Degree Project in Architectural Lighting Design
Second Cycle 15.0 hp

The White Canvas
A lighting proposal for the KTH Library Hall

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2023

School of Architecture and the Built Environment – Lighting Design
Degree of Master of Science – Architectural Lighting Design
Course Code: AF270X
ACKNOWLEDGMENTS

I would like to express my deepest gratitude to Yael Erel, my tutor, for her support and patience, and who never hesitated to share her knowledge. To all the teachers of the Master’s and the ALD division, who always taught with passion for our profession and love for their students. I would like to extend my sincere thanks to Sara and all the librarians and architects who provided all the information and they were always willing to solve all the doubts.

This endeavor would not have been possible without my family and my fiancé who supported me all the time and pushed me to keep going. And with whom we have endured the distance and my hours of calls looking for inspiration.

I had the pleasure of meet, travel and work with my friends and colleagues, who made this trip a great experience.

At last but not at least, to God. Thank you with all my heart.
ABSTRACT
Consolidating a library within the old patio of a building that for more than 100 years has undergone constant transformation is a challenge. Putting a roof over an area that was clearly defined to be open and under it a large library is a great opportunity. Due to its large area, a discussion was opened about implementing light on the surface of the ceiling, in a subtle and abstract way, aligned with the environmental parameters of the city. The white ceiling that appears to be suspended but is supported by large windows then became a White canvas for a play of lights brought on by daylight during the day and electric light for the long hours of darkness. Through qualitative and quantitative methods such as meetings, observations and surveys, the perception of the users was evaluated, and after tests, models and digital analysis, an intervention was defined on one of its facades that allows that ceiling to be reconnected with the natural and especially with the light. Exploring with elements such as the use of color or the management of reflections results in simple elements that can also be implemented from the architectural design, as support for lighting design.

KEYWORDS
Daylight, indoor, reflections, nature
INTRODUCTION

A blank space is an opportunity. And this is what is presented in the main hall of the KTH library, an area that was built in the early 1900s and remodeled around the year 2000. This emblematic building of the university is used by a large number of people on a daily basis and one of the characteristics of this space is its white ceiling, which is surrounded by large windows that allow natural light to enter throughout the year (Fig. 1). The ceiling is an extensive blank surface that is not being used and that could be integrated more into the design.

One of the ways in which it can be used is by incorporating elements that generate dynamism in the space. For instance, it is feasible to fade the boundary between the window and the ceiling and boost the benefits that daylight brings. We must start from the concept that the primary purpose of a window is to provide light to enable a building to function [1]. But daylight is much more than functional. Kilic and Hasirci mentioned: “It was found that daylight and other four environmental processes (namely privacy, personal space, territoriality, and crowding) are related. It is believed that the consideration of this relationship will encourage students to use their libraries fully as an essential component of university education and campus life” [2]. At the end, Kilic and Hasirci showed that there is a relationship between daylight and the frequency of use of the space since impressions of a room or activity are generated in the users. [2]

These are some of the reasons why in the last 20 or 30 years, daylighting design has begun to make a comeback. Designers have found an interest to provide dynamic light, fresh air and views to the outdoors in indoor’s spaces [3]. And although for a many people it is a desire of reduce energy consumption [3], the truth is that daylight is much more than that. For instance, some studies showed that students performed and achieved better in daylighting schools, that in artificially illuminated ones [4] [5]. Also, It is worth mentioning that visual performance depends upon the apparent size of the object, the illuminance level and the fatigue state of the observer [6] and daylight improves visual performance [7].

On the other hand, lighting design is closest to the idea of designing time [8], and with daylight it is related to the fact that humans have a strong desire to be able to perceive sunlight when it is known to be available [1]. In this way, the possibility of encouraging a better relationship with the passage of time opens up, since circumstances arise to make external atmospheric conditions such as wind and the presence of sunlight even more visible and incorporating them into the large white canvas.

At the end, as Mott at al [9] said, “the role of lighting in our daily lives is essential to operate ideally in every environment”. According to them and many other authors, light affects human beings in practically everything, including creative processes, rest and even perception [4] [3] [7]. Also, “lighting can be used to make an architectural space more aesthetically pleasing or it can create an atmosphere in that space, both affect people’s emotions” [9]. With this in mind, it should be added that Stockholm is a city where in summer it can have more than 18 hours of daylight and in winter only 6 hours [10]. And the library is used all year. Therefore, for the installation to be valid throughout the year, the support of artificial lighting is required. However, this is an indication that the installation can contribute to the well-being of users regardless of the season, turning that great white canvas into a play of light.

“The history of architecture is the history of the struggle for light.”
Le Corbusier [10]
Research Question and Aim of the project

At the beginning of the process it was possible to observe that the ceiling is considered an element that is in harmony with the space, but that, due to its large size, could be the basis for a project where the subtle predominates. This leads to the question: **How to create a lighting intervention in the ceiling that takes elements of nature that includes daylight and electric lighting?** For this, it must be started understanding that “daylight gives the occupants a sense of contact to the outdoors and provides color variations that can’t be match by artificial light and reduce eye fatigue as the human eyes adapt easily to daylight” [2]. Therefore, the aim of the project is to provide a connection with the exterior through the incorporation of daylight that comes from the façade and complement it with electric lighting.

Sustainability Statement.

