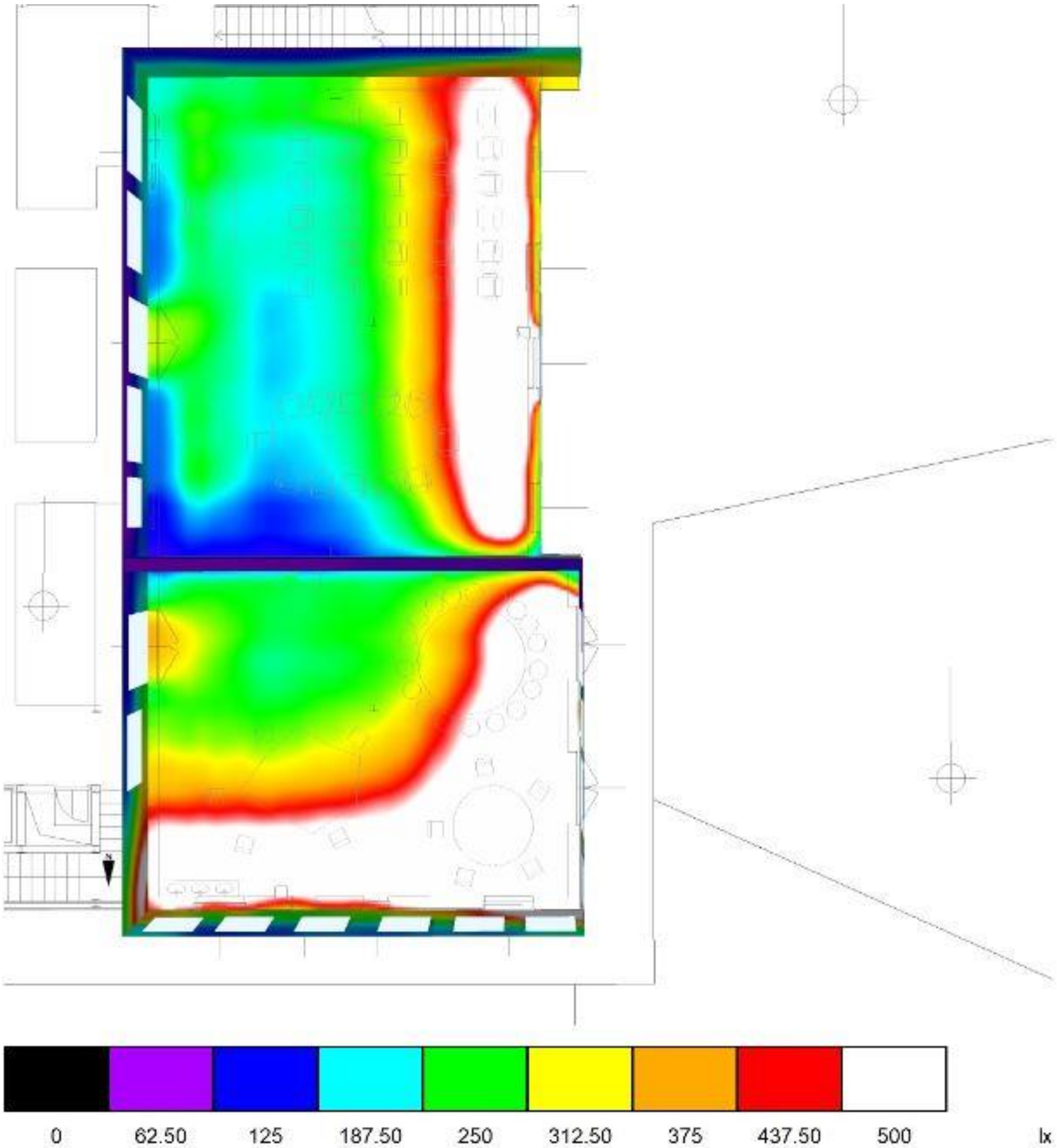


Image 36 – Public Space B, PHASE 02 – False Colour Rendering, December – Room 1-2 Zoom

From the image shown it is possible to identify the specific areas of calculation which will then be set within which the average lighitng level will corrspond to the requirements set of 500 and 300 Lux. It is worth noting that, compared to the previous case, there is a lower quantity of glazed surfaces since there were no recessed or bosses to the building. Since the Conference room corresponds to the required 500 Lux only half of the surface area will require modification of the internal layout to improve the use of the natural light.

SHAGIND SYSTEM DESIGN: PHASE 03

In order to reach the best solution three different shading systems were tested, in other words, slats, horizontal blades and vertical blades

Slats: Horizontal blades: Vertical blades:

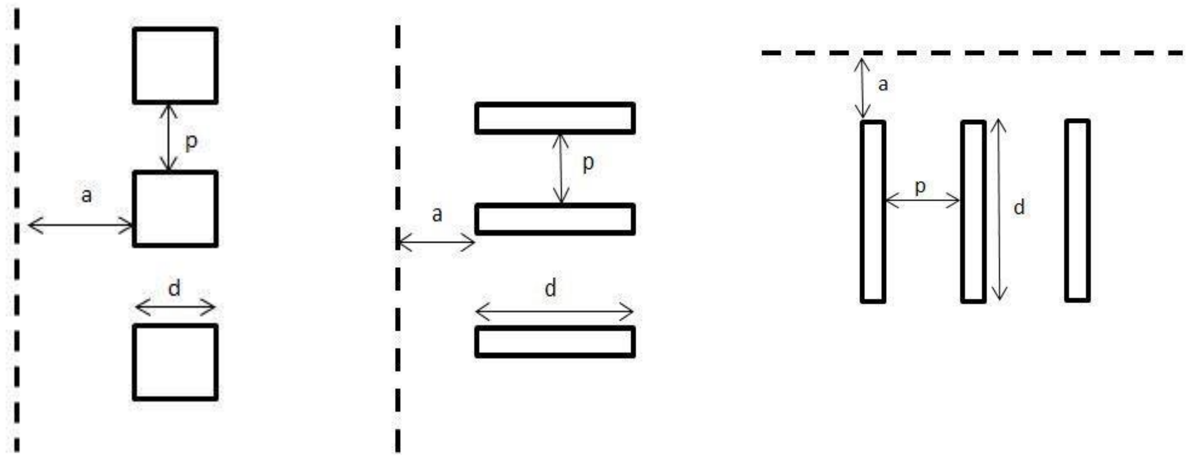


Image 37 – PHASE 03 – Different shading devices systems – Symbolic representation

Legend:
a: distance from the glass
d: width of the blades/slats
p: gap between the blades/slats

For each of these systems several simulations were done using the software in order to find the best system for the situations under analysis. The aim of this phase is to increase the light uniformity on the surfaces computed and from the simulations undertaken it emerged that the system which allowed the greatest diffusion of light was the one with horizontal blades. Once this fundamental parameter was defined no other analyses of the other two systems were made.

Therefore the system chosen was fixed horizontal blades. The choice was dictated by many factors amongst which was the simplicity of installation, even after the construction of the building complex, the scarce need for maintenance and the number of modifiable parameters in the layout of the installation[6]. In fact, it is possible to act upon various factors in the planning stage to find the best configuration possible according to the needs that emerged from the preliminary analysis. In addition, it was proven that its efficiency is increasingly evident by placing it on the external side of the glass so that is acts as the first barrier for solar radiation[7]. Empirically, since it is not part of the purpose of this thesis, it is also possible to state that such a shading system allows the reduction of cooling bills in the summer months. From the analyses undertaken it emerged that a dynamic system which modifies its orientation during the year acquires even more efficiency in increasing the glazed area. Therefore, because of these observations, a system of fixed blades was chosen since it was much cheaper and with lower maintenance. In fact, it will only need ordinary cleaning of the surfaces of the blades so as to keep their optical characteristics over time[8].

As it was already stated, this PHASE 3 is further divided into 3 sub-phases (PHASE3.1/3.2/3.3) which will be presented consecutively in such as manner as to make the reading of the data faster and more efficient. Following numerous simulations made at different angles, dimensions and gaps of the blades, the best configuration for the specific case under analysis has been reached. The final configuration is presented in the summary of the data for each area.

APARTMENT A: FASE 03

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 4.68mq

Glass surface Kitchen: 2.7mq (150x180cm)

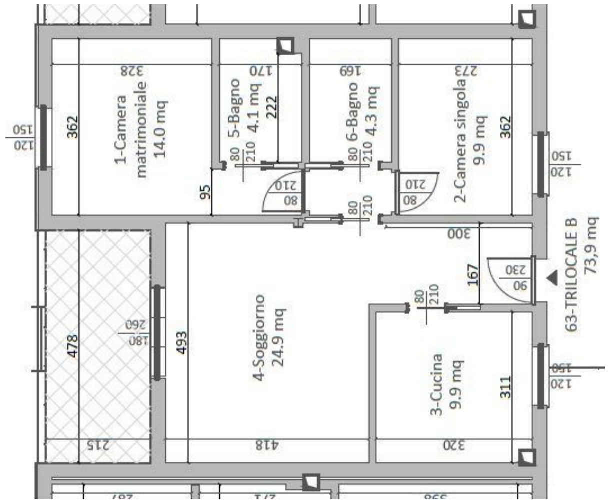


Image 13- Apartment A-Plan

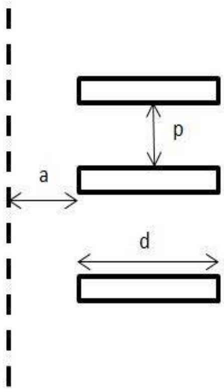
Solar shading system is composed of horizontal aluminium blades inclined 0° with height h = 2 cm, length d=20 cm, a gap of 45cm and a distance of 30cm from the glass.

Legend:

a: distance from the glass

d: width of the blades

p: gap between the blades



a [cm]	d [cm]	p [cm]	d/p
30	20	45	0,4

Image 38 – Horizontal shading system

The shading system was placed only in front of the kitchen window. The information just supplied is valid only for each of the following sub-phases in which only the coefficient of reflection of the blades following the scheme will be varied:

High Reflection	0,8	PHASE3.1
Medium Reflection	0,6	PHASE3.2
Low Reflection	0,3	PHASE3.3

It will now present all the calculated values for the configurations shown above:

LOCATION	Building A - 5th Floor											
PROJECT NAME	Apartment A - PHASE 3.1											
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane				Kitchen			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	258	0.439	3.05%	0.44	541	0.403	6.39%	0.408	230	0.677	2.70%	0.677
FEBRUARY	342	0.439	3.05%	0.44	716	0.403	6.39%	0.408	304	0.677	2.70%	0.677
MARCH	435	0.439	3.05%	0.44	910	0.403	6.39%	0.408	386	0.677	2.70%	0.677
APRIL	524	0.439	3.05%	0.44	1098	0.403	6.39%	0.408	466	0.677	2.70%	0.677
MAY	578	0.439	3.05%	0.44	1211	0.403	6.39%	0.408	514	0.677	2.70%	0.677
JUNE	599	0.439	3.05%	0.44	1254	0.403	6.39%	0.408	532	0.677	2.70%	0.677
JULY	590	0.439	3.05%	0.44	1236	0.403	6.39%	0.408	525	0.677	2.70%	0.677
AUGUST	552	0.439	3.05%	0.44	1157	0.403	6.39%	0.408	491	0.677	2.70%	0.677
SEPTEMBER	481	0.439	3.05%	0.44	1008	0.403	6.39%	0.408	428	0.677	2.70%	0.677
OCTOBER	387	0.439	3.05%	0.44	810	0.403	6.39%	0.408	344	0.677	2.70%	0.677
NOVEMBER	280	0.439	3.05%	0.44	587	0.403	6.39%	0.408	249	0.677	2.70%	0.677
DECEMBER	234	0.439	3.05%	0.44	491	0.403	6.39%	0.408	208	0.677	2.70%	0.677

Table 18 – Apartment A, PHASE 3.1 - Calculation Surfaces – Results Overview

LOCATION	Building A - 5th Floor											
PROJECT NAME	Apartment A - PHASE 3.2											
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane				Kitchen			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	258	0.434	3.04%	0.435	520	0.396	6.14%	0.401	220	0.674	2.58%	0.674
FEBRUARY	341	0.434	3.03%	0.434	688	0.396	6.14%	0.401	291	0.674	2.58%	0.674
MARCH	433	0.434	3.03%	0.434	874	0.396	6.14%	0.401	369	0.674	2.58%	0.674
APRIL	522	0.434	3.03%	0.434	1054	0.396	6.14%	0.401	446	0.674	2.58%	0.674
MAY	576	0.434	3.03%	0.434	1163	0.396	6.14%	0.401	492	0.674	2.58%	0.674
JUNE	597	0.434	3.03%	0.434	1204	0.396	6.14%	0.401	509	0.674	2.58%	0.674
JULY	588	0.434	3.03%	0.434	1187	0.396	6.14%	0.401	502	0.674	2.58%	0.674
AUGUST	551	0.434	3.03%	0.434	1111	0.396	6.14%	0.401	470	0.674	2.58%	0.674
SEPTEMBER	479	0.434	3.03%	0.434	968	0.396	6.14%	0.401	409	0.674	2.58%	0.674
OCTOBER	385	0.434	3.03%	0.434	778	0.396	6.14%	0.401	329	0.674	2.58%	0.674
NOVEMBER	279	0.434	3.03%	0.434	563	0.396	6.14%	0.401	238	0.674	2.58%	0.674
DECEMBER	234	0.434	3.03%	0.434	471	0.396	6.14%	0.401	199	0.674	2.58%	0.674

Table 19 – Apartment A, PHASE 3.2 - Calculation Surfaces – Results Overview

LOCATION	Building A - 5th Floor											
PROJECT NAME	Apartment A - PHASE 3.3											
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane				Kitchen			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	256	0.429	3.02%	0.431	495	0.392	5.84%	0.396	208	0.67	2.45%	0.67
FEBRUARY	339	0.429	3.02%	0.431	655	0.392	5.84%	0.396	276	0.67	2.45%	0.67
MARCH	431	0.429	3.02%	0.431	832	0.392	5.84%	0.396	350	0.67	2.45%	0.67
APRIL	520	0.429	3.02%	0.431	1004	0.392	5.84%	0.396	423	0.67	2.45%	0.67
MAY	573	0.429	3.02%	0.431	1107	0.392	5.84%	0.396	466	0.67	2.45%	0.67
JUNE	594	0.429	3.02%	0.431	1146	0.392	5.84%	0.396	483	0.67	2.45%	0.67
JULY	585	0.429	3.02%	0.431	1130	0.392	5.84%	0.396	476	0.67	2.45%	0.67
AUGUST	548	0.429	3.02%	0.431	1058	0.392	5.84%	0.396	446	0.67	2.45%	0.67
SEPTEMBER	477	0.429	3.02%	0.431	921	0.392	5.84%	0.396	388	0.67	2.45%	0.67
OCTOBER	383	0.429	3.02%	0.431	740	0.392	5.84%	0.396	312	0.67	2.45%	0.67
NOVEMBER	278	0.429	3.02%	0.431	536	0.392	5.84%	0.396	226	0.67	2.45%	0.67
DECEMBER	232	0.429	3.02%	0.431	449	0.392	5.84%	0.396	189	0.67	2.45%	0.67

