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STUDENT STATEMENT

I hereby declare that the present final thesis paper is solely my own work and that the references (written and electronic literature and tools used during the process) have been acknowledged and fully cited. I hereby grant the university and the task assigning institution permission to use free of charge the final results of this paper for their own purposes, abiding by the pertaining rules of encryption.

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ABSTRACT

The aim of this paper is to analyse how emergency lighting systems are implemented, focusing on the application of the European standard for emergency lighting systems, EN1838.

A case study was carried out at the Kandó Kálmán Faculty of the University of Óbuda to demonstrate the application.

The EN 1838 standard provides guidance on minimum light requirements, the use of reflections, calculation levels and system autonomy for different environments, as well as the correct positioning of signal lamps, which is crucial for improving occupant safety and evacuation efficiency.

Industry-standard software tools such as DIALux EVO and AutoCAD were used for design and simulation. The study examines the design of the emergency lighting system, including the selection of the correct devices and the dimensioning of the central battery.

The project implementation is based on actual observations, analysis and industry standard software. This case study provides valuable insight into the benefits of adhering to established standards for emergency lighting systems.

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INTRODUCTION

The concept of emergency lighting is central to ensuring the safety of occupants in the case of unforeseen failure of the normal lighting supply.

In this context, EN 1838, drafted and approved by the European Committee for Standardization (CEN), specifies the luminous requirements for emergency lighting systems, as well as requirements for the placement of signaling lamps.

It defines essential terms such as emergency lighting, escape route, emergency escape lighting, escape route lighting, open area lighting (also known as anti-panic lighting), high-risk task area lighting, standby lighting, emergency exit, safety sign, externally illuminated safety sign, and internally illuminated safety sign. These definitions are the basis for the requirements set out in this standard to ensure the effectiveness and safety of emergency lighting systems in different environments.

To illustrate the practical application of these standards, this study focuses on the implementation of EN1838 in Building B of the Kandó Kálmán Faculty, at Tavaszmező utca. It represents a valuable opportunity to evaluate the practical implementation of the guidelines established by the standard and to identify specific challenges and solutions that arise in a real context.

To carry out a comprehensive analysis of the emergency lighting system, the detailed floor plans of Building B were used. These plans were exported to DIALux EVO, widely recognized for its advanced lighting simulation capabilities.

In DIALux EVO, lighting calculations were made for each floor of the building. The results of these calculations were compiled into a document that included all relevant performance data.

The information generated by DIALux EVO was then exported to AutoCAD. In AutoCAD, the emergency and signaling luminaires were positioned and a count of the lighting and signaling equipment throughout the building was made.

This count was used to determine the battery capacity required to maintain the emergency lighting system in the event of a power failure. This critical step in the design process ensures that the building is adequately prepared for emergencies and the safety of its occupants.

Upon completion of the study, a thorough comparison was made between the actual state of the building's emergency lighting system and the proposed system. This comparison serves to highlight any disparities, successes, or areas for improvement, providing a comprehensive evaluation of the practical implications of adhering to EN1838 standards.

The following study details the entire analysis process, the results obtained, and the conclusions drawn from this meticulous approach to emergency lighting in Building B of Kandó Kálmán Faculty.

1. THE EN 1838 STANDARD

The EN 1838 standard, drafted and approved by the European Committee for Standardisation (CEN) in 1999, has been a pillar in the regulation and standardisation of emergency lighting in the European Union. In 2013, an update of this standard brought innovations and necessary adjustments to keep in line with technological advances and growing safety demands. The latest version of the standard, launched in 2022, brings with it a series of enhancements and improvements that are awaiting approval. This ongoing development reflects the constant adaptation of safety standards to address the complexities of modern buildings and growing concerns about protecting occupants in emergency situations.

1.1. Concepts

Before exploring the specific areas within the safety lighting concept, it's crucial to grasp the fundamental units used in lighting measurement. The quantities and concepts listed below are fundamental to understanding the elements of lighting technology.

- **Luminous flux (lm):** is the unit of measurement for the total amount of visible light emitted by a source. It quantifies the brightness of light, irrespective of the direction in which it is emitted. In essence, lumen represents the overall luminous flux.