As previously mentioned, there are many benefits of daylight. Especially in energy and health issues. For this first, the UN in its sustainability goals has many related elements, however, in the case of the library, it is aligned with the search to make cities and human settlements inclusive, safe, resilient and sustainable. One of the targets for 2030 is related to increased resource-use efficiency and greater adoption of clean and environmentally technologies [12]. For this improvement in efficiency, it is sought that the luminaire fixtures that are responsible for highlighting the ceiling can be turned off during the day. In the same way, this reduction in electrical energy and the increase in the use of daylight seeks to increase the benefits of daylight already mentioned, which promotes the well-being of users. The enhance of daylight in the space is also related to goal number 3 (Fig. 2) that pursue to ensure healthy lives and promote well-being for all at all ages. At the same time, by using electric light during the hours of darkness and small applications of color, the aim is to stimulate library users throughout the year.

Fig. 1. Ceiling of the main hall. Actual situation. Photo taken in February, 2023

Fig. 2. UN Sustainability goals related in the sustainability statement [11]
**METHODS**

**Procedure:**

The project was divided into 2 phases: analysis and proposal (Fig. 3). The first considered the value of the building both in history and its geographical location. Information was extracted from web pages, library documents, documents from the architecture firm in charge of the remodeling and from Akademiska Hus. The intention was to understand the changes that the building has undergone and how the main hall benefits from environmental factors.

The second was based on the concept and is given by testing. With the compiled information, shapes, colors and possible results were explored, through diagrams and simple models, which allowed to define a proposal in a short time. Revit, Autocad, Rhino, Climate studio and Dialux were used as part of the process.

At the same time the users were part of both phases since they were the ones who inspire the proposal. Users were defined for this project as those who sit to study in the library hall and whose perception was measured through a virtual survey, and the librarians, with whom a meeting was held and who provided a better overview of the limitations of the project. On the other hand, the survey was carried out digitally with more than 30 participants, who anonymously commented on their experience and the influence that daylight and the ceiling have on them.

**Fig. 3. Procedure diagram. Inner circle: General process. Middle circle: Elements of the process. External circle: UN goals**
**Limitations:**

This project had several limitations (Fig. 4). First, the main hall of the library has a large volume and is 14 meters high. Even though the area has implements to be able to work on the facades, it is required to be certified and have permission from Akademiska Hus to be able to do so. Therefore, an assembly on site is not part of this project. Instead, testing and behavior of the geometries were carried out. Additionally, since the project is not recent, the digital information is not complete, so the final level of detail depends on measurements taken on site and other information compiled. Finally, the project considered the results of the initial evaluation on the perception of space but did not measure the effect of the final design on the visual perception of users or other possible affectations. Qualitative measurements were limited to the initial survey, any digital analysis and the feedback received during the process.

**VALUE**

**Heritage:**

The building from 1917 was a laboratory for practical research and engineering, designed by Erik Lallerstedt. Between the angled longways was a triangular yard. In the 1950’s a hall building for water research, so the courtyard disappeared as well as its connection with the Borggården. Even though the building was considered heritage in 1935, it has suffered several modifications. However, the facades were preserved and most of the interiors were restored. At the end of the 1990s, it was defined that the building would be the library and the project began, which was later completed in 2002. [13]

The library, as an architectural project has been awarded several times, like in 2002, when the project was awarded the ROT prize by Sweden’s Byggmästareförening.

In 2014, Ahrborn & Partner was commissioned to design a new interior for the library. The main hall was transformed into a more socially oriented meeting place [15]. The space is much more flexible now thanks to the new furniture and layout and it holds different kind of activities than just studying.
Location and weather conditions:

Stockholm is a predominantly cloudy city (Fig. 7), which means that the proposal through daylight is also an invitation to get in touch with nature.

On the other hand, in terms of daylight and during the summer it can be 18 hours of daylight (Fig. 8), exceeding the library’s operating hours. Even between the equinoxes, it represents an opportunity to take advantage of natural light. However, in winter there are days with 6 hours of daylight, so complementing with electric lighting is necessary.

Finally, it is possible to observe that the building has a privileged orientation, since daylight enters up to 3 of the 4 facades during the year (Fig. 9).

Fig. 7. Cloud cover categories in Stockholm [16]

Fig. 8. Hours of Daylight and Twilight in Stockholm [16]

Fig. 9. KTH Library site plan and daylight sun chart. The sun is positioned at midday on the summer solstice.
Fig. 10. Actual lighting situation. On the left, lighting fixtures. On the right, some of the daylight reflections. Sometimes, daylight also generates patterns on the short facades.

“I can't define a space really as a space, unless I have natural light”
Louis Kahn [5]
Actual lighting situation:

The space is illuminated mostly by spots, in terms of electric lighting (Fig. 10). These stay ON, even the ones that are meant to light up the sky.

Through the south-western façade, a large amount of light usually enters, which can even generate patterns on the north-eastern façade. As can be seen in Fig. 10, daylight is also reflected on the sloping part of the roof, which also serves as a reflective element.

Regarding daylight lighting control, the librarians indicate that there is a blind system that is activated manually. And it is frequently used because the large amount of light that enters through the south-western façade produces glare.

Regarding the materiality of the space, it is possible to observe that the ceiling is white and the floor has a glossy finish; while the walls show the brick. And in terms of illuminance, under the direct rays of daylight that enter through the window, more than 1000 lux were measured (Fig. 11).