Table 20 – Apartment A, PHASE 3.3 - Calculation Surfaces – Results Overview

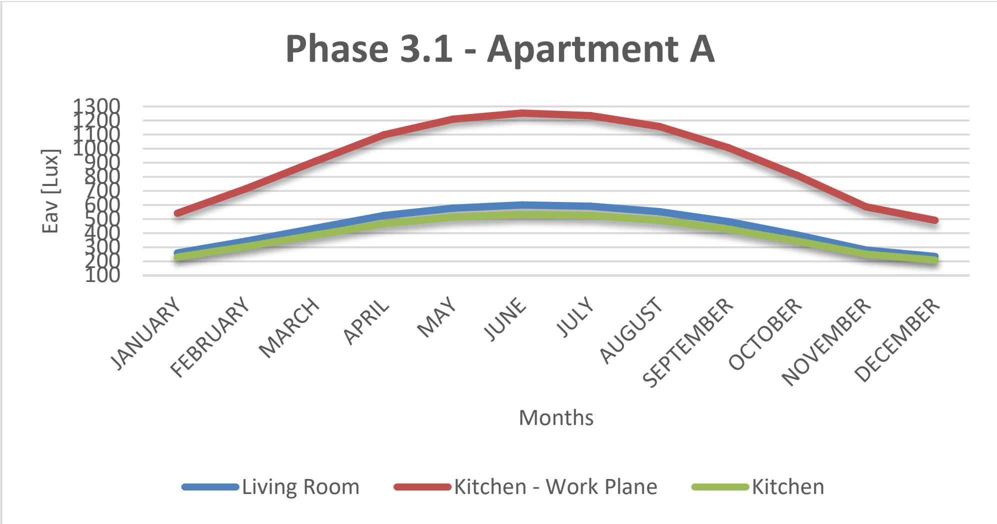


Diagram 17 – Apartment A, PHASE 3.1 - Calculation Surfaces – Results Overview

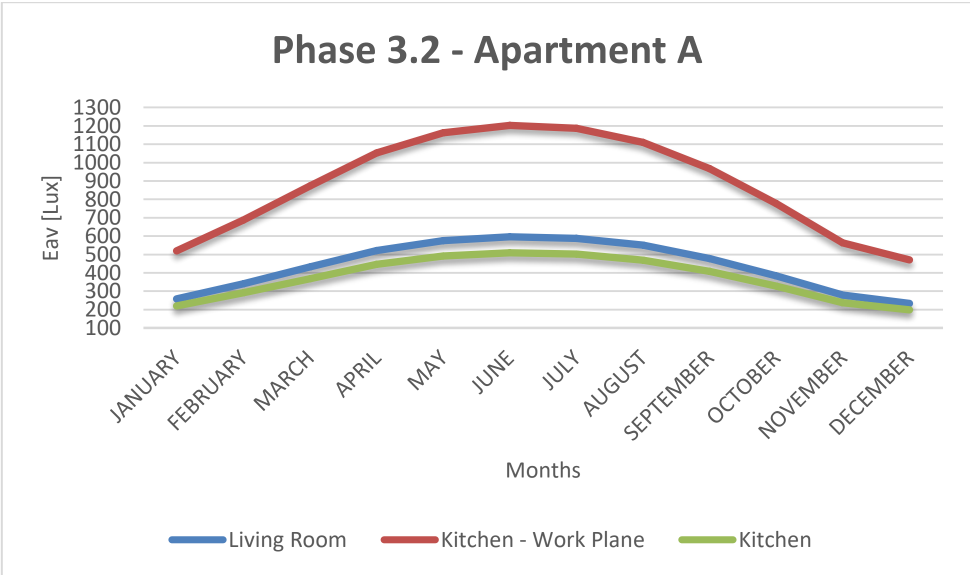


Diagram 18 – Apartment A, PHASE 3.2 - Calculation Surfaces – Results Overview

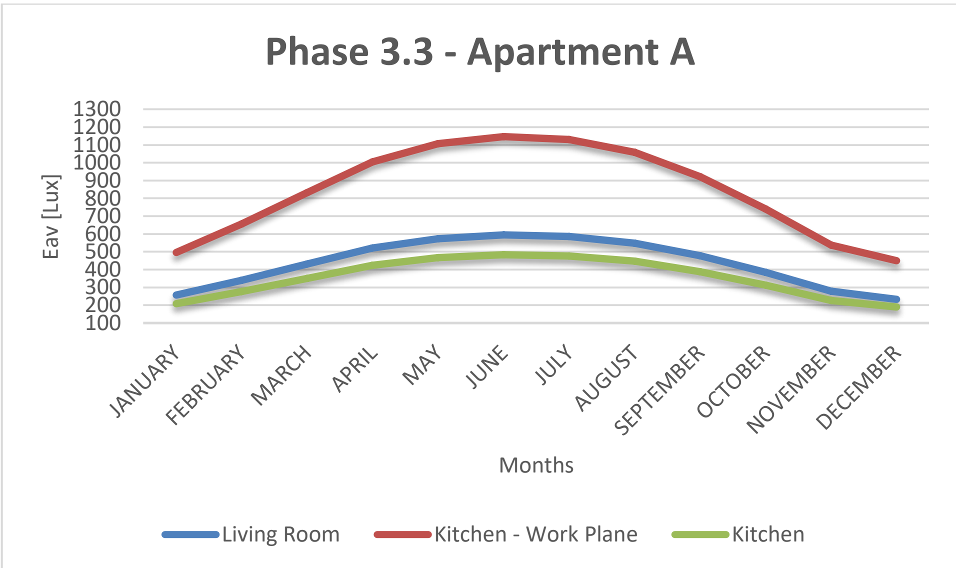


Diagram 19 – Apartment A, PHASE 3.3 - Calculation Surfaces – Results Overview

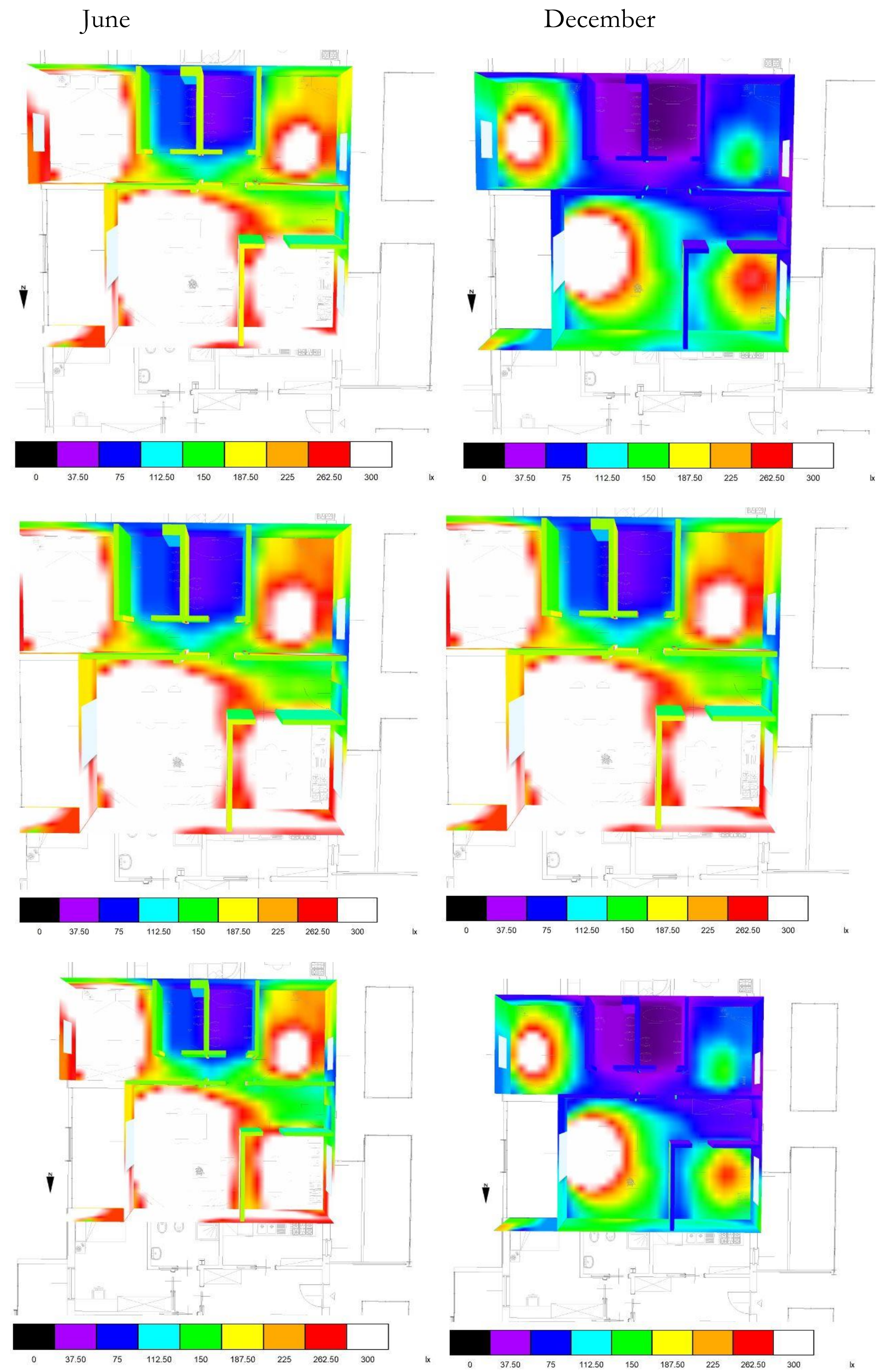


Image 39 – Apartment A, PHASE 3.1-3.2-3.3 – False Colour Rendering – June & December

What is has been just presented is the final phase of the optimization process which therefore achieves the planned targets. From the results obtained it can be notice that the best choice was that of the fixed high reflection blades (with a coefficient of reflection of 0.8) which allow us to comply with all the previously set parameters during the course of the whole year. Other materials for the blades were also analyzed, such as translucent materials which allow greater transmission of the luminous components while maintaining the reflective and solar screening characteristics. However, these materials are fragile and very expensive, in addition and following practical considerations which the software is not able to conduct, such phenomena as ageing, deposits of dirt over time and maintenance cycles which affect maintaining over time the performance analyzed with the simulations. For these reasons, it was decided to choose a system of aluminium blades which combines with a fairly low cost, excellent endurance over time and reduced maintenance needs. Furthermore additional considerations valid for all the areas analyzed will be presented.

APARTMENT B: FASE 03

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 3.57mq (210 x 170cm)

Glass surface Kitchen: 2.4mq (150 x 160cm)

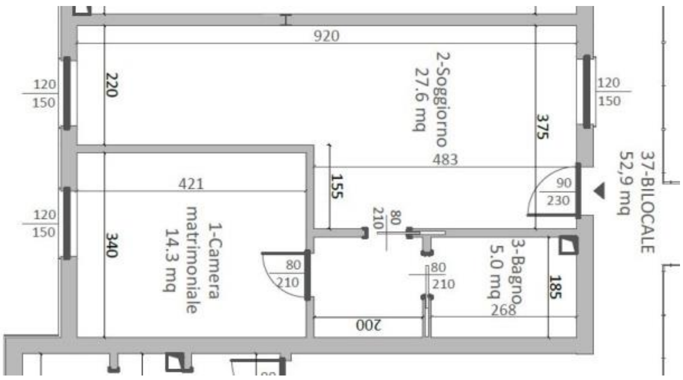


Image 14- Apartment B-Plan

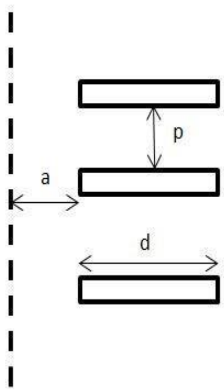
Solar shading system is composed of horizontal aluminium blades inclined 0° with height h = 2 cm, length d=20 cm, a gap of 45cm and a distance of 30cm from the glass.

Legend:

a: distance from the glass

d: width of the blades

p: gap between the blades



a [cm]	d [cm]	p [cm]	d/p
30	20	45	0,4

Image 38 – Horizontal shading system

The shading system was placed only in front of the kitchen window.
The information just supplied is valid only for each of the following sub-phases in which only the coefficient of reflection of the blades following the scheme will be varied:

High Reflection	0,8	PHASE3.1
Medium Reflection	0,6	PHASE3.2
Low Reflection	0,3	PHASE3.3

It will now present all the calculated values for the configurations shown above:

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment B - PHASE 3.1							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	238	0,49	2,79%	0,491	332	0,428	3,87%	0,432
FEBRUARY	315	0,49	2,79%	0,491	439	0,428	3,87%	0,432
MARCH	400	0,49	2,79%	0,491	558	0,428	3,87%	0,432
APRIL	483	0,49	2,79%	0,491	673	0,428	3,87%	0,432
MAY	533	0,49	2,79%	0,491	742	0,428	3,87%	0,432
JUNE	551	0,49	2,79%	0,491	769	0,428	3,87%	0,432
JULY	544	0,49	2,79%	0,491	758	0,428	3,87%	0,432
AUGUST	509	0,49	2,79%	0,491	709	0,428	3,87%	0,432
SEPTEMBER	443	0,49	2,79%	0,491	618	0,428	3,87%	0,432
OCTOBER	356	0,49	2,79%	0,491	496	0,428	3,87%	0,432
NOVEMBER	258	0,49	2,79%	0,491	360	0,428	3,87%	0,432
DECEMBER	216	0,49	2,79%	0,491	301	0,428	3,87%	0,432

Table 21 – Apartment B, PHASE 3.1 - Calculation Surfaces – Results Overview

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment B - PHASE 3.2							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	237	0,488	2,79%	0,489	325	0,426	3,79%	0,430
FEBRUARY	314	0,488	2,79%	0,489	430	0,426	3,79%	0,430
MARCH	399	0,488	2,79%	0,489	546	0,426	3,79%	0,430
APRIL	482	0,488	2,79%	0,489	659	0,426	3,79%	0,430
MAY	531	0,488	2,79%	0,489	727	0,426	3,79%	0,430
JUNE	550	0,488	2,79%	0,489	752	0,426	3,79%	0,430
JULY	542	0,488	2,79%	0,489	742	0,426	3,79%	0,430
AUGUST	507	0,488	2,79%	0,489	694	0,426	3,79%	0,430
SEPTEMBER	442	0,488	2,79%	0,489	605	0,426	3,79%	0,430
OCTOBER	355	0,488	2,79%	0,489	486	0,426	3,79%	0,430
NOVEMBER	257	0,488	2,79%	0,489	352	0,426	3,79%	0,430
DECEMBER	215	0,488	2,79%	0,489	295	0,426	3,79%	0,430

Table 22 – Apartment B, PHASE 3.2 - Calculation Surfaces – Results Overview

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment B - PHASE 3.3							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	237	0,486	2,78%	0,486	319	0,427	3,72%	0,428
FEBRUARY	313	0,486	2,78%	0,486	422	0,427	3,72%	0,428
MARCH	398	0,486	2,78%	0,486	536	0,427	3,72%	0,428
APRIL	480	0,486	2,78%	0,486	646	0,427	3,72%	0,428
MAY	529	0,486	2,78%	0,486	713	0,427	3,72%	0,428
JUNE	548	0,486	2,78%	0,486	738	0,427	3,72%	0,428
JULY	541	0,486	2,78%	0,486	728	0,427	3,72%	0,428
AUGUST	506	0,486	2,78%	0,486	681	0,427	3,72%	0,428
SEPTEMBER	441	0,486	2,78%	0,486	593	0,427	3,72%	0,428
OCTOBER	354	0,486	2,78%	0,486	477	0,427	3,72%	0,428
NOVEMBER	257	0,486	2,78%	0,486	345	0,427	3,72%	0,428
DECEMBER	215	0,486	2,78%	0,486	289	0,427	3,72%	0,428