- **Illuminance (lx):** takes into account the area over which the luminous flux is distributed. It is the unit of measurement for illuminance and represents the amount of light that falls on a surface. Specifically, one lux is equal to one lumen per square meter. Lux is a crucial metric in lighting design as it helps determine the intensity of illumination at a given point. The lux level at a point can be calculated using the formula:

$$\text{Lux} = \text{Luminous Flux (lm)}/\text{Area (m}^2\text{)} \quad (1)$$

- **Luminance (cd/m²):** The sensation of clarity produced in the eye by a light source or surface illuminated in a particular direction; the luminous intensity of the surface divided by its apparent area, given the position of the observer.

- **Luminous intensity (cd):** is the intensity of light (visible radiation) measured in a given direction. It is the luminous flux per unit solid angle around a given direction.

- **Luminous efficiency (lm/W):** is the ratio between the total amount of light emitted by a light source and the power consumed. It is also fundamental to choosing the best option that uses the least amount of electricity in relation to the amount of light in each room.

- **Photometric curve:** refers to the light intensity distribution curve that shows how the light from a light source is distributed in different directions in space.

  Every luminaire has a particular light distribution curve and the way in which the light source that the luminaire projects is represented is expressed by these curves or photometric diagrams. Understanding photometry is fundamental to making good use of information such as luminous flux, direction and intensity.

- **Color temperature:** expresses the colour appearance of the light emitted by the light source. This definition is based on the relationship between the temperature of a hypothetical standard material and the energy distribution of the light emitted as the temperature of the black body is increased. The unit of measurement for colour temperature is Kelvin (K). The higher the temperature, the lighter the hue. The term warm or cold light refers to the shade of light emitted by the lamp. A softer hue makes the room more comfortable and relaxing, while a brighter hue makes the room more stimulating. Colour temperature is an analogy between the colour of light emitted by a black body heated to a certain temperature in Kelvin and the colour we are comparing. For example, an incandescent lamp with a colour temperature of 2,700 K has a yellowish hue, while one with a colour temperature of 6,500 K has a bluish hue.

1.2. Defining the type of space

The EN 1838 classifies various spaces within the safety lighting paradigm, recognizing the nuanced requirements essential for diverse environments. This subsection embarks on a exploration of three distinctive types of areas integral to the emergency lighting concept, each tailored to address specific safety needs.

- **Escape route lighting (**CEN/CENELEC, 2013): refers to lighting along escape routes such as corridors, stairwells and emergency exits. Lighting in these areas is essential to enable occupants to quickly and safely identify and follow escape routes in the event of an emergency evacuation. Thy should have a minimum of 1 lux along the centre line, and a minimum of 0,5 lux in the 1m wide central band, measured at ground level. Image 1 shows an example of scape route area.