Fig. 11 Illuminance measurement in the library main hall

USERS

In a meeting with the librarians, they indicate that the university seeks to encourage students to use this area to carry out their projects or installations and that this is due to the great flexibility provided by the space. Subsequently, a virtual survey was carried out through Google forms, where those who sit to study in the main hall of the library provide their perspective and even made a brief proposal for the space. 42 people were surveyed anonymously in total (See Appendix). The survey consisted of 11 questions on their own perception of the main hall and its ceiling. The aim was to measure the number of times people go to the place per week, how often they look at the roof and how often they notice the sunlight and its movement. These questions were mostly measured through scales. Additionally, people could include comments and simple proposals to the space, as well as opinions about the use of color, which could be answered with the use of short sentences or response selection. Also, two demographic information questions about age and gender. The approach was made in person, to a total of 50 people, with a similar number between men and women and it was sought that they were in different locations within the space. It was carried out around 4:00 p.m., at which time light entered through the south-western façade. The form specified that the information collected would be used for this document and that submission implied its acceptance.

From the results it was found that the general elements that the respondents highlighted were the great height, the windows and the calm atmosphere that is offered in the space. However, when analyzing the opinions of the ceiling, those were mixed. While some classified it as flat, heavy and even boring, others indicated that they felt like a yard, although they would like it to be more transparent.

However, a large portion of the respondents showed that it is rare to observe the ceiling of the main hall. At the same time, although most claim to have noticed the movement of the sun, the perception of the passage of time is not recurring.

When asked what they would like to do on the ceiling, many indicated that they would like to add color and moving elements such as projections or reflections. However, many said that they would prefer to seek to delete the ceiling or connect with the feeling of having the sky. While a few said that making a small intervention that did not generate distractions because this was a space where they required focusing on a task.
Based on the analysis and the research question, a proposal was generated that had components of local nature (Fig. 12). The proposal was based mainly on the use of daylight, with a complementary component of electric light. The idea was to celebrate when the sun is out, but also turn the ceiling into an element that inspires, since that is up where we usually look when we need inspiration or even a break. Also the addition of colors try to remember, especially in winters, that the same system will work when the sun rises again the next day.

Reference images were defined for decision-making, as well as emotions that it seeks to evoke. It was sought to define the elements to be taken to highlight as light, reflections, organic shapes and the colors of the city sky at the end of the afternoon (Fig. 13). In the same way, the project seeks to connect the user with the ceiling, under a dynamic but balanced proposal (Fig. 14)

![Fig. 12. (Left) Initial concept diagram](image)

![Fig. 13. (Below) Image board. Both the daylight and the electric light that enters through the window are highlighted. Likewise, the textures and shapes that light can acquire when reflected. Finally, the colors of the city sky during sunsets. Some images were taken from the web, these are CC0 [17] [18].](image)

![Fig. 14. Mood board. For this project, the aim is to direct the user’s attention to the ceiling, where there is a balance between the existing and a proposal that seeks to implement elements of nature in an abstract way. The images were taken from the web, these are CC0 [19] [20] [21].](image)
DESIGN PROCESS

The design process was carried out in 4 stages. Each was complementing the proposal as it was developed (Fig. 15). Programs such as Revit and Dialux are used to make quick calculations.

**Step 1:**

After building a REVIT model, the shadows inside the building are analyzed (Fig. 16) and the model is exported to be inserted in climate studio. In the results (see appendix) it can be seen that the daylight factor is high and that in terms of glare, 3% is intolerable, while 95% is imperceptible.

**Step 2:**

Reflections:

The presence of walls illuminated by solar reflections are recurrent in Sweden, so much so that are called “Solkatt” [22]. And the KTH library is also part of this phenomenon. Currently, the main hall has reflections that are usually captured on walls and that at certain angles generate glare. The project proposes to send these reflections to the ceiling, thus reducing unwanted reflections and taking advantage of the ceiling as the place to capture the atmospheric condition of the exterior (Fig. 17). For this, an analysis of the different elements that could be used and their angles of incidence was required.

Using reflectors is a tool to bring light to the ceiling. And in everyday life it can be seen elements that reflect light in various ways (see appendix).

To determine the position and shape of the reflectors, the angles of incidence on the façade that is most exposed during the year were first analyzed. It was observed that during the winter, the sunlight would not enter directly, and that there are other angles of incidence that could be taken into account.
Three analysis scenarios are initially proposed: some reflectors located on the exterior of the south-western façade, a curved reflector on the interior that was inspired by the Church of Beatified Restituta by Atelier Stepan in the Czech Republic. And finally, a series of reflectors on the roof of the north gallery were proposed. (Fig. 18, Fig. 19)

For the first proposal, various inclinations were tested, with the best result being 22° from the horizontal. Seeing how limited the result was, the same system was tested inside the building. With 20° it was possible for the projected rays to reach further. In order to reduce the length of the elements, it was proposed in a parallel way and its quantity was determined by the number of mullions in the current windows. One of the problems to face with external reflectors, was their true reflectance percentage: “As external reflectors are not protected from weathering, their reflectance usually does not exceed 60% [...] and their reflection is partially diffuse” [6] As the result was not as expected and after finding that the reflectance percentage would be affected by environmental conditions, the same series of analyzes were carried out with indoor reflectors. For aesthetic reasons, it was tested with a width that does not exceed the inclined edge of the roof. However, although the result is improved, more reflected light stays closer to the window.
Due to the above, the Church of Beatified Restituta became a project to be analyzed [23] and it is decided to generate a convex surface that starts from the wall and gradually extends towards the interior. This type of solution does not give the desired result, since it generates diffused light in the space, but does not project reflections on the ceiling. However, it opens the possibility for curved and inclined surfaces to be mixed to have smaller reflectors with better range.