Table 23 – Apartment B, PHASE 3.3 - Calculation Surfaces – Results Overview

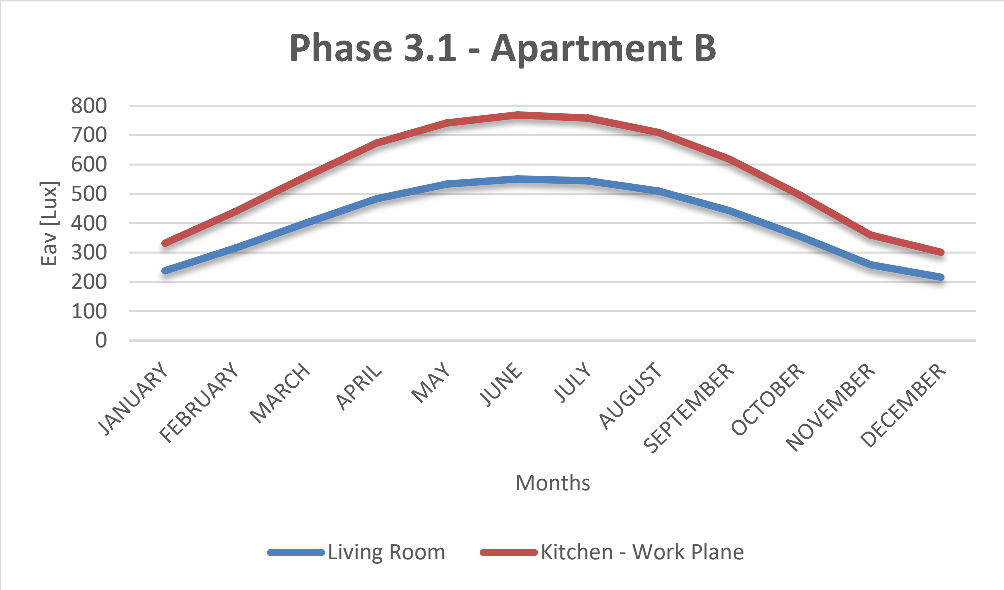


Diagram 20 – Apartment B, PHASE 3.1 - Calculation Surfaces – Results Overview

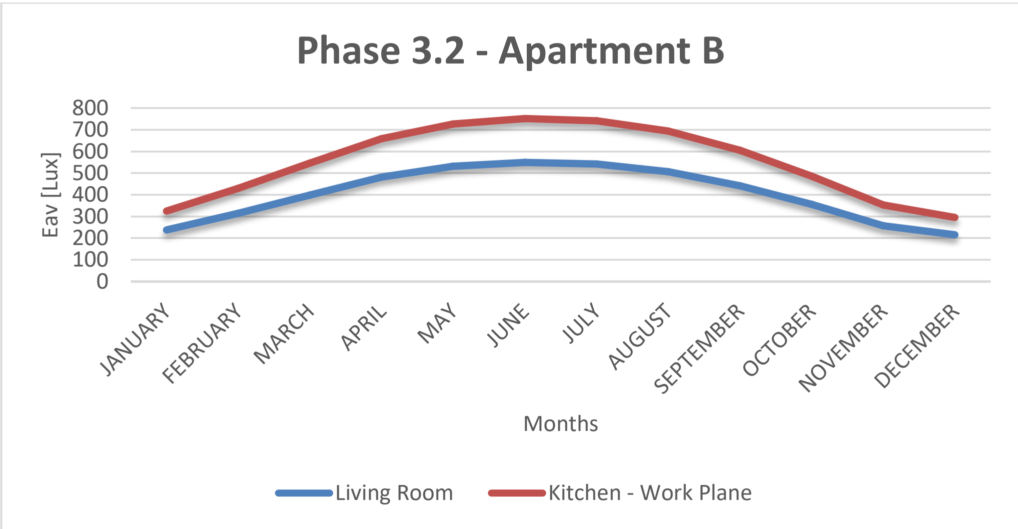


Diagram 21 – Apartment B, PHASE 3.2 - Calculation Surfaces – Results Overview

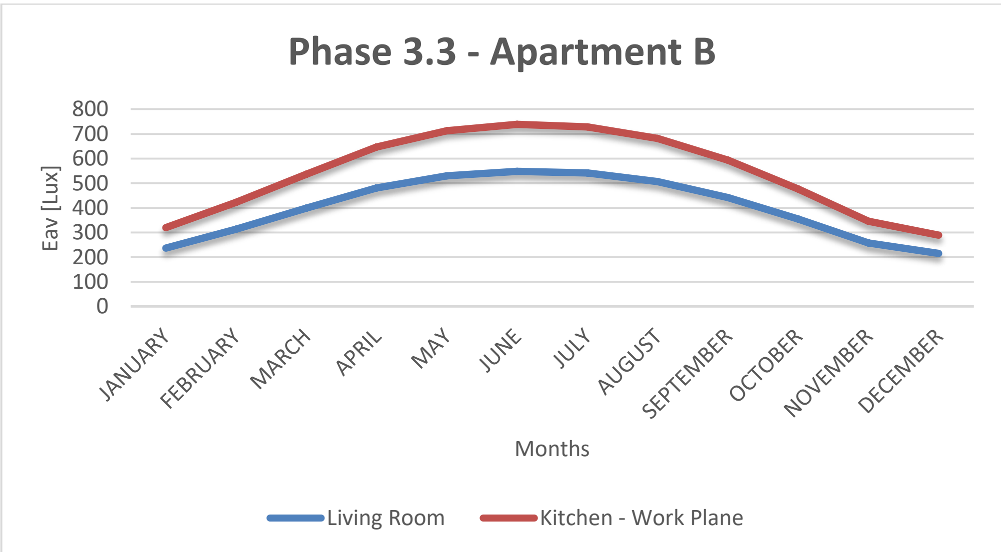


Diagram 22 – Apartment B, PHASE 3.3 - Calculation Surfaces – Results Overview

June December

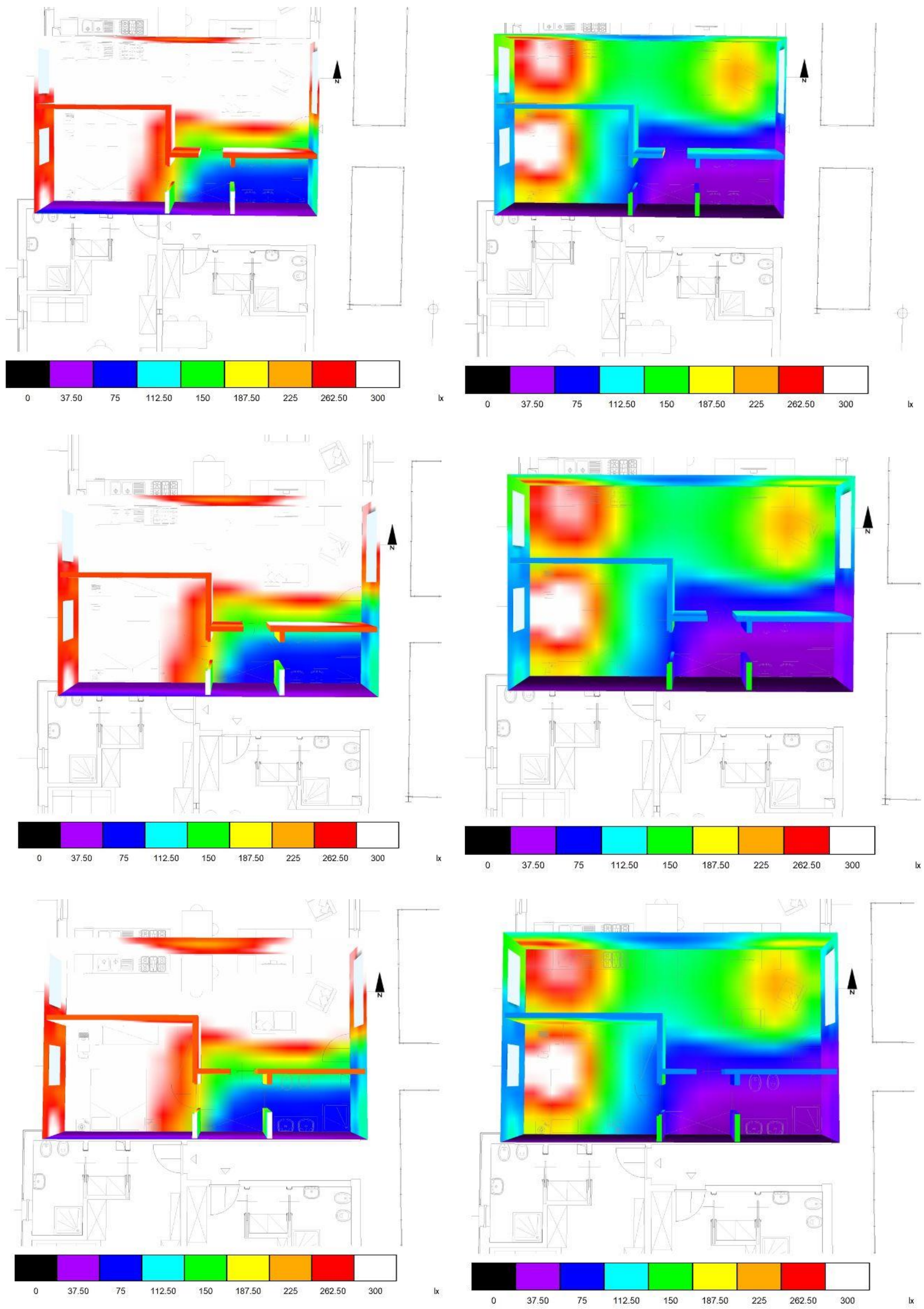
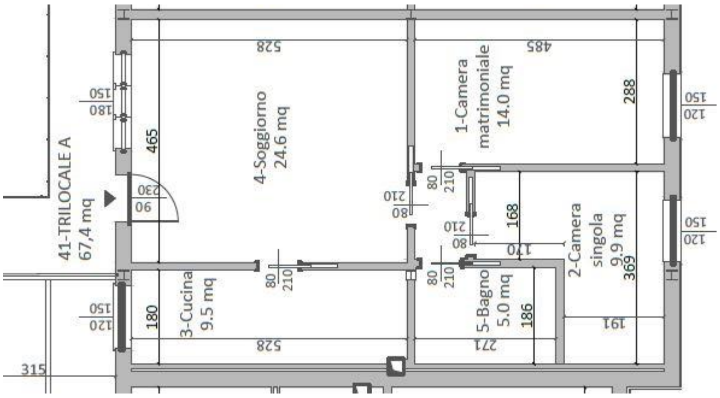


Image 40 – Apartment B, PHASE 3.1-3.2-3.3 – False Colour Rendering – June & December

From the data just presented it is evident that the proposed solution respects the parameters of uniformity for each of the 3 configurations. As for the lighting values only the first option (High Reflection) satisfies the required levels during the whole year. However, by analyzing the details it can be noted that in the second and third options only the month of December creates problems, with levels that have drawn much closer to those required. From the purely numerical point of view, the only acceptable option therefore is the first. It will be the architects who will make the choice that links better all the parameters to be considered, such as functionality, esthetic appearance and economically. In addition, another factor to be considered at the time of planning choices is the fact that uniformity of light distribution is a constant factor over the months, while the level of light, which varies during the year, could not be respected only in small periods of time, such as the case just presented, in which the only month without the minimum light requirements is December.

APARTMENT C: FASE 03



Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Living Room: 3.74mq (220 x 170cm)

Glass surface Kitchen: 2.55mq (150 x 170cm)

Image 12 - Apartment C-Plan

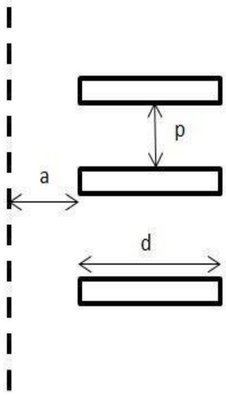
Solar shading system is composed of horizontal aluminium blades inclined 0° with height h = 2 cm, length d=20 cm, a gap of 45cm and a distance of 30cm from the glass.

Legend:

a: distance from the glass

d: width of the blades

p: gap between the blades



a [cm]	d [cm]	p [cm]	d/p
30	20	45	0,4

Image 38 – Horizontal shading system

The shading system was placed only in front of the kitchen window.

The information just supplied is valid only for each of the following sub-phases in which only the coefficient of reflection of the blades following the scheme will be varied:

High Reflection	0,8	PHASE3.1
Medium Reflection	0,6	PHASE3.2
Low Reflection	0,3	PHASE3.3

It will now present all the calculated values for the configurations shown above:

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment C - PHASE 3.1							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	250	0,474	2,93%	0,475	350	0,404	4,11%	0,403
FEBRUARY	330	0,474	2,93%	0,475	463	0,404	4,11%	0,403
MARCH	420	0,474	2,93%	0,475	588	0,404	4,11%	0,403
APRIL	507	0,474	2,93%	0,475	709	0,404	4,11%	0,403
MAY	559	0,474	2,93%	0,475	782	0,404	4,11%	0,403
JUNE	579	0,474	2,93%	0,475	810	0,404	4,11%	0,403
JULY	571	0,474	2,93%	0,475	799	0,404	4,11%	0,403
AUGUST	534	0,474	2,93%	0,475	747	0,404	4,11%	0,403
SEPTEMBER	465	0,474	2,93%	0,475	651	0,404	4,11%	0,403
OCTOBER	374	0,474	2,93%	0,475	523	0,404	4,11%	0,403
NOVEMBER	271	0,474	2,93%	0,475	474	0,404	4,11%	0,403
DECEMBER	226	0,474	2,93%	0,475	317	0,404	4,11%	0,403

Table 24 – Apartment C, PHASE 3.1 - Calculation Surfaces – Results Overview

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment C - PHASE 3.2							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	246	0,464	2,89%	0,465	327	0,407	3,85%	0,406
FEBRUARY	325	0,464	2,89%	0,465	433	0,407	3,85%	0,406
MARCH	413	0,464	2,89%	0,465	550	0,407	3,85%	0,406
APRIL	498	0,464	2,89%	0,465	664	0,407	3,85%	0,406
MAY	550	0,464	2,89%	0,465	732	0,407	3,85%	0,406
JUNE	569	0,464	2,89%	0,465	758	0,407	3,85%	0,406
JULY	561	0,464	2,89%	0,465	748	0,407	3,85%	0,406
AUGUST	525	0,464	2,89%	0,465	700	0,407	3,85%	0,406
SEPTEMBER	457	0,464	2,89%	0,465	609	0,407	3,85%	0,406
OCTOBER	368	0,464	2,89%	0,465	490	0,407	3,85%	0,406
NOVEMBER	266	0,464	2,89%	0,465	355	0,407	3,85%	0,406
DECEMBER	223	0,464	2,89%	0,465	297	0,407	3,85%	0,406

Table 25 – Apartment C, PHASE 3.2 - Calculation Surfaces – Results Overview

LOCATION	Building B - 5th Floor							
PROJECT NAME	Apartment C - PHASE 3.3							
CALCULATION SURFACE - NAME	Living Room				Kitchen - Work Plane			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	242	0,456	2,84%	0,457	304	0,392	3,57%	0,391
FEBRUARY	320	0,456	2,84%	0,457	402	0,392	3,57%	0,391
MARCH	406	0,456	2,84%	0,457	511	0,392	3,57%	0,391
APRIL	490	0,456	2,84%	0,457	616	0,392	3,57%	0,391
MAY	540	0,456	2,84%	0,457	679	0,392	3,57%	0,391
JUNE	560	0,456	2,84%	0,457	704	0,392	3,57%	0,391
JULY	552	0,456	2,84%	0,457	694	0,392	3,57%	0,391
AUGUST	516	0,456	2,84%	0,457	649	0,392	3,57%	0,391
SEPTEMBER	450	0,456	2,84%	0,457	565	0,392	3,57%	0,391
OCTOBER	361	0,456	2,84%	0,457	454	0,392	3,57%	0,391
NOVEMBER	262	0,456	2,84%	0,457	329	0,392	3,57%	0,391
DECEMBER	219	0,456	2,84%	0,457	275	0,392	3,57%	0,391