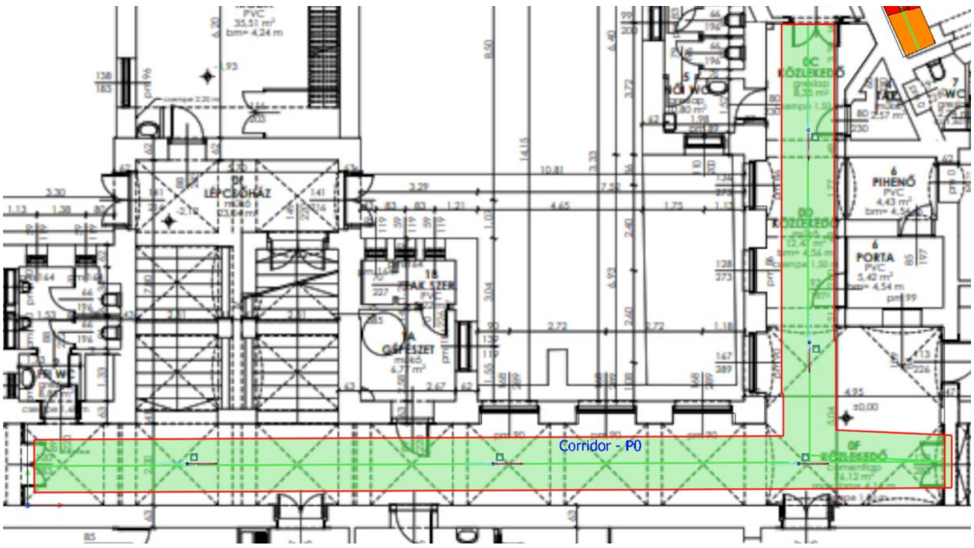

Figure 1: Highlighted, example of escape route, according to EN1838

- **Open area lighting (anti-panic) (**CEN/CENELEC, 2013): is designed to illuminate large areas such as communal spaces, meeting rooms or places where large numbers of people might gather in an emergency. This type of lighting, also known as 'anti-panic lighting', aims to minimise panic and provide sufficient visibility to guide people to escape routes and safe areas. In open areas, illumination of 0,5 lux minimum should be provided**,** measured at ground level.

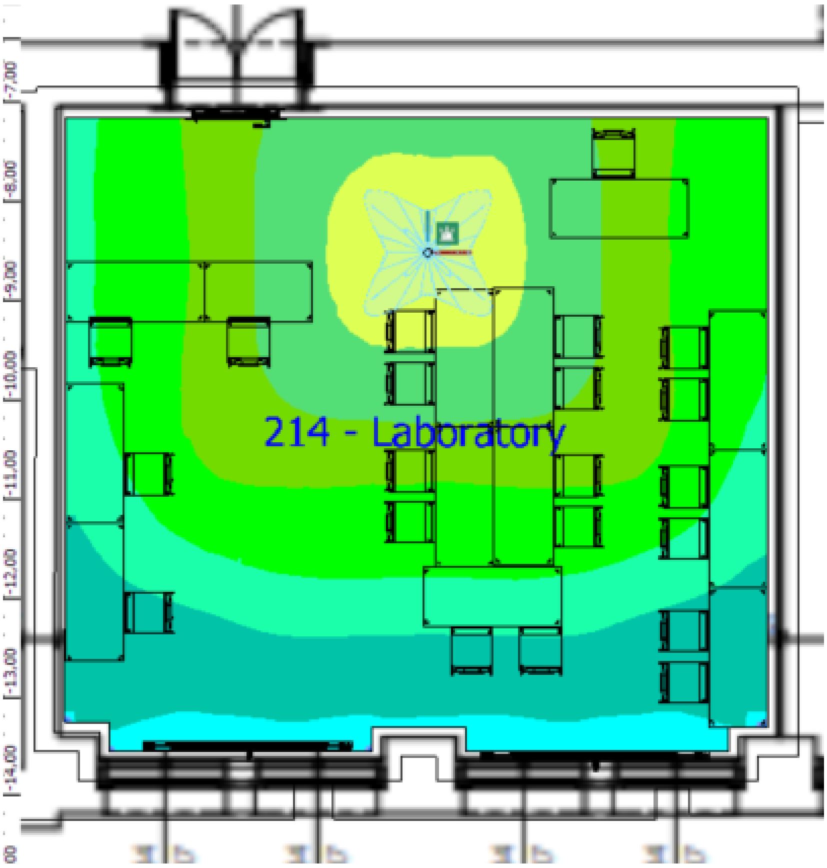

Figure 2: Example of open space, according to EN1838

- **High-risk task area lighting** (CEN/CENELEC, 2013): is designed to maintain adequate visibility in places where precision and safety are critical. By defining specific requirements for lighting in these environments, the standard aims to minimise the risk of accidents and allow critical activities to continue with minimal disruption, ensuring the safety of occupants and the processes carried out in these areas.

1.3. Glaring and uniformity

Another important consideration in lighting calculations is the contrast ratio (Pinto, 2010). Glare is often associated with a high contrast ratio between a bright light source and its surroundings. Contrast ratio is a measure of the difference in brightness between two elements in a visual field.

Glare refers to the visual discomfort or difficulty experienced when there are extreme contrasts in brightness within a person's field of vision. It occurs when there are bright light sources, such as direct sunlight, oncoming headlights at night, or reflections, that differ significantly in brightness from the surrounding environment. The human eye constantly adapts to the average brightness of the scene it is viewing. When a highly luminous source is present, it can interfere with the eye's adaptation, making it difficult to see clearly and comfortably.