This analysis of the Church of Beatified Restituta case, together with the first case of flat reflectors, led to a series of analyzes with concave and convex surfaces. In the end, a better result is obtained by mixing surfaces of 2 different radii in opposite directions as shown in the Fig. 20.

As for locating reflectors on the roof of the north gallery, it can be seen that the building itself generates shadows on the roof, so this only can be a support solution. In other words, the light projected from this roof can improve the lighting on the north side of the ceiling, which is where intensity has been lost in some cases, since it is the most difficult area to reach.

Shapes:

An interesting aspect that was observed in the current situation of the main hall is that the light that enters through the window generates irregular patterns on the wall. Such patterns are often generated by distortions in the glass [24]. These reflections move during the day on the surfaces, according to the position of the sun. However, with the use of reflectors, these patterns will break up and become diffuse.

For its part, deforming the reflectors is another way of generating shapes on the ceiling. After analyzing the behavior of the rays with the different shapes, an exercise in textures was proposed using mirrors and aluminum foil. For this, a laser pointer and a 230 lumen downlight with 45° beam were used. With the laser pointer, more complex shapes were obtained as the surface was rougher, while with the luminaire, better projections were obtained with simple roughness. This last exercise opened up 2 possibilities: having large reflectors with a limited amount of texture along the façade or, small interventions made up of rough reflectors and the incorporation of Fresnel lenses in the windows to convert daylight into small rays (Fig. 21).

Step 3:

As mentioned above, Sweden has months with few daylight hours per day. As a support within the project, a series of exterior luminaires located outside the south-west façade point towards the rows of reflectors were proposed. The test was carried out in Dialux with RGBW luminaires with different optics, WideFlood, Flood and Narrow spot, first separately and then a mixture of these, several fluxes, distances, angles and combinations were tested. The attempts were made to locate the luminaires with angles similar to those studied in the daylight diagrams so that the reflectors would work correctly.
The luminaires that are currently installed within the space were included in the study, the information about it was provided by Akademiska Hus. A numerical value was not sought, but rather that the light projected was visible despite having all the lights in the place turned on. Even though Dialux has limitations in the construction of geometric shapes, it was possible to get an idea of the scope that can be achieved with optics and reflectors. Due to the curvature of the surface, Dialux tends to separate it into segments, which prevents the resulting angles from being accurate and the projection from looking segmented.

The study only defined the minimum flux required by the luminaire, the best type of optics and a recommended distance. A more detailed study would be needed to execute the project. Therefore, it was defined that projectors with narrow spot optics would be required, with a flux greater than 6000 lumens and that they should be installed at least 2 meters away from the window (Fig. 22, Fig. 23). This is because the open beams and the mixture of the different types of optics, gave less visible results and it is less feasible to control the result.

**Step 4:**

![Fig. 22 Result with narrow spot beams only. The luminaires have different inclinations and colors to see if they are visible.](image)

![Fig. 23 Section with the location of the luminaire’s fixtures.](image)

![Fig. 24 Colors of the sky and water reflections in Stockholm](image)
The presence of daylight inside the library makes the experience pleasant for many. However, since the ceiling is white, and the reflections that are observed only generate contrast due to the level of illuminance, the question of the use of color was present in the process. According to N. Baker and K. Steemers, it is unusual to use saturated colors in large surfaces, mainly because it demands too much attention [6]. But, if the inspiration comes from nature, it is observed that Stockholm has sunsets in saturated warm tones and the water continuously reflects the white color of sunlight. Under this premise, the incorporation of different tones to the proposal was sought and the importance of reflections was reinforced (Fig. 24).

As mentioned above, involving color within the project has been part of the design intentions. Two alternatives were proposed: The first was to incorporate pieces of color in the façade, inspired by the Façade for Harpa Reykjavik Concert Hall and Conference Center designed by Olafur Eliasson [25]. The second was to let the game of color only take place at night with RGB lights that point to the reflectors.

The Harpa project has a façade inspired by the Quasi brick, an element originally developed by Einar Thorstein [25]. This polyhedron generates regularity and irregularity in space at the same time because its modules are chaotic. For this façade, panes of color-effect filter glass were incorporated (Fig. 25). Its distribution was made taking into account environmental factors such as the sun, but in turn, other factors such as the movement of users. For example, the three-dimensional façade is located on the south façade, while the other façades are two-dimensional. As it is a dodecahedron, the possibilities of incorporating color are varied and this makes it an element that adjusts to practically any latitude. Within the project it is possible to observe colored reflections on the floor as well as in some points, passers-by can observe themselves due to high reflectance panels. In terms of color, yellows, greens and blues predominate. This type of element has also been used on another scale and with variations.
RESULTS:

The aim of the project was to create an intervention in the ceiling that took elements of nature and included daylight and electric lighting. After the analysis and exploration of alternatives in each of the phases of the process, the following decisions were made that lead to the final result.

Reflections:
After exploring diverse forms and locations of reflectors within the project, compound curved reflectors were chosen to allow the rays of light to spread across the ceiling of the main hall. As an architectural decision, the width intended for the sloping roof was respected, and each of the reflectors were projected under that area. Besides, the number of reflectors was determined by the existing amount of mullions within the window design.