Table 26 – Apartment C, PHASE 3.3 - Calculation Surfaces – Results Overview

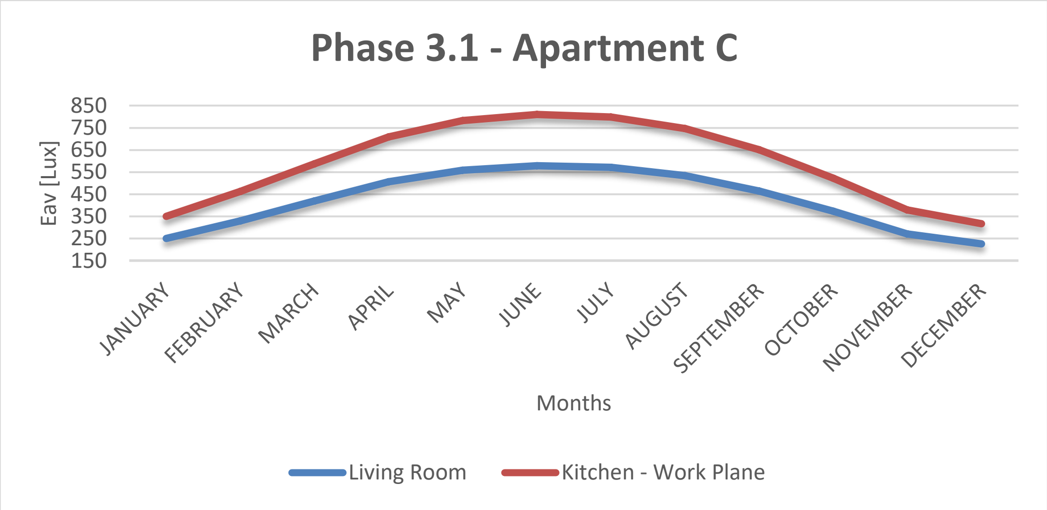


Diagram 23 – Apartment C, PHASE 3.1 - Calculation Surfaces – Results Overview

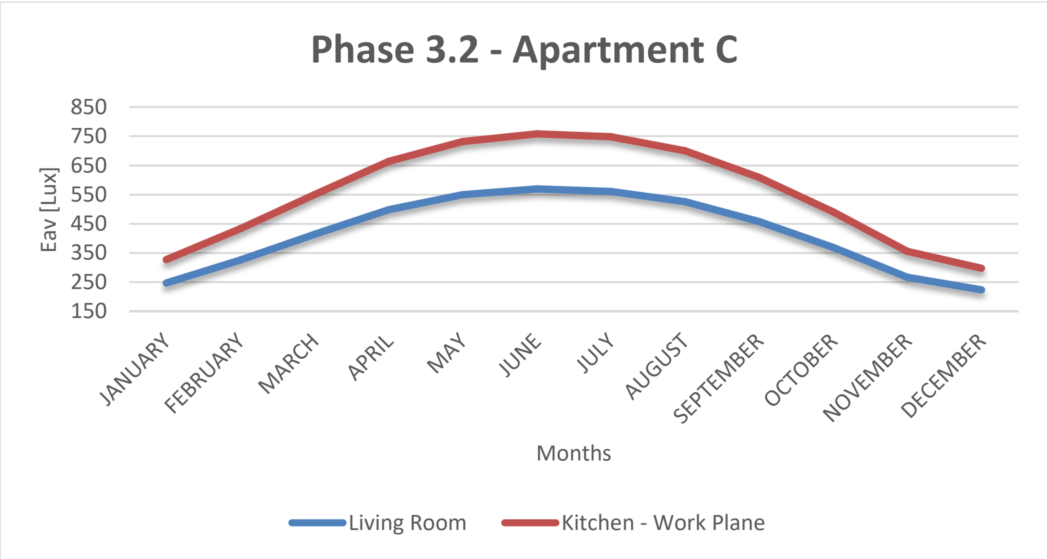


Diagram 24 – Apartment C, PHASE 3.2 - Calculation Surfaces – Results Overview

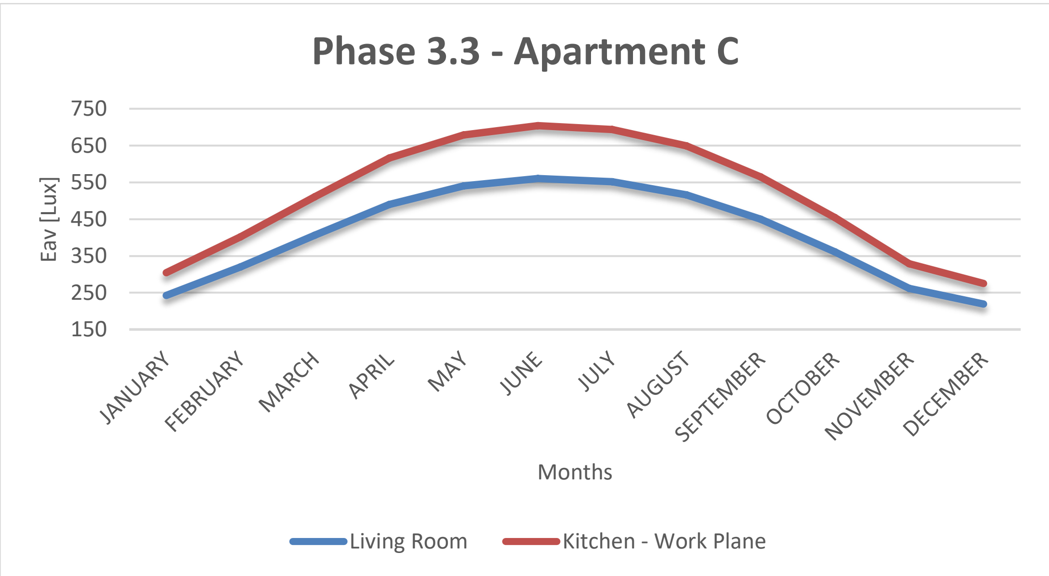


Diagram 25 – Apartment C, PHASE 3.3 - Calculation Surfaces – Results Overview

June December

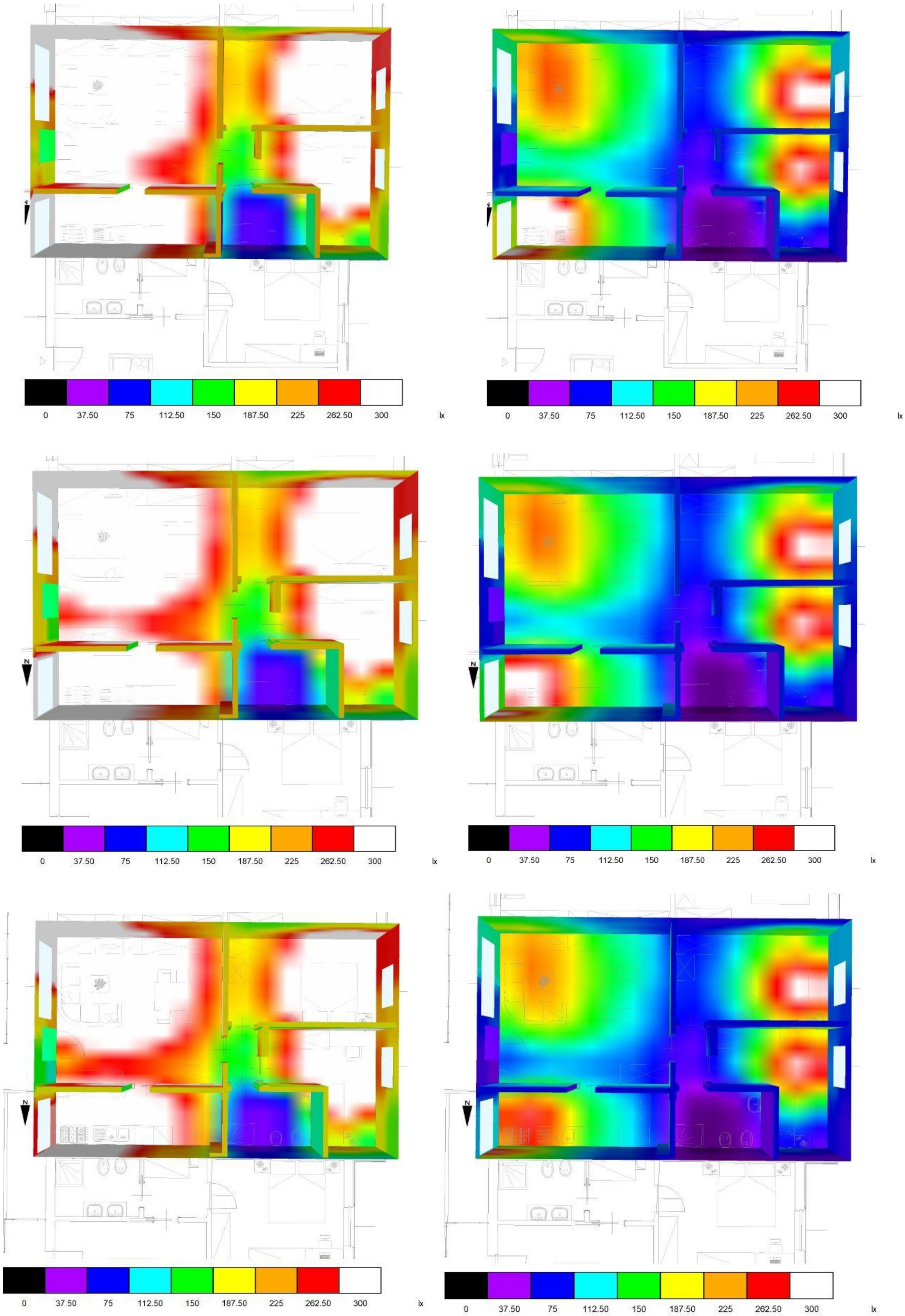


Image 41 – Apartment C, PHASE 3.1-3.2-3.3 – False Colour Rendering – June & December

Even in this case, the hypothesis which corresponds to all the preset targets is the first, in other words high reflection blades. However, it is possible to also choose a medium reflection solution since the deviation compared to the optimum value is in the month of December and only in the kitchen work area is about 3 Lux, compared to the objective of 300 Lux (1%) the recommendation is always that of favouring respecting the values which do not vary during the year, in other words uniformity and Daylight factor which allow comfort, greater and unvaried visions in absolute terms and during all the months.
The investigation carried out in this thesis, particularly in the residential part, has shown evidence of repeatable behavior in various types of lodging, with different orientations, external obstructions, blocks and internal dimensions. The initial process of investigation on the current layout handed to the lighting engineering planner the data necessary for the subsequent stages of development and optimization by standardizing the path to follow. The system of optimization proposed allows us to reach the targets in all the cases examined and therefore it is possible to affirm, with all due caution, that the cascade effect process proposed is valid for all types of environment situated in geographical environments with similar characteristics.

PUBLIC SPACE A: FASE 03

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Room 1: 43.62mq (Reading Room)

Glass surface Room 2: 35.55mq (Atelier)

Image 17 - Public Space A-Plan

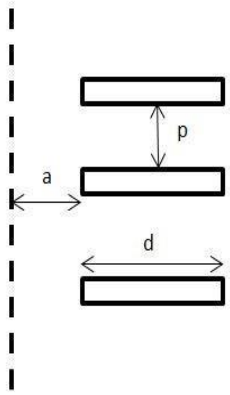
Solar shading system is composed of horizontal aluminium blades inclined 0° with height h = 2 cm, length d=20 cm, a gap of 45cm and a distance of 30cm from the glass.

Legend:

a: distance from the glass

d: width of the blades

p: gap between the blades



a [cm]	d [cm]	p [cm]	d/p
30	20	45	0,4

Image 38 – Horizontal shading system

The shading system was placed only in front of the windows facing NORTH (Atelier), and the windows facing EAST (Reading Room).

The information just supplied is valid only for each of the following sub-phases in which only the coefficient of reflection of the blades following the scheme will be varied:

High Reflection	0,8	PHASE3.1
Medium Reflection	0,6	PHASE3.2
Low Reflection	0,3	PHASE3.3

It will now present all the calculated values for the configurations shown above:

LOCATION	Building A - Mezzanine											
PROJECT NAME	Public Space A - PHASE 3.1											
CALCULATION SURFACE - NAME	Room 1 - General				Room 1 - 500 Lux Area - DF > 4%				Room 2 - General			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	370	0.555	4.16%	0.58	575	0.502	6.68%	0.53	568	0.512	6.50%	0.514
FEBRUARY	489	0.555	4.16%	0.58	761	0.502	6.68%	0.53	752	0.512	6.50%	0.514
MARCH	621	0.555	4.16%	0.58	967	0.502	6.68%	0.53	955	0.512	6.50%	0.514
APRIL	750	0.555	4.16%	0.58	1167	0.502	6.68%	0.53	1153	0.512	6.50%	0.514
MAY	827	0.555	4.16%	0.58	1287	0.502	6.68%	0.53	1271	0.512	6.50%	0.514
JUNE	856	0.555	4.16%	0.58	1333	0.502	6.68%	0.53	1316	0.512	6.50%	0.514
JULY	844	0.555	4.16%	0.58	1314	0.502	6.68%	0.53	1298	0.512	6.50%	0.514
AUGUST	790	0.555	4.16%	0.58	1230	0.502	6.68%	0.53	1215	0.512	6.50%	0.514
SEPTEMBER	688	0.555	4.16%	0.58	1071	0.502	6.68%	0.53	1058	0.512	6.50%	0.514
OCTOBER	553	0.555	4.16%	0.58	861	0.502	6.68%	0.53	850	0.512	6.50%	0.514
NOVEMBER	401	0.555	4.16%	0.58	624	0.502	6.68%	0.53	616	0.512	6.50%	0.514
DECEMBER	335	0.555	4.16%	0.58	522	0.502	6.68%	0.53	515	0.512	6.50%	0.514

Table 27 – Public Space A, PHASE 3.1 - Calculation Surfaces – Results Overview

LOCATION	Building A - Mezzanine											
PROJECT NAME	Public Space A - PHASE 3.2											
CALCULATION SURFACE - NAME	Room 1 - General				Room 1 - 500 Lux Area - DF > 4%				Room 2 - General			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	363	0.553	4.09%	0.577	562	0.505	6.54%	0.524	550	0.515	6.28%	0.52
FEBRUARY	480	0.553	4.09%	0.577	744	0.505	6.54%	0.524	728	0.515	6.28%	0.52
MARCH	610	0.553	4.09%	0.577	945	0.505	6.54%	0.524	925	0.515	6.28%	0.52
APRIL	736	0.553	4.09%	0.577	1140	0.505	6.54%	0.524	1116	0.515	6.28%	0.52
MAY	812	0.553	4.09%	0.577	1258	0.505	6.54%	0.524	1231	0.515	6.28%	0.52
JUNE	841	0.553	4.09%	0.577	1302	0.505	6.54%	0.524	1275	0.515	6.28%	0.52
JULY	829	0.553	4.09%	0.577	1284	0.505	6.54%	0.524	1257	0.515	6.28%	0.52
AUGUST	776	0.553	4.09%	0.577	1202	0.505	6.54%	0.524	1177	0.515	6.28%	0.52
SEPTEMBER	676	0.553	4.09%	0.577	1047	0.505	6.54%	0.524	1025	0.515	6.28%	0.52
OCTOBER	543	0.553	4.09%	0.577	841	0.505	6.54%	0.524	824	0.515	6.28%	0.52
NOVEMBER	394	0.553	4.09%	0.577	609	0.505	6.54%	0.524	597	0.515	6.28%	0.52
DECEMBER	329	0.553	4.09%	0.577	510	0.505	6.54%	0.524	499	0.515	6.28%	0.52