A ratio of 10:1 for the immediate field of view and 20:1 in the periphery is generally considered reasonable. This means that the brightness of the bright source should not exceed 10 times the ambient brightness in the immediate field of view and 20 times the ambient brightness in the periphery.

In emergency lighting systems, for both escape routes and open areas, the contrast ratio should not exceed 40:1, that is, if the minimum is 1 lux, the maximum should not exceed 40 lux.

An additional factor to be mentioned are the requirements for the signaling lamps. Safety signs include signs for escape routes, emergency exits and other exits, and other safety signs which, based on risk assessment, need to be legible under emergency lighting conditions. Manufacters need to comply with the international standards ISO 3864-1, ISO 3864-4 and ISO 7010.

1.4. Safety signs

The purpose of this type of lamp is to indicate the existence, location and procedures to facilitate safe evacuation in an emergency. In addition to identify hazardous locations, fire safety and first aid equipment.

Firefighting and alarm equipment is indicated by signs with a red background and a photoluminescent symbol, the purpose of which is to indicate the location of the equipment.

The EN 1838 foresees the use of internally illuminated devices, since it is distinguishable at a greater distance than an externally illuminated signal of the same size.

Figure 3: Safety Sign[1]

For safety signs, an important aspect is the viewing distance. The maximum distance of visibility must be determined using the following formula:

$$d=200*h \qquad (2)$$

where:

- d is the viewing distance (mm);
- h is the height of the signing lamp (mm);
- 200 is a constant for internally illuminated signals;
- The dimensional units of h and d must be the same.

[1] https://stock.adobe.com/br/images/senal-verde-emergencia-se051-pictograma-vector-abajo-flecha-puerta-derecha-hacia-abajo-salida-evacuacion-salir-ruta-flecha-hacia-abajo-imagen-indicar-norma-normatividad-vector/489784621?prev_url=detail, accessed on November 1st, 2023.

The standard provides a description of the points of emphasis within a building. They are:

- Begining of each escape route, including direction changes.
- Along escape routes and in open areas leading to them.
- Exit doors
- Staircases
- Change of direction
- Floor level changes
- Open areas
- At each corridor intersection
- Highlighting firefighting and first aid equipment
- High risk task areas
- Near each final exit

1.5. Autonomy

The emergency lighting system, whether centralised or self-contained, must meet the minimum lighting levels required and have an autonomy of at least 1 hour. In special cases, the operating time may be extended.

1.6. Country-specific requirements

Achieving a standardized approach to emergency lighting across diverse European countries involves navigating unique national regulations and priorities. In this exploration, we delve into the country-specific requirements for emergency lighting, shedding light on the distinct considerations and deviations in standards. From France's emphasis on product certification and alternative planning criteria to Italy's meticulous requirements for certified luminaires and precise positioning, each country presents a tailored approach. Germany, the United Kingdom, and Ireland introduce specific criteria for safety lighting and illuminance levels, reflecting their commitment to robust emergency lighting systems.

France: emergency lighting requirements include certified products with defined quality features. Luminance and illuminance levels are not considered in planning. For safety lighting in escape routes, certified emergency luminaires with specific positioning requirements are necessary. Anti-panic lighting must provide a minimum of 5 lm/m^2 of floor area, with at least two luminaires per room. Safety lighting for hazardous workplaces is based on risk assessment. Safety signs should adhere to the French standard NF 08-003 or compatible standards from other European countries.

Italy: public places must have a minimum illuminance of 5 lx near stairways and exits, measured 1 m above floor level. Along escape routes, a minimum of 2 lx is required. Illuminance values should be measurable on-site, and specifications alone are not sufficient for planning. Measurements are made on site, including reflections.

Germany: regulations stipulate a maximum time of 15 seconds between the failure of the general lighting system and achieving necessary illuminance levels for escape routes and anti-panic lighting in workplaces.

United Kingdom: emergency lighting systems in the UK must start within 5 seconds of the general lighting system failure. In buildings mainly used by those familiar with escape routes, authorities can extend this period to a maximum of 15 seconds. Horizontal illumination of unobstructed escape routes requires at least 0.2 lx along the central axis and at least 0.1 lx over half the width.