Colored glass facades are not a recent invention. Large cathedrals with stained glass windows, the Orosi windows from Iran [27], and modernist architects like Le Corbusier have also proposed them.

Although having fixed color elements on the façade can generate patterns that move with the position of the sun (Fig. 26), there is a component of flexibility that may not be exploited. During electric lighting tests at Dialux, RGBW luminaires were tested. The result allows the colors to vary according to the needs of the space. Although having a large range of colors can be considered problematic, a small sample with a reflective surface and two Philips GU10 color changing bulbs was proposed (Fig. 27). During the test it was observed that having similar colors and opposite colors can be a strategy for the continuity of harmony within the main hall. For instance, through the use of colored lights, the colors that recall the sunsets can be prolonged and gradually transformed into more saturated tones.

Fig. 27 Exploration about the interaction of 2 different colors. Left: pink and orange. Middle: Blue and purple. Right: Red and blue

Fig. 28 Final result at day
For better control of the reflectance, it was determined that only the upper face must be free of color and should have a glossy but non-smooth surface quality; it was important that this face had a slight percentage of noise or texture, but that the shapes were clear so that the reflections were accurate. The lower face had to be matte so that the rays that reach said surface do not bounce and generate glare that can reach the eyes of the users.

Electric lighting:

Since electric lighting is complementary, it was thought to be able to continue replicating the results that have been obtained with daylight. However, it would require fixtures with too much consumption to make a replica. This project is committed to the proper use of resources, which is why luminaires with a narrow spot optic were proposed. With closed optics, it was possible to generate intersecting-colored lines that intensify the sensation of irregular patterns. These luminaires are located outside and inclined with angles between 40 and 56°, similar to those found in daylight during the analysis.

Color:

After the analysis it is considered that to give a character of day and night scenarios, the windows were left without materiality modifications. Therefore, the patterns generated by daylight were in their current color temperature (Fig. 28). However, when the nights are long and connected with the idea of extending the sunset, the use of electric light with color was proposed. It was sought then to saturate the space a little more with color at night, and at the same time, it was proposed that the system was interconnected to sensors that allow both the colors and the light intensity to vary as daylight runs out. Artificial light in RGBW also allowed the library to modify the color patterns according to its activities. This change in artificial light sought to continue with the concept of flexibility that the space has and allow the ceiling to also transform according to the occasion.

“On studying the causes and motives of nature, the observer is fascinated, above all, by light”
Da Vinci [8]
DISCUSSION

Mariana G. Figueiro mentioned in 2019 for Building and Environment magazine that the ceiling is not the limit and for this project [28], this statement is true. The ceiling is not always the protagonist of a space, but in the case of the main hall of the library, it was proposed as an element integrated into the architecture of the place and the activities of the users, as well as the environmental factors that surround it.

One of the most worked topics in this project, leads to the conclusion that using reflectors is a nice way to bring daylight to the ceiling with a low energy consumption. According to B. Matusiak and O. Aschehoug, in high latitudes the use of reflectors has shown that it is possible to increase the total light flux falling into a space without changing its proportions [27]. However, its location within the project may mean that the result is not as efficient as expected [6]. Maintenance recommendations for these should then be taken into account, to prevent loss of efficiency.

There are several benefits to implementing daylight within a space, but electric light can be a support element for dark nights. If the right balance is created, great levels of energy savings can be achieved. This also highlights the importance of lighting controls within the projects, since the good interaction between the two systems can lead to the satisfaction of its occupants. [28] As Gentile et all mentioned “With careful design of windows, shading, and lighting systems and controls, [...] both integrated performance goals for energy efficiency and comfort and integrative non-visual objectives could be satisfied.”

Conclusion

After a process of exploration and tests on several topics, it is possible to conclude that the spaces continue their processes of constant transformation and this is demonstrated from the willingness of the university to make them flexible. The main hall is an area of opportunities and the large surface of the ceiling is an ideal space to apply the proposal.

This project requires a more detailed development, but it leaves open the possibility of continuing with its design, improving it and even implementing it. A step to follow would be to look for the opportunity to do some test on site that allows us to see its true incidence in space. Additionally, the use of color can align not only with the notion of flexibility, but also with circadian rhythms. Finally, a more subtle solution can be sought regarding the location of the luminaires.