Table 28 – Public Space A, PHASE 3.2 - Calculation Surfaces – Results Overview

LOCATION	Building A - Mezzanine											
PROJECT NAME	Public Space A - PHASE 3.3											
CALCULATION SURFACE - NAME	Room 1 - General				Room 1 - 500 Lux Area - DF > 4%				Room 2 - General			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	357	0.551	4.02%	0.575	551	0.511	6.42%	0.519	536	0.52	6.10%	0.526
FEBRUARY	472	0.551	4.02%	0.575	729	0.511	6.42%	0.519	709	0.52	6.10%	0.526
MARCH	600	0.551	4.02%	0.575	926	0.511	6.42%	0.519	901	0.52	6.10%	0.526
APRIL	724	0.551	4.02%	0.575	1117	0.511	6.42%	0.519	1087	0.52	6.10%	0.526
MAY	799	0.551	4.02%	0.575	1232	0.511	6.42%	0.519	1199	0.52	6.10%	0.526
JUNE	827	0.551	4.02%	0.575	1276	0.511	6.42%	0.519	1242	0.52	6.10%	0.526
JULY	816	0.551	4.02%	0.575	1258	0.511	6.42%	0.519	1225	0.52	6.10%	0.526
AUGUST	763	0.551	4.02%	0.575	1177	0.511	6.42%	0.519	1146	0.52	6.10%	0.526
SEPTEMBER	665	0.551	4.02%	0.575	1025	0.511	6.42%	0.519	998	0.52	6.10%	0.526
OCTOBER	534	0.551	4.02%	0.575	824	0.511	6.42%	0.519	802	0.52	6.10%	0.526
NOVEMBER	387	0.551	4.02%	0.575	597	0.511	6.42%	0.519	581	0.52	6.10%	0.526
DECEMBER	324	0.551	4.02%	0.575	499	0.511	6.42%	0.519	486	0.52	6.10%	0.526

Table 29 – Public Space A, PHASE 3.3 - Calculation Surfaces – Results Overview

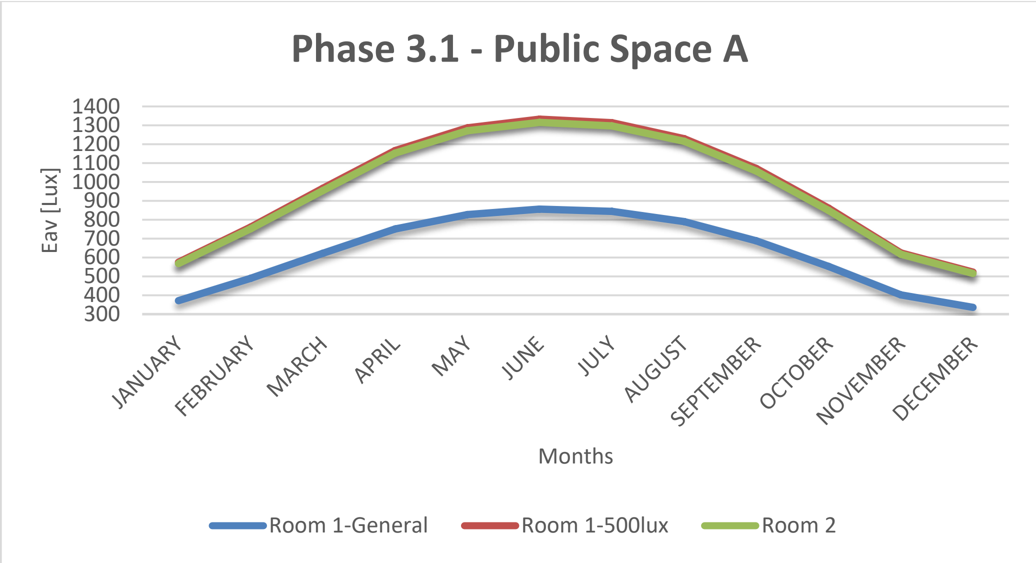


Diagram 26 – Public Space A, PHASE 3.1 - Calculation Surfaces – Results Overview

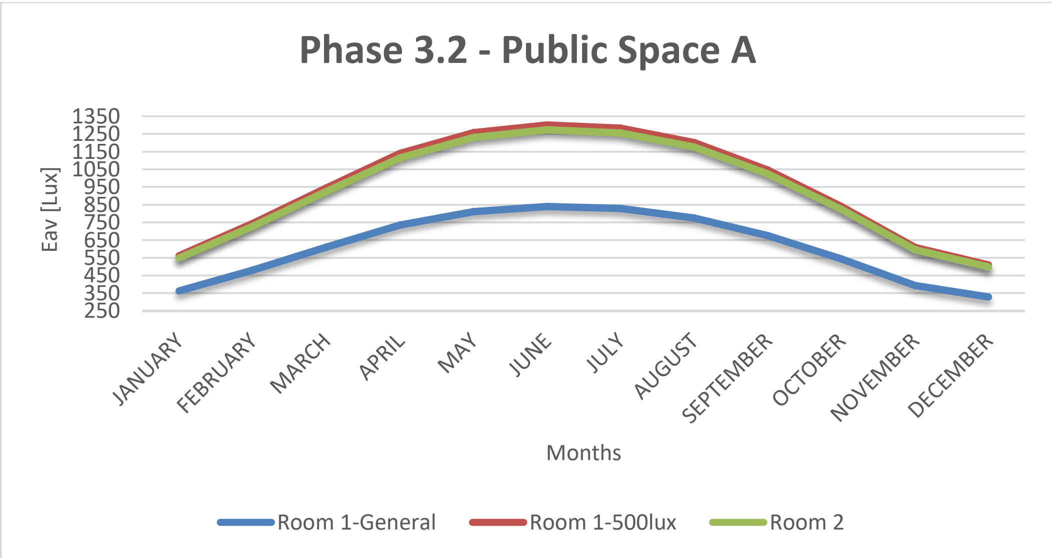


Diagram 27 – Public Space A, PHASE 3.2 - Calculation Surfaces – Results Overview

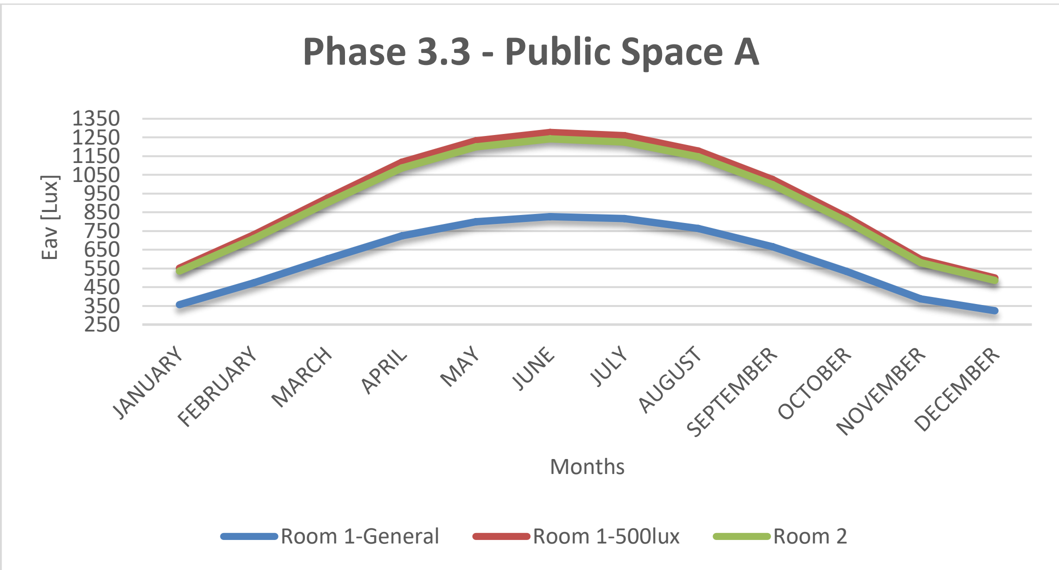


Diagram 28 – Public Space A, PHASE 3.3 - Calculation Surfaces – Results Overview

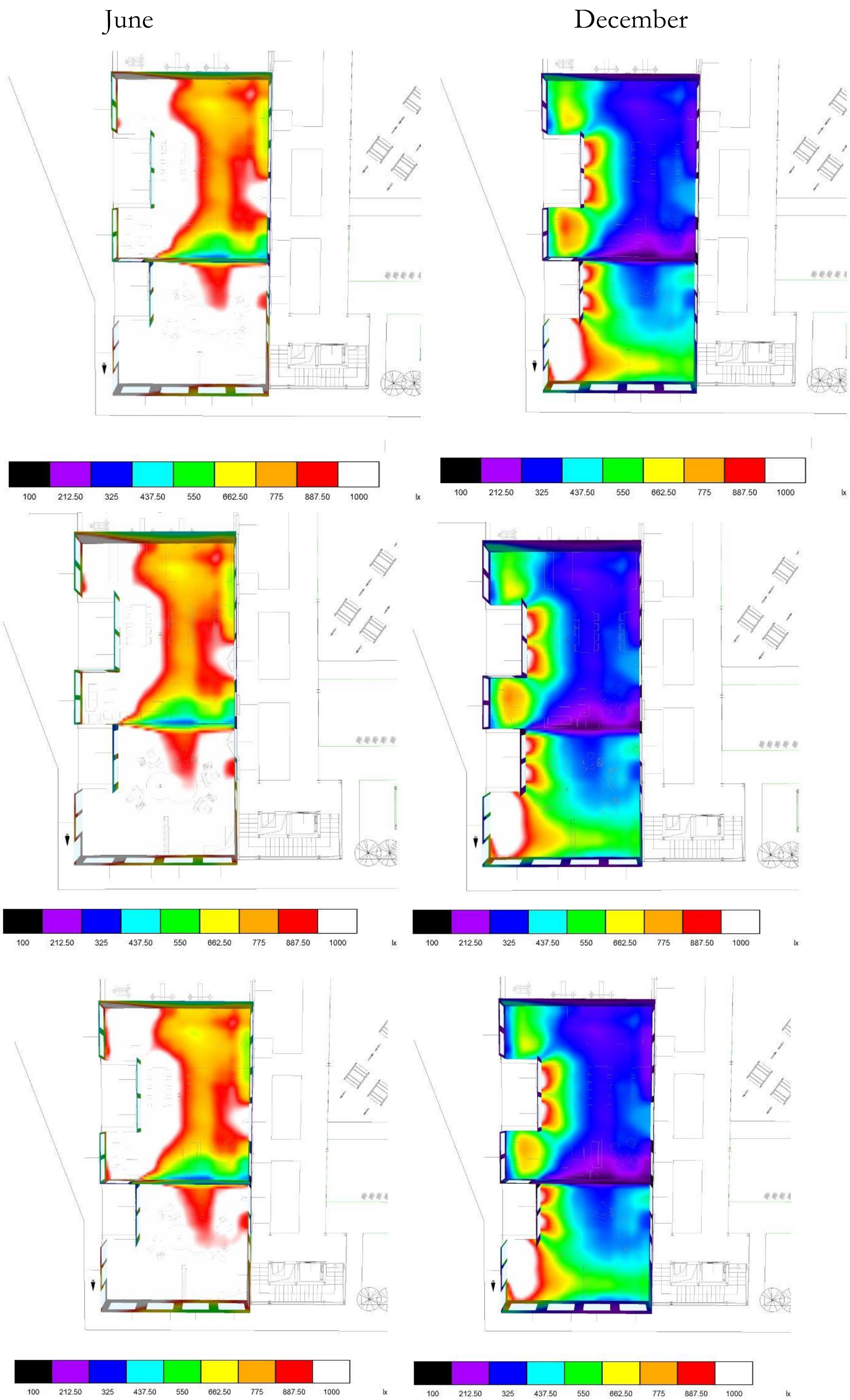


Image 42 – Public Space A, PHASE 3.1-3.2-3.3 – False Colour Rendering – June & December

As stated in the previous PHASE 2, the internal space of the Atelier (Room 2) does not need to be divided since its lighting levels respect the required values for all the year. Thanks to the shading system the light that enters can be distributed even more. In fact, as can be seen from the results, the uniformity rises to levels above 0.5 (in all three cases).
The planner's choice reverts to the first two systems, high and medium reflection, since these are the only ones in which the average light levels are greater than 500 and 300 Lux in the respective areas.
For all the configurations presented the level of glare always remained well below the levels imposed by the standard (for these types of activity they must remain <20). In fact, they are all <10 and therefore it is possible to assert that the visual comfort within these environments is high everywhere.
However, as far as the Reading room is concerned, it was necessary to divide it into two parts. All the part exposed to the EAST can in fact be used as a reading room, while the remaining part is to be used as a lounge area or for storing books. Therefore a useful tool for the planning of internal distribution is given into the hands of the architect. In fact, beginning with the false colour diagrams it is possible to see the light distribution taking into account the evolution of the design choices.

PUBLIC SPACE B: FASE 03

Summary data on entry:

Reflection factor:

Walls: 0.7

Floors: 0.3

Ceiling: 0.8

Maintenance factor: 0.8

Glass surface Room 1: 31.8mq (Kids Area)

Glass surface Room 2: 30.9mq (Conference Room)

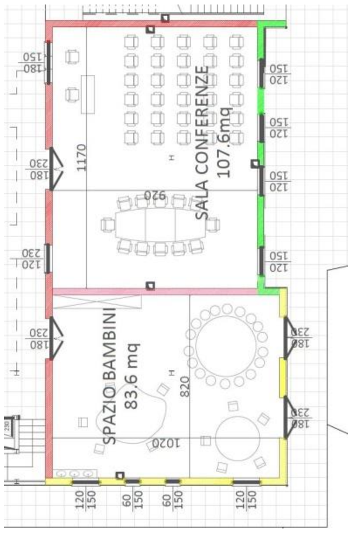


Image 16 - Public Space B-Plan

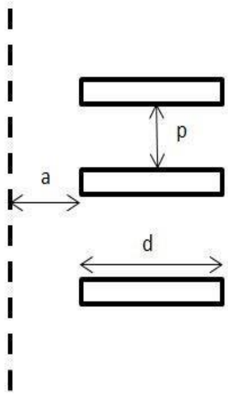
Solar shading system is composed of horizontal aluminium blades inclined 0° with height h = 2 cm, length d=20 cm, a gap of 45cm and a distance of 30cm from the glass.

Legend:

a: distance from the glass

d: width of the blades

p: gap between the blades



a [cm]	d [cm]	p [cm]	d/p
30	20	45	0,4

Image 38 – Horizontal shading system

The shading system was placed only in front of the windows facing WEST, both for Kids Area and Conference Room.