Ireland: emergency lighting systems must start within 5 seconds of failure. The horizontal illumination of identified escape routes should be at least 0.5 lx along the central axis at floor level.

2. CHARACTERISTICS OF THE LUMINAIRES

2.1. Light distribution

When choosing the type of luminaire to be used in a project, a number of technical and stylistic aspects must be considered. The first of these is light distribution.

Emergency luminaires can be offered with different light distributions to meet the specific needs of the areas in which they are installed (Boyce, 1985). Typical emergency lighting distributions can be divided into three main categories: symmetric, asymmetric, and concentrated.

- **Symmetrical optics**: Emergency luminaires with symmetrical optics emit light evenly in all directions, creating an even distribution of illumination around them. This type of distribution is often used in anti-panic areas such where uniform lighting is needed. Figure 4 shows an example of lamp that uses symmetrical optics. The colors represent pre-fixed levels of illuminance emitted by this lamp. It is possible to obser the uniform ligh distribution over the calculation plane.

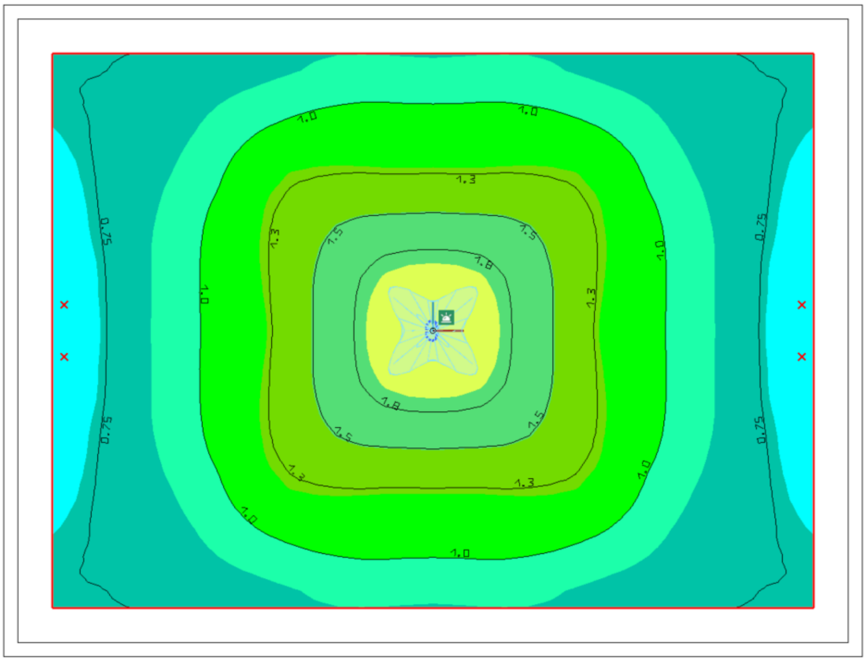

Figure 4: Symmetrical light distribution

- **Asymmetric optics:** Emergency luminaires with asymmetrical optics direct light unevenly, concentrating it in a particular direction. This type of distribution is often used in areas where light needs to be directed more effectively, such as stairs, ramps, and corridors, to avoid glare and provide optimum visibility of escape routes. Figure 5 shows an example of lamp that uses asymmetrical optics. The colors represent pre-fixed levels of illuminance emitted by this lamp. It is possible to obser that the ligh distribution is concentrated over the central horizontal line of the calculation plane.