At last but not at least, the ceiling represents for many that inspirational space that today could be being wasted. And the large windows that evoke what was once a large patio, are that connection between the interior and the exterior that can be potentiated.
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Fig. 35 Reflectance of the materials. The glossy finish of the horizontal surfaces is observed.
Fig. 36. Illuminance measurements related with the amount of daylight that is entering to the main hall.
Fig. 37 Survey answer to How often do you use this space?
Fig. 38 Survey answer to write what most attracts your attention in this space.
Fig. 39 Survey answer to give a short description/opinion about the ceiling of the main hall of the library.
Fig. 40 Survey answer to How ofter do you look at the ceiling of the library?
Fig. 41. Survey answer to When you work in this space in the library, How often do you notice the passage of time?
Fig. 42 Survey answer to Do you notice the movement of sunlight in this space?
Fig. 43 Survey answers to Suppose the ceiling is a blank canvas and you can intervene on it however you like, what would you like to do on it?
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Fig. 73 Incidence of daylight on the façade. Sixth attempt with indoor compound convex and concave reflectors.
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Fig. 75 Incidence of daylight on the façade. Eight attempt with indoor compound convex and concave reflectors.
Fig. 76 Incidence of daylight using reflectors over the roof of the northern gallery.
Fig. 77 Actual reflections on the ceiling of the main hall.
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Fig. 79 Daylight reflections given by a car. It has the shadows from the trees.
Fig. 80  Daylight refractions given by glasses filled with water.
Fig. 81  Incidence of light over different types of textures. Light fixture used: Hidealight, optic deep XS, 4W, 230 Lumens, 2700K, 45°. Top left: mirror. Top right: crumpled aluminum foil. Bottom left: convex surface in aluminum foil. Bottom right: concave surface made of aluminum foil.
Fig. 82  Incidence of light over different types of textures. Light used: laser pointer. Top left: mirror. Middle Top: flat aluminum foil with horizontal wrinkles. Top right: flat aluminum foil with vertical wrinkles. Bottom left: crumpled aluminum foil. Middle Bottom: convex surface in aluminum foil. Bottom right: concave surface made of aluminum foil.
Fig. 83  Specification sheet of the Narrow spot luminaire.
Fig. 84  Specification sheet of the Flood luminaire.
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Fig. 86  Dialux result with flood fixtures
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Fig. 95  Reflection of color light on a flat surface with slight roughness. Left: light blue, simulating cold tones. Right: orange light, simulating warm tones.
Fig. 96  Exploration about the interaction of red and blue. Left: side by side, the light is pointing down. Middle: Each light in one corner. Right: light with a low angle and blue with a high angle.

APPENDIX

METHODS

APPENDIX

VALUE

Location and weather conditions:

![Graph showing daily chance of precipitation in Stockholm](image1)

![Graph showing sunrise & sunset with twilight and daylight saving time in Stockholm](image2)
Fig. 32 Incidence of daylight on the building at the solstices and the spring equinox. The yellow lines show the direction of light rays at noon. Taken with sunseeker.
Actual lighting situation:

Fig. 33 Façade detail. Reduction of the unidirectional transmission of the daylight [6].

Fig. 34 Luminance levels using Fusion Optix

Fig. 35 Reflectance of the materials. The glossy finish of the horizontal surfaces is observed.

Fig. 36 Illuminance measurements related with the amount of daylight that is entering to the main hall.
Fig. 37 Survey answer to How often do you use this space?

Please write what most attracts your attention in this space:

- The individual seats to study
- I like that it is very open, like a lot of ideas flowing
- The enormous height, volume and space contradicting the usual standards for studying places.
- Windows and light coming from the sides
- The Ambiance
- The feeling of space offered by the height of the ceiling
- The central atrium
- The combination of historical and contemporary architecture
- The natural light and the spaciousness. Also I like to see other people around studying.
- Furniture
- The skylight
- The high ceilings that makes it feel spacious
- The open windows in the roof
- I love how the turned something that was probably an open space into a closed space but keeping all the sensation of big space.
- Huge space / good illumination
- Height and scale
- Spaciousness
- High ceilings
- Skylight
- Easy access and good place to meet
- Open and spacious
- The space
- Big, open space, Decent amount of seats
- The merging of indoors and outdoors, old and new.
- High ceiling open space (missing study spaces however)
- The light
- Tables
- The natural light
- Books
- Atmosphere
- The sky from the skylight which invites light into the library unlike most libraries
- The light
- Calm and serious feeling
- Nice atmosphere, and quiet
- Good lighting, big windows, quiet and ergonomic seats
- Friendly atmosphere
- Positive vibes, see international students
- The sitting areas and the light that enters in the spaces
- The openness of the library. It’s very airy and it’s the only place with this amount of natural light I can find.
- The glass facade
- The illumination
- Indoor “outdoor”, spacious with lots of daylight, calm and quiet space

Fig. 38 Survey answer to write what most attracts your attention in this space.

Please give a short description/opinion about the ceiling of the main hall of the library:

- Too simple, I would like to have more sunlight from the roof
- Too plain
- The ceiling is very high. Now that you mention it though I rarely look at it. I mostly look at the side window openings.
- I like how subtle it is, and that is has no major intervention
- When I think about it, I find it a bit too bland. The glass which brings in natural light, the roofs on the outside and the walls are more contrasting to the roof.
- The combination with the windows and the white ceiling, offers a feeling of space and openness to light
- It feels like an open square
- It is plain and seems heavy
- I really like it, love the big windows
- Does not interrupt the narrative of the historical architecture, allows the passage of daylight and the transparencies are amazing
- Simple, not fully connected with the aesthetic of the space
- I think it’s very nice because it makes the library feel less cluttered. I like the windows because it allows for more natural light inside the main hall
- I love it
- The windows look really nice, but with this picture I just notices that the ceiling is just white.
- No comments
- Off white
- Clear, less happening
- Plain
- Smooth, white, not too memorable
- Haven’t really thought about it
- Nice
- It’s a bit boring
- It’s large and open, feels nice
- It is boring
- I like big windows, would like roofs
- Empty
- White
- Almost perfect, although I’d like if even more of it was clear glass
- I like the windows that let the natural light in
- Cream white and monochrome
- I love the natural light
- Too, don’t have any opinion about it
- Never thought about it so I think I like it
- The ceiling looks quite bland and not enough natural lighting
- Light ceiling that gives you a bigger and brighter feeling that helps me feel less bland
- About the ceiling, I like its height and its white color
- Because it made of glass, the space is so light and make the environment like a jungle. It is very useful and interesting
- I think is good that is plain so you don’t get distracted by it!
- Plain but nicely scatters the light
- It feels like the ceiling is floating
- Needs some lights
- Looks to plain, matt, flat, too solid and heavy

Fig. 39 Survey answer to give a short description/opinion about the ceiling of the main hall of the library
Fig. 40 Survey answer to How often do you look at the ceiling of the library?