The information just supplied is valid only for each of the following sub-phases in which only the coefficient of reflection of the blades following the scheme will be varied:

High Reflection	0,8	PHASE3.1
Medium Reflection	0,6	PHASE3.2
Low Reflection	0,3	PHASE3.3

It will now present all the calculated values for the configurations shown above:

LOCATION	Building B - Mezzanine											
PROJECT NAME	Public Space B - PHASE 3.1											
CALCULATION SURFACE - NAME	Room 1 - General				Room 2 - General				Room 2 - 500Lux Area - DF > 4%			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	399	0,508	4,71%	0,508	247	0,556	2,79%	0,555	509	0,566	5,62%	0,555
FEBRUARY	528	0,508	4,71%	0,508	326	0,556	2,79%	0,555	674	0,566	5,62%	0,555
MARCH	672	0,508	4,71%	0,508	415	0,556	2,79%	0,555	856	0,566	5,62%	0,555
APRIL	810	0,508	4,71%	0,508	500	0,556	2,79%	0,555	1033	0,566	5,62%	0,555
MAY	894	0,508	4,71%	0,508	552	0,556	2,79%	0,555	1139	0,566	5,62%	0,555
JUNE	925	0,508	4,71%	0,508	572	0,556	2,79%	0,555	1180	0,566	5,62%	0,555
JULY	912	0,508	4,71%	0,508	564	0,556	2,79%	0,555	1163	0,566	5,62%	0,555
AUGUST	854	0,508	4,71%	0,508	527	0,556	2,79%	0,555	1089	0,566	5,62%	0,555
SEPTEMBER	744	0,508	4,71%	0,508	459	0,556	2,79%	0,555	984	0,566	5,62%	0,555
OCTOBER	598	0,508	4,71%	0,508	369	0,556	2,79%	0,555	762	0,566	5,62%	0,555
NOVEMBER	433	0,508	4,71%	0,508	267	0,556	2,79%	0,555	552	0,566	5,62%	0,555
DECEMBER	362	0,508	4,71%	0,508	224	0,556	2,79%	0,555	462	0,566	5,62%	0,555

Table 30 – Public Space B, PHASE 3.1 - Calculation Surfaces – Results Overview

LOCATION	Building B - Mezzanine											
PROJECT NAME	Public Space B - PHASE 3.2											
CALCULATION SURFACE - NAME	Room 1 - General				Room 2 - General				Room 2 - 500Lux Area - DF > 4%			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	392	0,507	4,64%	0,506	239	0,557	2,70%	0,557	493	0,561	5,43%	0,55
FEBRUARY	521	0,507	4,64%	0,506	316	0,557	2,70%	0,557	653	0,561	5,43%	0,55
MARCH	662	0,507	4,64%	0,506	402	0,557	2,70%	0,557	830	0,561	5,43%	0,55
APRIL	798	0,507	4,64%	0,506	485	0,557	2,70%	0,557	1001	0,561	5,43%	0,55
MAY	880	0,507	4,64%	0,506	535	0,557	2,70%	0,557	1104	0,561	5,43%	0,55
JUNE	912	0,507	4,64%	0,506	554	0,557	2,70%	0,557	1143	0,561	5,43%	0,55
JULY	899	0,507	4,64%	0,506	546	0,557	2,70%	0,557	1127	0,561	5,43%	0,55
AUGUST	841	0,507	4,64%	0,506	511	0,557	2,70%	0,557	1055	0,561	5,43%	0,55
SEPTEMBER	733	0,507	4,64%	0,506	445	0,557	2,70%	0,557	919	0,561	5,43%	0,55
OCTOBER	589	0,507	4,64%	0,506	358	0,557	2,70%	0,557	738	0,561	5,43%	0,55
NOVEMBER	427	0,507	4,64%	0,506	259	0,557	2,70%	0,557	535	0,561	5,43%	0,55
DECEMBER	357	0,507	4,64%	0,506	217	0,557	2,70%	0,557	447	0,561	5,43%	0,55

Table 31 – Public Space B, PHASE 3.2 - Calculation Surfaces – Results Overview

LOCATION	Building B - Mezzanine											
PROJECT NAME	Public Space B - PHASE 3.3											
CALCULATION SURFACE - NAME	Room 1 - General				Room 2 - General				Room 2 - 500Lux Area - DF > 4%			
VALUE	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav	Eav [lx]	u0 (Emin/Eav)	Dav [%]	Dmin/Dav
JANUARY	386	0,504	4,55%	0,506	232	0,558	2,63%	0,557	480	0,554	5,27%	0,542
FEBRUARY	511	0,504	4,55%	0,506	307	0,558	2,63%	0,557	635	0,554	5,27%	0,542
MARCH	650	0,504	4,55%	0,506	390	0,558	2,63%	0,557	806	0,554	5,27%	0,542
APRIL	784	0,504	4,55%	0,506	471	0,558	2,63%	0,557	973	0,554	5,27%	0,542
MAY	864	0,504	4,55%	0,506	520	0,558	2,63%	0,557	1073	0,554	5,27%	0,542
JUNE	895	0,504	4,55%	0,506	538	0,558	2,63%	0,557	1111	0,554	5,27%	0,542
JULY	883	0,504	4,55%	0,506	531	0,558	2,63%	0,557	1096	0,554	5,27%	0,542
AUGUST	826	0,504	4,55%	0,506	496	0,558	2,63%	0,557	1025	0,554	5,27%	0,542
SEPTEMBER	719	0,504	4,55%	0,506	432	0,558	2,63%	0,557	893	0,554	5,27%	0,542
OCTOBER	578	0,504	4,55%	0,506	347	0,558	2,63%	0,557	718	0,554	5,27%	0,542
NOVEMBER	419	0,504	4,55%	0,506	252	0,558	2,63%	0,557	520	0,554	5,27%	0,542
DECEMBER	350	0,504	4,55%	0,506	211	0,558	2,63%	0,557	435	0,554	5,27%	0,542

Table 32 – Public Space B, PHASE 3.3 - Calculation Surfaces – Results Overview

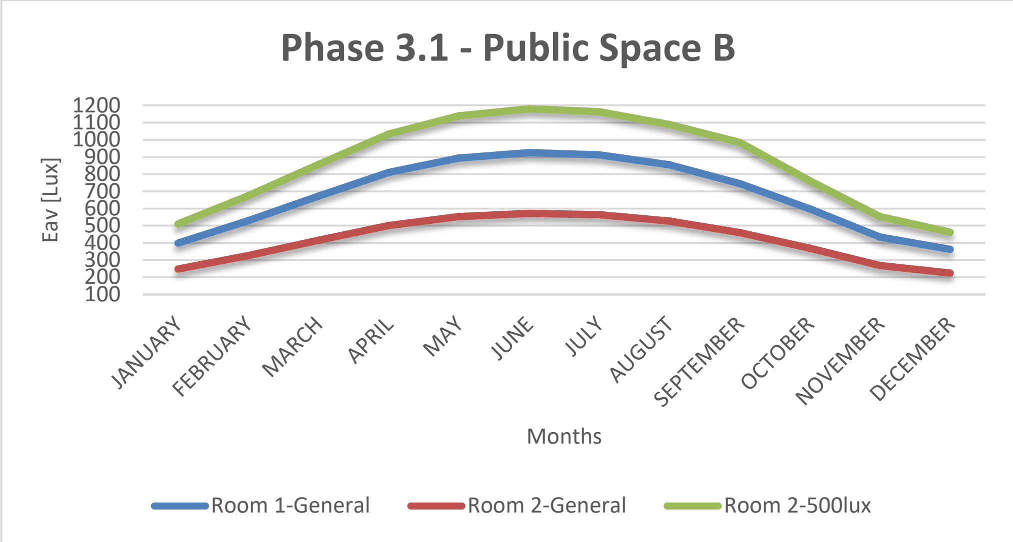


Diagram 29 – Public Space B, PHASE 3.1 - Calculation Surfaces – Results Overview

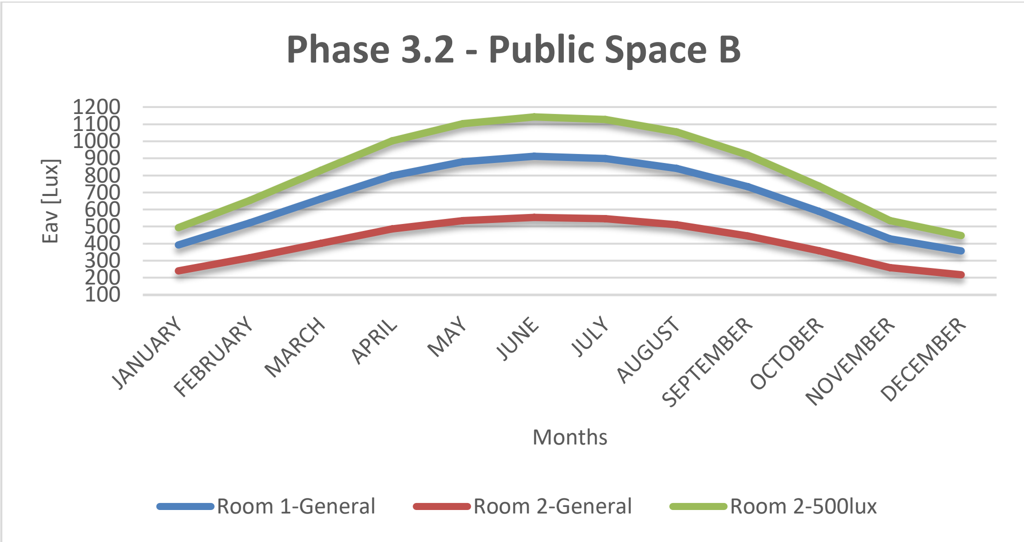


Diagram 30 – Public Space B, PHASE 3.2 - Calculation Surfaces – Results Overview

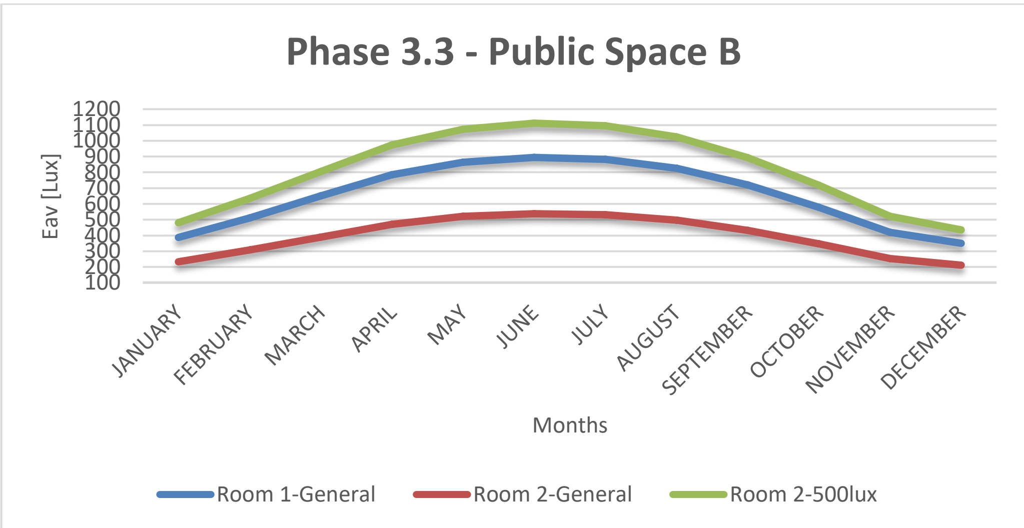


Diagram 31 – Public Space B, PHASE 3.3 - Calculation Surfaces – Results Overview

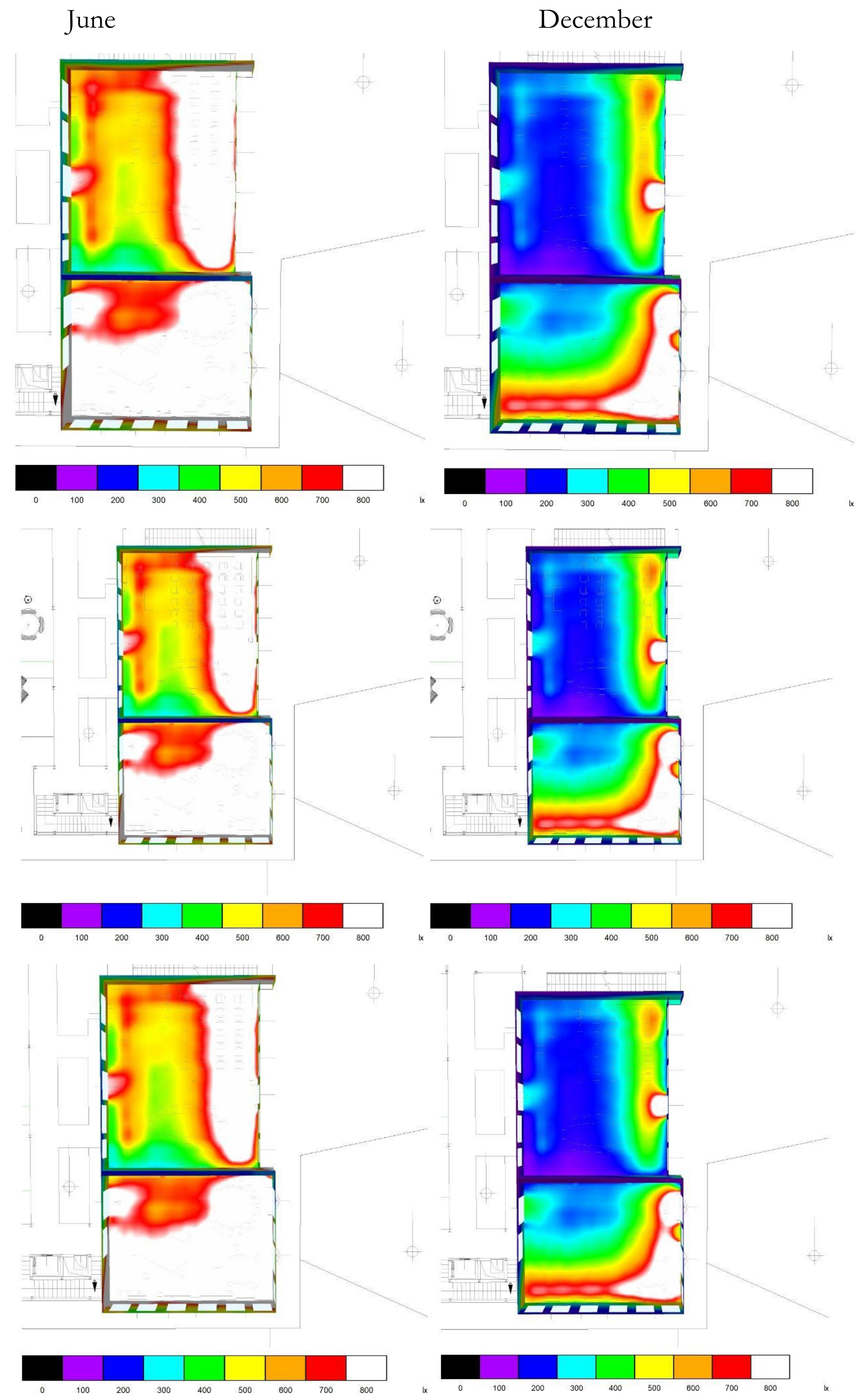


Image 43 – Public Space B, PHASE 3.1-3.2-3.3 – False Colour Rendering – June & December

The comments for this area are divided into two parts since, as far as concerning to the Children's room (Room 1), further optimization was not needed as all the target values, including those concerning glare, were always respected. In addition, it can be added that this space is able to respond to the average need for illumination of 500 in nearly the total surface area. In fact, only a small entry area to the EAST did not respect this value. This factor is to be considered in any future changes of use.

On the other hand, the Conference room is more problematical despite the installation of the greatest quantity of glazed surface possible. In fact, it does not reach the minimum levels required, if not for a small part of the surface area, which is not enough for the planned use. To solve this problem an alternative was tried by dividing the place into two spaces, with the installation a longitudinal partition, but this did not give satisfying values. Therefore, it reveals the need for constant use of artificial illumination for Public Space B beginning from the current layout (PHASE 00). The data extracted from this simulation will then be used to undertake additional consideration, also of an economic nature.

ARTIFICIAL LIGHTING OPTIMIZED DESIGN: FASE 04

- PHASE 4.1: design of the lighting system to reach the target Eav = 500 Lux, u0 > 0.6, for both spaces. For obvious reasons the systems will be dimensioned without considering the influence of natural lighting.
- PHASE 4.2: presentation of the data taken out from the simulation as per the above with natural light (Fill on)
- PHASE 4.2.1: Optimization of the system through differential turn on- turn off solutions (dividing the systems into rows)
- PHASE 4.2.2: Optimization of the system through the installation of a dimming system which regulates the quantity of artificial light according to the natural light component present

In each of these phases the conditions at stake do not vary, that is that the glass surface and the coefficients of reflection do not vary.