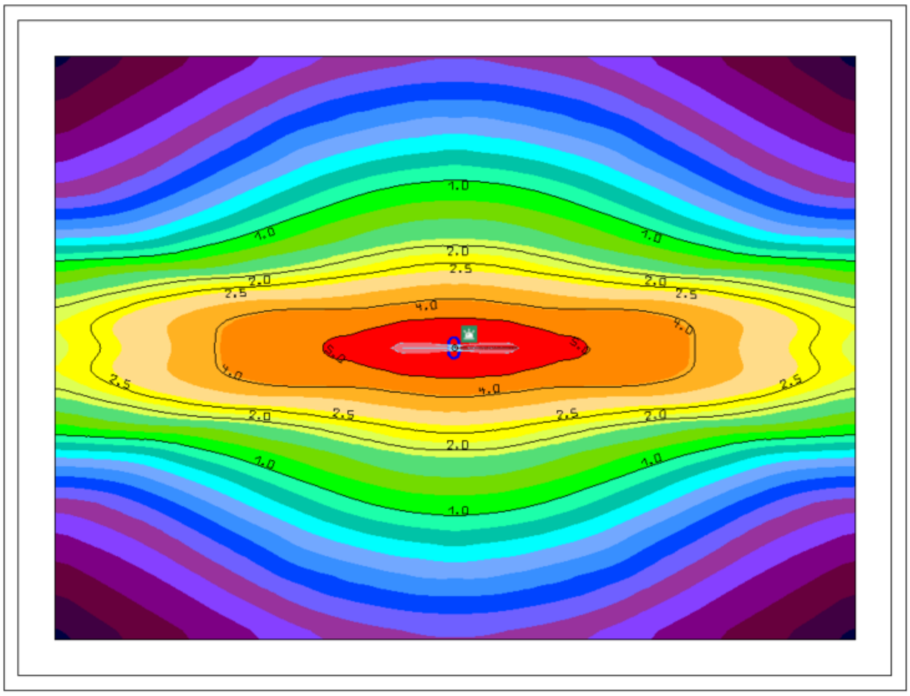

Figure 5: Asymmetrical light distribution

- **Concentrated optics:** Concentrated optics are used where high-risk areas or critical tasks need to be illuminated. These emergency luminaires project light in a narrow, concentrated beam, targeting specific areas where precise detail or maximum visibility is critical. This kind of fixture is used to light safety and fire devices in public buildings. Figure 6 shows an example of lamp that uses concentrated optics. The colors represent pre-fixed levels of illuminance emitted by this lamp. It is possible to obser that the ligh distribution is concentrated over a small space in the calculation plane.

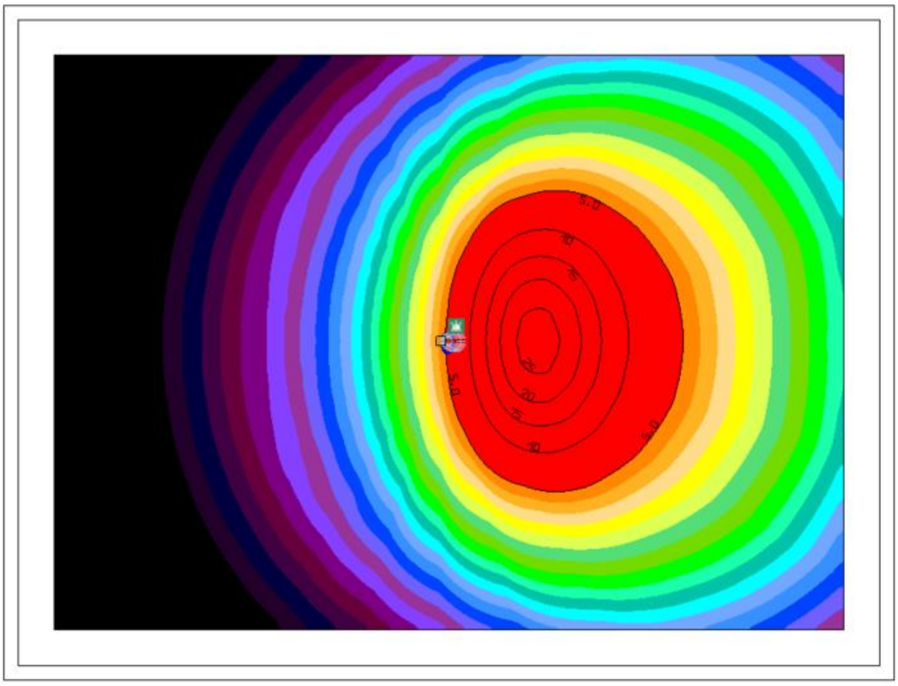

Figure 6: concentrated light distribution

In conclusion, the consideration of light distribution is paramount when selecting luminaires for emergency lighting applications. The three main categories - symmetrical, asymmetrical, and concentrated optics - offer distinct advantages tailored to the specific needs of different areas within a building.