Fig. 41 Survey answer to When you work in this space in the library, how often do you notice the passage of time?

Fig. 42 Survey answer to Do you notice the movement of sunlight in this space?

Fig. 43 Survey answers to Suppose the ceiling is a blank canvas and you can intervene on it however you like, what would you like to do on it?

Suppose the ceiling is a blank canvas and you can intervene on it however you like, what would you like to do on it?

- I would like to have more natural light. I prefer a whole roof made of glass
- Add a lot of color and Swedish like ideas, inventions to the world
- I would use special light reflections, or some other lighting methods to elegantly intervene without filling it with too much information.
- Flows, waves, some kind of movement
- Some texture or colour would be nice. Maybe with light to mimic daylight.
- Leave it blank, otherwise it would have to much focus on what is put on it... and what is great of it is the overall combination with windows and the feeling of space

An artistic intervention

- Projections
- I like it as it is, I think otherwise I would be too distracting, if I have to add anything I think it would be more windows
- Something to break the height of the building, a huge luminaire to create an exciting impact when you enter the space
- Illuminated it better with artificial or natural light
- I would support any artistic intervention that maintains the light colors
- Leave it without roof like only glass
- Maybe paint it sky blue to remember the color during winter, and also add more glass

Paintings

- Not sure
- Colours maybe, to balance out what is going on the floor
- Add some color
- Let in more sunlight through windows or coloring it to make it more calming

Mirror

- I like it the way it is
- Mirror or a mosaic of the university's history
- Add windows
- Nothing
- Nothing
- Make it clear, although with some protection for peak sunlight if it becomes inconvenient due to e.g. heat or brightness that overpowers laptop screens
- Add skylights
- Nothing, if it aint broke don't fix it
- Have a mural on it
- Not sure if I understand, how would I intervene with a ceiling?

Like the sky

- Would love more natural lighting like sun roofs
- Nothing, I like to see/feel how the sunlight move in the room. Natural lights are better than lamps, you dont get tired as easy
- I would keep the ceiling white and maybe put glass in some parts of the ceiling so that the sky can be seen above
- I make a semi-circle glass ceiling to see the sky and beautiful clouds
- I think is better to leave it as is or maybe a warmer color, to give a more inviting feeling

Some green plants, vines hanging from it.
- More skylights maybe. Or a central one
- Some interesting lights

- Skylights, a light well or a part of the ceiling in glass, the rest with some more reflective (shiny) material
Although the 3 values are similar, the 2 that include color prevail.

Fig. 44: Survey answers to Do you think it would be interesting to add color to the ceiling? Each number represents the number of respondents.

Fig. 45: Survey answers to Do you think it would be interesting to highlight the changes in daylight? Each number represents the number of respondents.

Fig. 46: Survey answers to Any additional comments/ideas?

Any additional comments/ideas?
I think the ceiling should stay white, but when night arrives artificial light of different distributions/patterns should hit the white canvas.

Brilliant idea to provide texture to the roof and to show the time changes of the day.
Mirrors
Design skylights
In winter will be nice to have lights that remembers the sun
It would be really nice to see something interesting when looking up
The application during winter can be very interesting
Church sealing?
I feel like the space could benefit greatly from plants, even artificial ones. The tree that used to be there is what I miss the most.
When the intensity of the sun is high, we can reduce it by changing the color of the glasses (automatic replacement of the glasses same as the airplane windows).
I was thinking that maybe if the columns that hold the ceiling were in a light bright colour, maybe the feeling of the floating ceiling can increase.
Maybe some elements could be hanging from the ceiling, to add play of brilliants when sunlight hits them.

Fig. 47: Survey answers to Age

Fig. 48: Survey answers to Gender
DESIGN PROCESS

Step 1

Fig. 49 Daylight factor results using Climate Studio.

Fig. 50 Daylight factor results using Climate Studio. Top View.

Fig. 51 Daylight factor results using Climate Studio. Perspective View.

Fig. 52 Annual glare results using Climate Studio.

Fig. 53 Annual glare results using Climate Studio. Top View.
Step 2

Calculating the angles of incidence allowed me to explore several shapes.

Fig. 54 Annual glare results using Climate Studio. Perspective View.

Fig. 55 Incidence of daylight at its maximum height in summer (54°) and in winter (7°).

Fig. 56 Incidence of daylight on the upper window (54° and 25°).

Fig. 57 Incidence of daylight on the middle window (54° and 41°).

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Fig. 59 Incidence of daylight on the façade. First attempt with outdoor horizontal reflectors.
Fig. 60 Incidence of daylight on the façade. Second attempt with outdoor horizontal reflectors. Inclination 10°.

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Fig. 62 Incidence of daylight on the façade. First attempt with indoor horizontal reflectors.

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Fig. 64 Incidence of daylight on the façade. Third attempt with indoor horizontal reflectors. Inclination 20°.

Fig. 65 Incidence of daylight on the façade. Attempt with indoor convex reflectors. Based on the Church of Beatified Restituta.
Fig. 66 Incidence of light on a convex surface, with two different radii.