PUBLIC SPACE B: FASE 04

Summary data on entry:

Reflection factor:

Walls: 0.5

Floors: 0.2

Ceiling: 0.7

Maintenance factor: 0.8

Glass surface Room 1: 17.82mq (Kids Area)

Glass surface Room 2: 18.24mq (Conference Room)

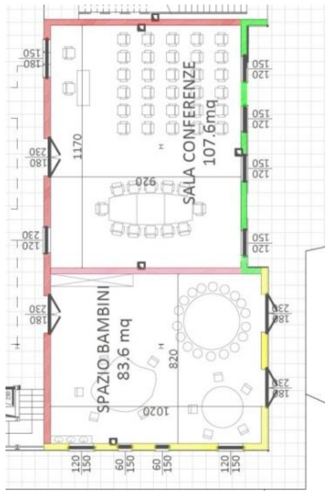


Image 16 – Public Space B-Plan

PHASE4.1

The lighting system will be LED since it is the system that at the present time allows the greatest energy savings by guaranteeing initial performance even over very long time frames, greater than 10 years. They will be used in a total of 36 lighting units of 45W, 16 for the Children's area and 20 for the Conference room for a total installed power of 1,620kW arranged according to a regular scheme as shown in the image:

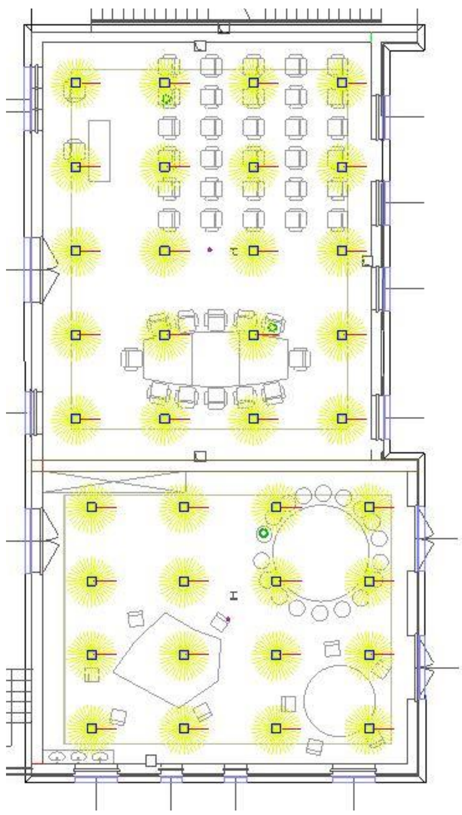


Image 44 – Public Space B, PHASE 4.1 – Luminaires layout plan

This configuration guarantees optimum levels of both illumination and uniformity. Obviously, the Daylight factor is not included in this simulation. The summary of the surfaces is shown as in the software:

Calculation Surface List

No.	Designation	Type	Grid	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
1	Horizontal Value - Room 1	horizontal	100 x 100	509	345	620	0.676	0.556
2	Horizontal Value - Room 2	horizontal	100 x 100	504	419	603	0.831	0.696

Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
horizontal	2	507	345	620	0.68	0.56

Table 33 – Public Space B, PHASE 4.1 - Calculation Surfaces – Results Overview – DIALux Output

As can be read, the values fall perfectly within the limits set previously. The false colour image which shows the distribution of light and also the positions of the lighting units is shown below:

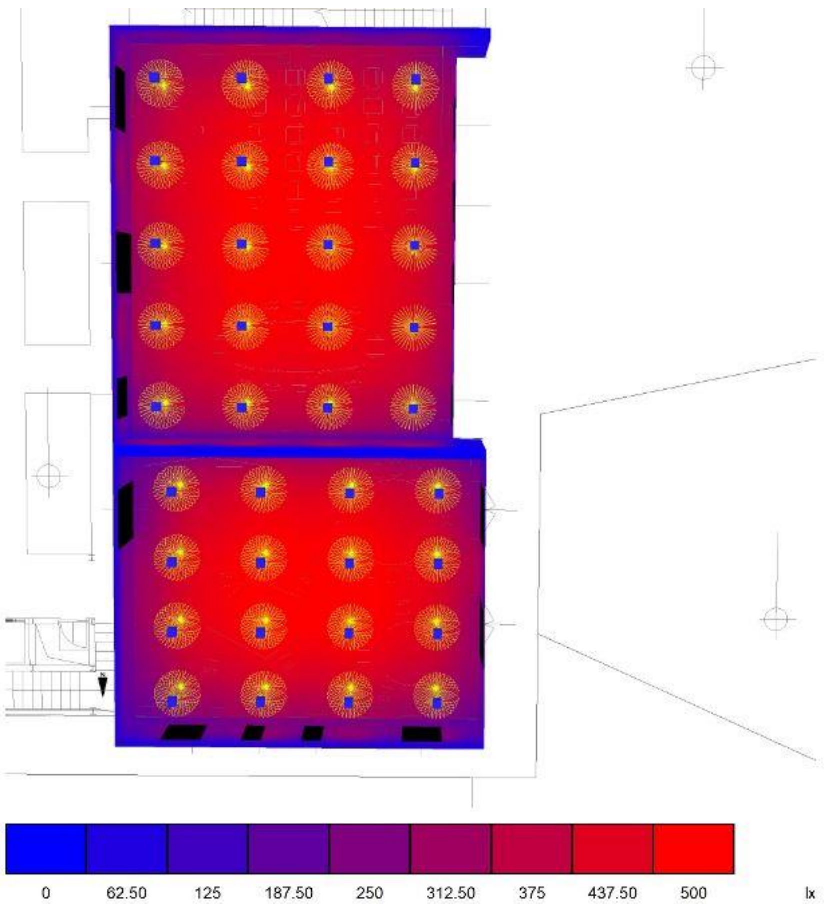


Image 45 – Public Space B, PHASE 4.1 – False colour rendering

In addition, it is possible to take out from the software the values of glare which, with this configuration are <20, the maximum level allowed by the regulations. In the case this level is greater than the maximum level a possible strategy could be to increase the number of projectors, choosing a lower power cut model and subsequently less luminous flux (lm). The data just displayed do not take into account the contribution of natural light which will be considered beginning with the next phase.

PHASE 4.2 – Full ON

It will now show the average light levels and the respective uniformity during the course of the year, summing the artificial light system and the contribution of natural light:

LOCATION	Building B - Mezzanine			
PROJECT NAME	Public Space B - PHASE 4.2			
CALCULATION SURFACE - NAME	Room 1		Room 2	
VALUE	Eav [lx]	u0 (Emin/Eav)	Eav [lx]	u0 (Emin/Eav)
JANUARY	653	0.673	584	0.772
FEBRUARY	699	0.656	610	0.757
MARCH	751	0.638	640	0.741
APRIL	802	0.623	669	0.726
MAY	833	0.612	686	0.72
JUNE	844	0.607	693	0.717
JULY	839	0.609	690	0.719
AUGUST	818	0.616	678	0.726
SEPTEMBER	778	0.628	655	0.732
OCTOBER	724	0.647	625	0.75
NOVEMBER	655	0.669	591	0.768
DECEMBER	639	0.675	576	0.777

Table 34 – Public Space B, PHASE 4.2 - Calculation Surfaces – Results Overview

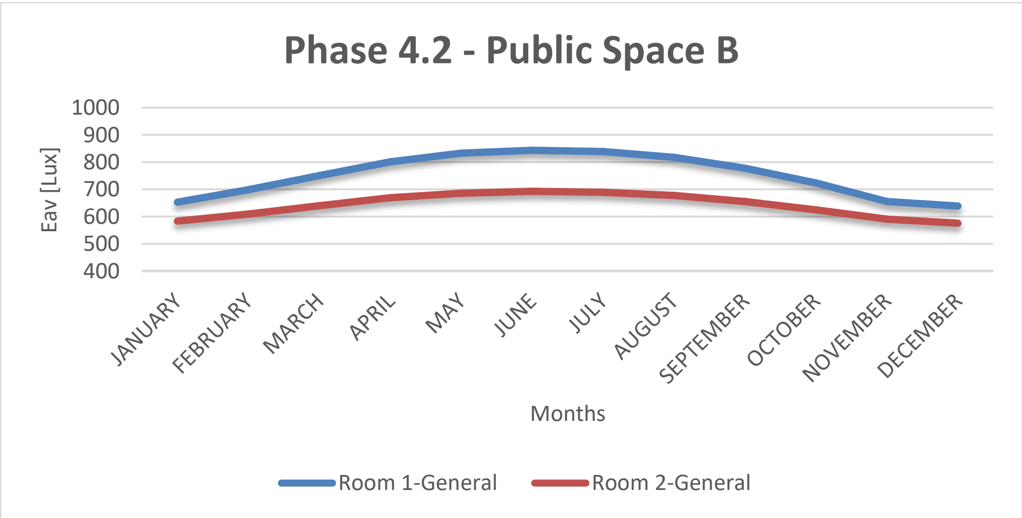


Diagram 32 – Public Space B, PHASE 4.2 - Calculation Surfaces – Results Overview

As can be seen from the data just displayed the values of illumination do not deviate much from the minimum value of 500 Lux. This means that there is not much margin for optimization since switching off even some of the projectors there is the risk that the quantity of light in the work area will fall below the minimum value.

PHASE 4.2.1 – Switching on and off differential (divided into rows)

The electrical circuit for artificial lighting was divided into vertical rows, parallel to the major glass surface according to the plan in the figure:

Image 46 – Public Space B, PHASE 4.2 – Electrical circuits division

Two scenarios are presented below.

1- Circuits on 1-2-4-5, circuits off 3-6 (Total active power 1215 W)
2- Circuits on 2-5, circuits off 1-3-4-6 (Total active power 810 kW)

This arrangement is dictated by the fact that it is necessary to keep the two central circuits 2 and 5 always switched on, as a result of the geometry of the project. From the values extrapolated, it is possible to understand the effective need for artificial illumination according to the time of the year.

PHASE 4.2.1-A:

LOCATION	Building B - Mezzanine			
PROJECT NAME	Public Space B - PHASE 4.2.1 - A			
CALCULATION SURFACE - NAME	Room 1		Room 2	
VALUE	Eav [lx]	u0 (Emin/Eav)	Eav [lx]	u0 (Emin/Eav)
JANUARY	551	0.587	483	0.531
FEBRUARY	600	0.626	506	0.588
MARCH	653	0.664	533	0.644
APRIL	704	0.693	559	0.696
MAY	736	0.709	575	0.724
JUNE	748	0.715	580	0.735
JULY	743	0.712	578	0.73
AUGUST	721	0.701	567	0.711
SEPTEMBER	680	0.681	546	0.673
OCTOBER	626	0.645	519	0.616
NOVEMBER	564	0.596	489	0.545
DECEMBER	538	0.573	476	0.513

Table 35 – Public Space B, PHASE 4.2.1-A - Calculation Surfaces – Results Overview

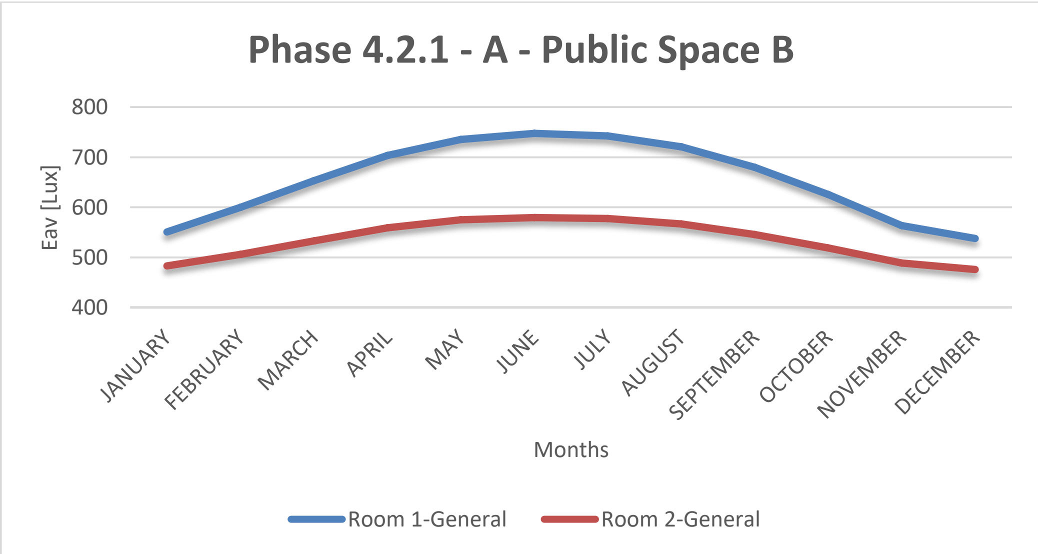


Diagram 33 – Public Space B, PHASE 4.2.1-A - Calculation Surfaces – Results Overview

This option guarantees a 25% saving on the Full ON one. As it can be seen from the presented data, this option is applicable for the Kids Area (Room 1), as it provides higher vales than those imposed by the regulations, both for lighting levels and its uniformity. By analysing the values of the Conference Room (Room 2), this option is applicable from February to October. It will be necessary to use the all artificial lighting system to cover the rest of the year.

PHASE 4.2.1-B:

LOCATION	Building B - Mezzanine			
PROJECT NAME	Public Space B - PHASE 4.2.1 - B			
CALCULATION SURFACE - NAME	Room 1		Room 2	
VALUE	Eav [lx]	u0 (Emin/Eav)	Eav [lx]	u0 (Emin/Eav)
JANUARY	440	0.326	391	0.381
FEBRUARY	488	0.335	415	0.392
MARCH	541	0.342	441	0.401
APRIL	593	0.352	466	0.407
MAY	624	0.358	482	0.411
JUNE	636	0.36	488	0.413
JULY	631	0.359	486	0.412
AUGUST	609	0.356	474	0.409
SEPTEMBER	568	0.347	454	0.403
OCTOBER	514	0.338	427	0.396
NOVEMBER	452	0.328	397	0.384
DECEMBER	426	0.321	384	0.379

Table 36 – Public Space B, PHASE 4.2.1-B - Calculation Surfaces – Results Overview

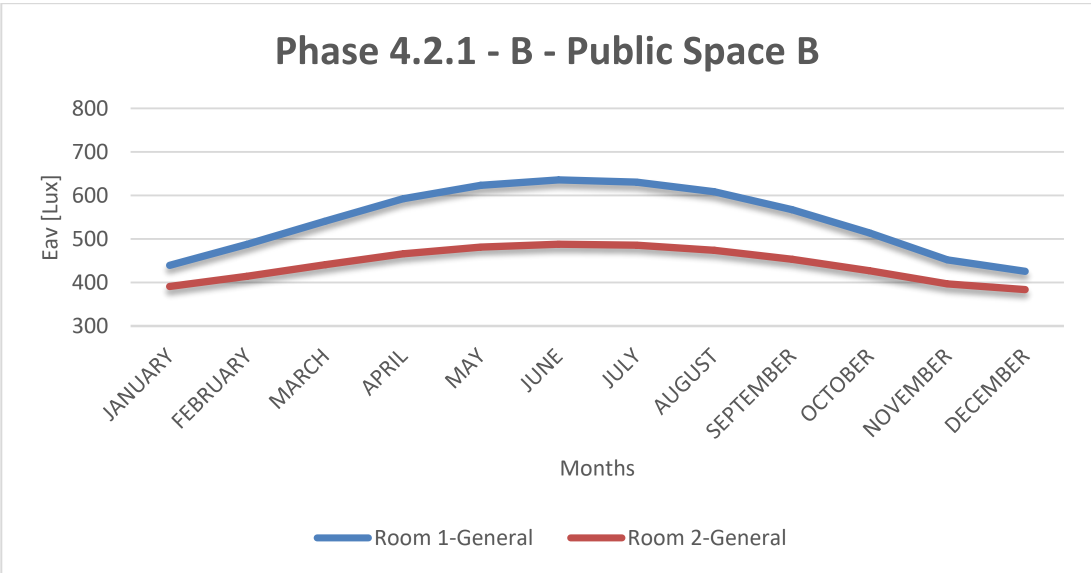


Diagram 34 – Public Space B, PHASE 4.2.1-B - Calculation Surfaces – Results Overview

This second option, however, greatly reduces uniformity in each of the two rooms, so no further analysis will take place in this direction.