Symmetrical optics ensure even illumination in all directions, making them ideal for anti-panic areas where uniform lighting is crucial. This type of distribution promotes a sense of security and aids in maintaining a calm and controlled evacuation process.

On the other hand, asymmetrical optics direct light unequally, concentrating it in specific directions. This focused illumination is particularly valuable in areas such as stairs, ramps, and corridors, where the avoidance of glare and the optimal visibility of escape routes are priorities.

Concentrated optics serve a specialized purpose, projecting light in a narrow beam to target specific high-risk areas or critical tasks. Such fixtures are instrumental in illuminating safety and fire devices, ensuring that precise details are visible, and visibility is maximized in crucial locations.

The selection of the appropriate light distribution is not a one-size-fits-all decision but rather a nuanced process guided by the unique characteristics and requirements of each space. A well-informed choice between symmetrical, asymmetrical, or concentrated optics is fundamental to the creation of effective and customized emergency lighting systems. It underscores the importance of directing light appropriately for each situation, contributing significantly to the overall safety and efficiency of emergency evacuation scenarios within modern buildings.

2.2. IP and IK ratings

In the field of emergency lighting, technical considerations go beyond mere light output. Two critical factors that require attention are Ingress Protection (IP) and Impact Protection (IK) ratings.

Ingress Protection (IP) Rating

Established by the International Electrotechnical Commission (IEC) in the standard IEC 60529, is a numerical code that defines the degree of protection provided by an electrical enclosure against the intrusion of foreign objects (like dust and dirt) and water. This rating is crucial in determining the suitability of luminaires for specific environmental conditions.

The IP rating is presented as a two-digit code, where each digit corresponds to a specific type of protection. The first digit assesses the level of protection against solid objects, while the second digit assesses protection against liquids.

First Digit (Solid Objects Protection):

- 0: No protection.
- 1: Protected against solid objects larger than 50mm.
- 2: Protected against solid objects larger than 12.50mm.
- 3: Protected against solid objects larger than 2.50mm.
- 4: Protected against solid objects larger than 1.00mm.
- 5: Dust-protected.
- 6: Dust-tight, complete protection against dust ingress.

List 1: First digit for IP degree

Second Digit (Liquid Protection):

0: No protection.

1: Protection against vertical water drop

2: Protection against water drops at an angle:

3: Protection against spraying water:

4: Protection against splashing water

5: Protected against water jets.

6: Protection against powerful water jets

7: Protected against the effects of immersion in water between 15cm and 1m for a limited time.

8: Protected against the effects of immersion beyond 1m

9: Protected against high-pressure and high-temperature water jets, providing ingress protection against close-range high-pressure, high-temperature spray downs.

List 2: Second digit for IP degree

For instance, a luminaire with an IP65 rating offers substantial protection against dust (6) and is resistant to water jets (5). This means it is suitable for environments where dust and water exposure is anticipated, such as outdoor or industrial settings.

In emergency lighting, the nature of the environment dictates the required IP rating. Areas like theatres or hotels may not demand high IP ratings, whereas industrial settings, sports venues, or locations subjected to adverse conditions necessitate luminaires with higher IP ratings to ensure durability and performance in challenging environments.

Figure 7: Guide for IP rating, IEC[2]

[2] https://www.iec.ch/basecamp/ingress-protection-ip-ratings-guide, accessed on November 1st, 2023.

IK Ratings

The Impact Protection rating, stablished by the IEC 60068-2-75 (IEC, 2014), measures the degree of protection provided by an electrical enclosure against external mechanical impacts, such as shock or impact from objects. Similar to the IP rating, the IK rating is also represented by a two-digit code, conveying specific information about the luminaire's resistance to impact.

IK00: No protection against impact.
IK01: Protection against 0.15 joules impact.
IK02: Protection against 0.20 joules impact.
IK03: Protection against 0.35 joules impact.
IK04: Protection against 0.5 joules impact.
IK05: Protection against 0.7 joule impact.
IK06: Protection against 1 joules impact.
IK07: Protection against 2 joules impact.
IK08: Protection against 5 joules impact.
IK09: Protection against 10 joules impact.
IK10: Protection against 20 joules impact.