Fig. 67 Incidence of daylight on the façade. First attempt with indoor convex reflectors of 10cm height, aligned horizontally.

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Fig. 70 Interpolation of the 2 convex figures for the design of the new reflector.
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Fig. 73 Incidence of daylight on the façade. Sixth attempt with indoor compound convex and concave reflectors.

Fig. 74 Incidence of daylight on the façade. Seventh attempt with indoor compound convex and concave reflectors.

Fig. 75 Incidence of daylight on the façade. Eight attempt with indoor compound convex and concave reflectors.

Fig. 76 Incidence of daylight using reflectors over the roof of the northern gallery.
Different elements can produce different types of reflections. Each one with its angle of projection, texture and definition. For a more defined reflection, direct sunlight is required.
Fig. 82 Incidence of light over different types of textures. Light used: laser pointer. Top left: mirror. Middle Top: flat aluminum foil with horizontal wrinkles. Top right: flat aluminum foil with vertical wrinkles. Bottom left: crumpled aluminum foil. Middle Bottom: convex surface in aluminum foil. Bottom right: concave surface made of aluminum foil.

Step 3
In this part of the process, several luminaires were analyzed with the use of Dialux. Three different optics were used. The tests began with 5,000 lumen luminaires and the flux was increased until the desired result was obtained. The following files correspond to the luminaires that gave the best result according to their optics.

<table>
<thead>
<tr>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of fixture</strong></td>
</tr>
<tr>
<td>LED Outdoor spotlight</td>
</tr>
<tr>
<td><strong>Flux (lm)</strong></td>
</tr>
<tr>
<td>6096</td>
</tr>
<tr>
<td><strong>Wattage (W)</strong></td>
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<tr>
<td>94.4</td>
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<tr>
<td><strong>Luminous efficiency (lm/W, real value)</strong></td>
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<td>64.6</td>
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<tr>
<td><strong>CCT</strong></td>
</tr>
<tr>
<td>RGBW - 3000K</td>
</tr>
<tr>
<td><strong>Optic</strong></td>
</tr>
<tr>
<td>Narrow spot</td>
</tr>
<tr>
<td><strong>Beam angle</strong></td>
</tr>
<tr>
<td>8°</td>
</tr>
<tr>
<td><strong>CRI</strong></td>
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<tr>
<td>82</td>
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<tr>
<td><strong>Control</strong></td>
</tr>
<tr>
<td>DMX</td>
</tr>
<tr>
<td><strong>Current</strong></td>
</tr>
<tr>
<td>230V</td>
</tr>
<tr>
<td><strong>Life time</strong></td>
</tr>
<tr>
<td>100,000h - L80 - B10 (Ta 25°C)</td>
</tr>
</tbody>
</table>

**Physical properties**
- **Body**: Die-cast aluminium optical assembly, bracket and box for the power supply with a clear tempered sodium-calcium safety glass cover
- **Rotation**: Can be adjusted on a horizontal plane at an angle between -50° / +90°
- **Accessories**: Diffuser glass covers, lamellar louvers, refractors for ellipsoidal light, cylindrical screens, visors and protective grilles
- **Installation**: Floor, ceiling or wall-mounted installation
- **Colour**: White (01) | Black (04) | Grey (15) | Rust Brown (F5)
- **IP**: 66
- **IK**: 8

Fig. 83 Specification sheet of the Narrow spot luminaire.
### Technical data

<table>
<thead>
<tr>
<th>Type of fixture</th>
<th>LED Outdoor spotlight</th>
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<tbody>
<tr>
<td>Flux (lm)</td>
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<td>Wattage (W)</td>
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<td>Luminous efficiency (lm/W, real value)</td>
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<td>CCT</td>
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<tr>
<td>Optic</td>
<td>Flood</td>
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<td>Beam angle</td>
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<td>CRI</td>
<td>82</td>
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<tr>
<td>Control</td>
<td>DMX</td>
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<tr>
<td>Current</td>
<td>230V</td>
</tr>
<tr>
<td>Life time</td>
<td>100,000h - L80 - B10 (Ta 25°C)</td>
</tr>
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</table>

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<th>Body</th>
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<tbody>
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<tr>
<td>Accessories</td>
<td>Diffuser glass covers, lamellar louvers, refractors forelliptical light, cylindrical screens, visors and protective grilles</td>
</tr>
<tr>
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<td>Floor, ceiling or wall-mounted installation</td>
</tr>
<tr>
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<td>White (01)</td>
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<td>IP</td>
<td>66</td>
</tr>
<tr>
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<tr>
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<tr>
<td>CCT</td>
<td>RGBW - 3000K</td>
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<td>Optic</td>
<td>Wideflood</td>
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<tr>
<td>Beam angle</td>
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<tr>
<td>Control</td>
<td>DMX</td>
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<td>Current</td>
<td>230V</td>
</tr>
<tr>
<td>Life time</td>
<td>95,000h - L80 - B10 (Ta 25°C)</td>
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Fig. 86. Dialux result with flood fixtures

Fig. 87. Dialux result with wideflood fixtures

Fig. 88. Dialux result with narrow spot and flood fixtures

Fig. 89. Dialux result with narrow spot and wideflood fixtures
The tests showed that wide optics fade the pattern produced.
Fig. 96. Exploration about the interaction of red and blue. Left: side by side, the light is pointing down. Middle: Each light in one corner. Right: light with a low angle and blue with a high angle.