PHASE 4.2.2

This is the most complex option, as well as the most expensive, as it involves installing, for each of the luminaires, dimming drivers, and specific switches that allow it to be controlled. However, this system allows a very dynamic control of the luminaires, which can thus be controlled by the user with maximum flexibility. In the table below, a column has been added to indicate the dimming percentage value set up to the totality of the lighting fixtures in the room:

LOCATION	Building B - Mezzanine					
PROJECT NAME	Public Space B - PHASE 4.2.2					
CALCULATION SURFACE - NAME	Room 1			Room 2		
VALUE	Eav [lx]	u0 (Emin/Eav)	Dimming	Eav [lx]	u0 (Emin/Eav)	Dimming
JANUARY	555	0.705	80%	540	0.795	90%
FEBRUARY	552	0.662	70%	517	0.764	80%
MARCH	555	0.621	60%	549	0.739	80%
APRIL	555	0.57	50%	530	0.707	70%
MAY	536	0.538	40%	548	0.695	70%
JUNE	548	0.534	40%	505	0.674	60%
JULY	543	0.536	40%	552	0.692	70%
AUGUST	571	0.565	50%	539	0.702	70%
SEPTEMBER	582	0.607	60%	565	0.729	80%
OCTOBER	578	0.651	70%	533	0.751	80%
NOVEMBER	568	0.697	80%	547	0.79	90%
DECEMBER	542	0.713	80%	532	0.802	90%

Table 37 – Public Space B, PHASE 4.2.2 - Calculation Surfaces – Results Overview

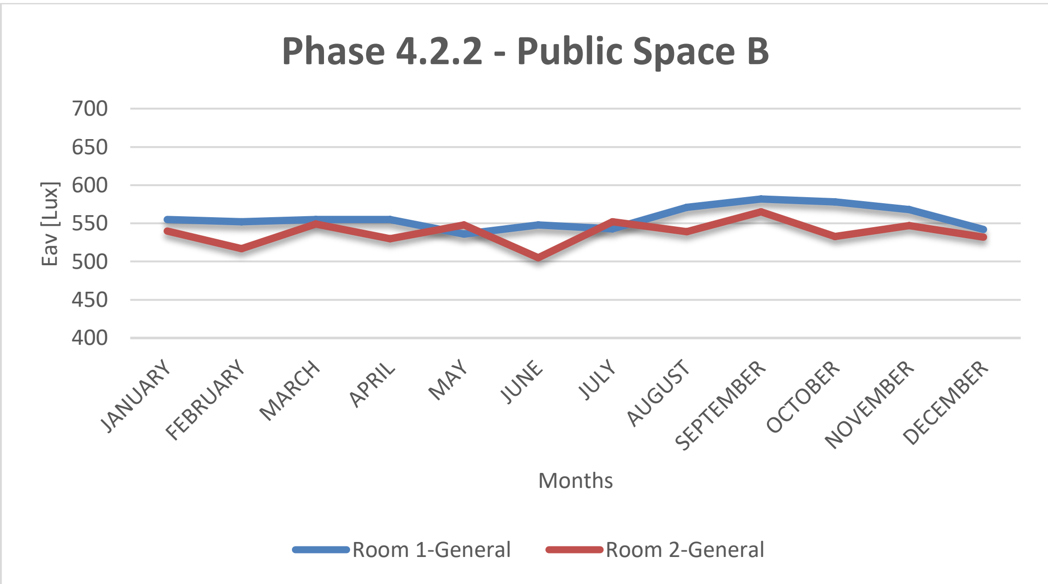


Diagram 35 – Public Space B, PHASE 4.2.2 - Calculation Surfaces – Results Overview

This system allows an average saving of 32%, higher than the previously presented system (saving 25%). With this system it can be always choose the amount of light present in the room, a very useful option especially in a conference room. . As it can be seen from the previous graph, the trend over the year remains very constant, as the amount of natural light decreases as the artificial light decreases. This system requires an employee who knows the dimmer value to be set at the lamps during the year; it would be theoretically possible to automate this process by means of special "twilight" sensors, which should, however, be placed at different points in the room and often conflict with each other.

ECONOMIC CONSIDERATIONS

The following is a payback of the investment including initial purchase, installation and running costs for the year. The comparison will be between the installation of the new artificial lighting system and the proposed light technology optimization, which allows the maximum possible use of natural light.

The addition of the windows and the shading system entails an expense of € 12750, which is to be added to the costs of structural work, quantified at 6750 Euro, for a total of 19500 Euro. The total cost of purchasing the artificial lighting system (which is still present) is 7560 Euro (210 Euros per piece), to which an installation cost of 2500 Euro is added for a total of 10060 Euro. Below is a summary table of the investment costs of the artificial lighting system:

Cost of energy	[€/kWh]		0.22
Artificial Lighting System			
Investment		€	10.060
n° of Devices			36
Yearly Upkeep for device		€	10
Total Power	[kW]		1.620
Annual Consumption	[kWh]		7.096
Yearly Energy cost		€	1.561
Yearly Upkeep cost		€	360
Inflation			3%

Table 38 – Input costs for artificial lighting system

Years	1	2	3	4	5	6
Energy expenses	€ 1.561	€ 1.608	€ 1.656	€ 1.706	€ 1.757	€ 1.810
Upkeep Expenses	€ 360	€ 371	€ 382	€ 393	€ 405	€ 417
Total Running Expenses	**€ 1.921**	€ 1.979	€ 2.038	€ 2.099	€ 2.162	€ 2.227
Total Cumulated Costs	**€ 11.981**	€ 13.960	€ 15.998	€ 18.097	€ 20.259	€ 22.486

Table 39 – Running costs for artificial lighting system

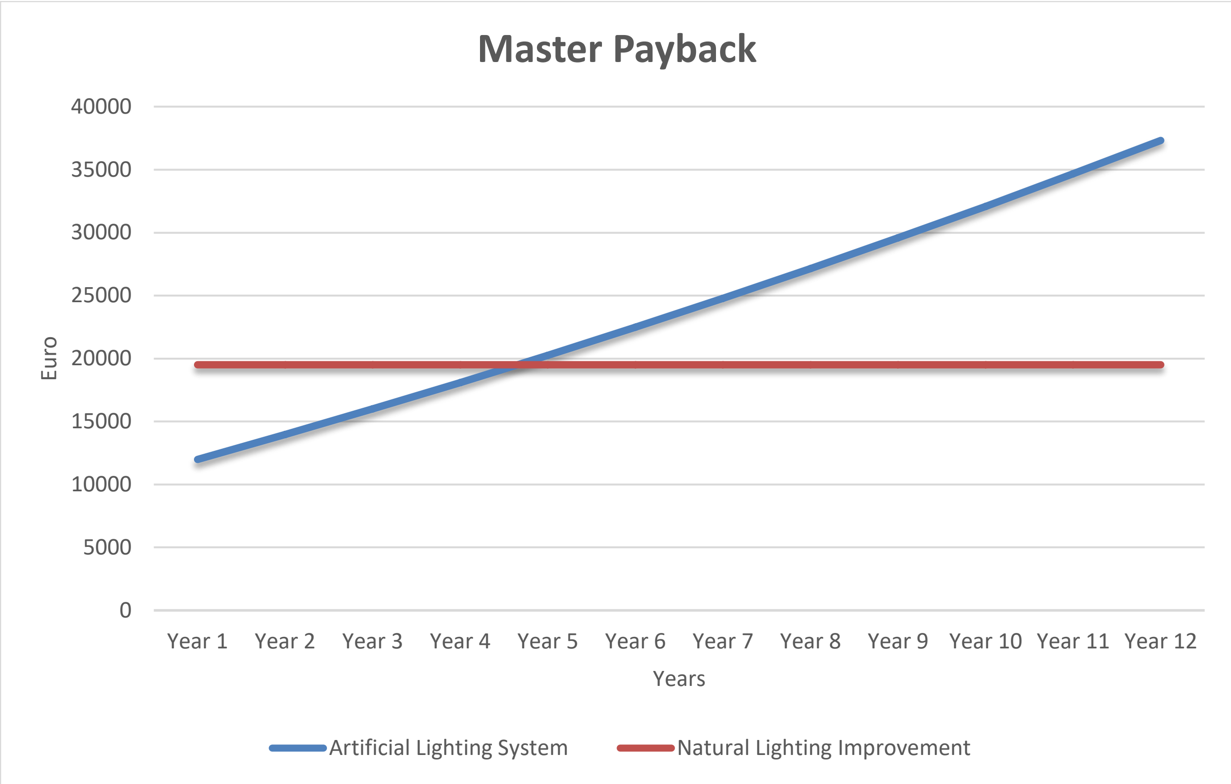


Diagram 36 – Master Payback - A

The annual saving guaranteed by the proposed optimization system is 1921 Euro / year, Payback is set to 4.77 years. This time has to be considered extremely positive, as the useful life of the building is 50 years. Below is a graph showing the same data as above, but considering the use of artificial lighting energy of 20% plus the investment costs for lighting optimization:

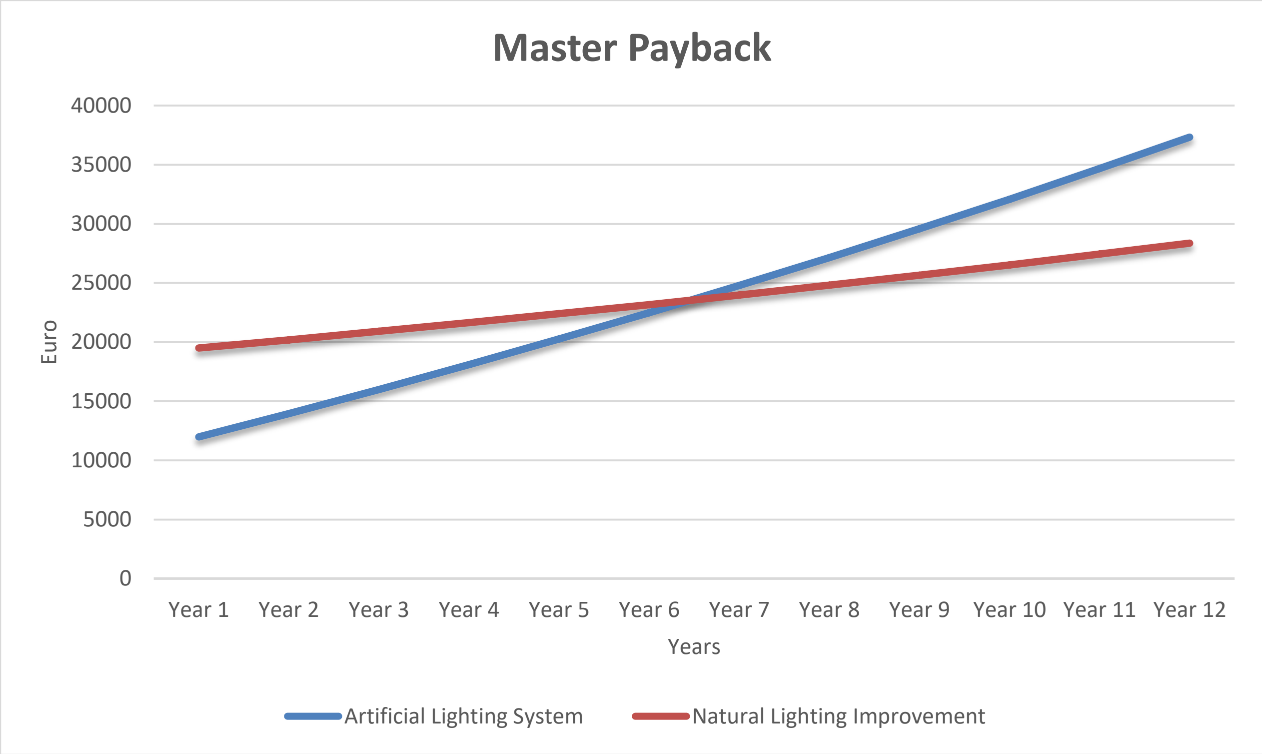


Diagram 36 – Master Payback - B

Even in this case Payback is very convenient, as it is 6.74 years. In general, considering the useful life of the building, a return period of less than nine years is considered to be positive.

CONCLUSION

The aim of this thesis is to give to the lighting designer the tools needed for a conscious design that allow to exploit the biggest possible amount of natural resources, in order to minimize energy consumption load for lighting.

The presented model is easy to use and provides a step-by-step guide through all the parameters that affect visual perception and lighting comfort.

The ideal case, however, foresees that the lighting design starts from the preliminary design stage, since it can take into account aspects of extreme importance such as exposure of the various environments. Additionally, intervening on an already built building entails additional costs and disadvantages to users, even if for a limited time. It should be emphasized that lighting analysis, especially at the preliminary stage, has to go hand in hand with energetic analyses, since as mentioned above, the implementation of glass surfaces implies, on the one hand, a lower consumption of electricity, but on the other hand it could have a major impact on the summer cooling loads of the entire building, although it has positive effects on winter heating loads (free solar contributions). In general, it is necessary to balance all characters involved in a process of optimization that can generally be defined as energetic.

A possible future development could thus be the support to the analyses carried out in this thesis with energy considerations, analysing the summer and winter requirements of the building under analysis.

The success of the proposed optimization process remains very important, which confirms the possibility, through the case study, of a significant improvement in lighting quality for a better use of indoor environments from the users; the goodness of the proposed process is also supported by the economic considerations previously presented.

The type of analysis proposed, that goes through a parametric approach, allows its own use also in different climate contexts or completely different latitudes, since it acts on the individual factors that characterize the quality of the light one by one, by linking the needs of the users with the external reference context.

FOOTNOTES

1. page 1 - Boyano A, Hernandez P, Wolf O. Energy demands and potential savings in European office buildings: Case studies based on EnergyPlus simulations. Energy Build 2013 10;65:19-28.

2. page 1 - Hee WJ, Alghoul MA, Bakhtyar B, Elayeb O, Shameri MA, Alrubaih MS, et al. The role of window glazing on daylighting and energy saving in buildings. Renewable and Sustainable Energy Reviews, 2015 2;42:323-343.

3. page 1 - Planning of sustainable cities in view of green architecture. 2011 International Conference on Green Buildings and Sustainable Cities, GBSC 2011, September 15, 2011 - September 16; 2011; Bologna, Italy: Elsevier Ltd; 2011.

4. page 8 - Piano di Governo del Territorio del Comune di Milano, Componente geologica, idrogeologica e sismica, 2014

5. page 19 - Software Manual, DIALux 4.13, 2017

6. page 64 - Mandalaki M, Zervas K, Tsoutsos T, Vazakas A. Assessment of fixed shading devices with integrated PV for efficient energy use. Solar Energy 2012 9;86(9):2561-2575.

7. page 64 - Freewan AAY. Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions. Solar Energy 2014 4;102:14-30.

8. page 64 - Huang Y, Niu J, Chung T. Comprehensive analysis on thermal and daylighting performance of glazing and shading designs on office building envelope in cooling-dominant climates. Appl Energy 2014;12/1;134:215-228.

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