List 3: IK rating

Number	Measure of protection – impact energy (joules)	Test
IK00	No protection to this standard -	
IK01	0.15	0.20 kg impact
IK02	0.20	0.20 kg impact
IK03	0.35	0.20 kg impact
IK04	0.50	0.20 kg impact
IK05	0.70	0.20 kg impact
IK06	1.00	0.50 kg impact from 200mm
IK07	2.00	0.50 kg impact from 400mm
IK08	5.00	1.70 kg impact from 295mm
IK09	10.00	5.00 kg impact from 200mm
IK10	20.00	5.00 kg impact from 400mm
When higher impact energy protection is required 50 joules is recommended.		

Figure 8: Guide for IK rating[3]

Understanding the IK rating is essential when selecting luminaires for areas where the risk of mechanical impact is a consideration. For example, luminaires in industrial settings or public spaces with a higher risk of impact might require a higher IK rating to ensure durability and longevity in the face of potential physical stress.

[3] https://www.sylvania-lighting.com/de-de/technische-informationen/ip-ik-bewertungen/, accessed on November 8th, 2023.

2.3. Emergency lighting systems – autonomy and testing

Understanding the intricacies of emergency lighting systems is pivotal for effective emergency preparedness. Two fundamental technologies, self-contained and central battery systems (CBS), play a crucial role in providing illumination during power failures or emergencies (Ajrina, 2021).

In a self-contained system, the luminaire operates autonomously with its dedicated battery. The battery continuously charges under normal conditions through the main lighting circuit. In the event of a power failure, the battery takes over to ensure uninterrupted illumination. This system integrates all components, including the battery, light source, control unit, and monitoring equipment, within the luminaire's enclosure or an adjacent enclosure (Güngör, 2010). Refer to Figure 9 for a visual representation of a self-contained system.

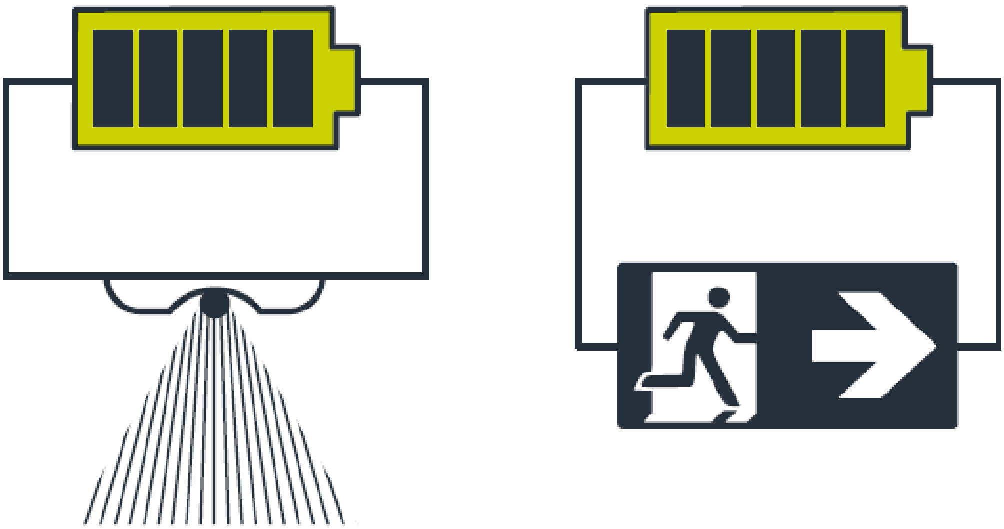

Figure 9: Self-Contained System[4]

[4] https://www.eaton.com/gb/en-gb/markets/buildings/how-we-drive-building-efficiency-and-safety/safe-evacuation/evacuate/basics-emergency-lighting-systems.html, accessed on November 1st, 2023.

Contrastingly, a central battery system, also known as central power supply (CPS) or low power system (LPS), powers multiple 'slave' emergency luminaires without individual integral batteries. In this system, luminaires are automatically powered by a central battery within the building. This central battery triggers the charger, switching systems, alarms, and instrumentation in the event of a failure of the normal lighting system (Li, 2004). Notably, centralized systems are typically more expansive and are commonly employed in larger plants and expansive spaces where the centralized management of emergency lighting proves to be more efficient and cost-effective. Figure 10 illustrates the functionality of a central battery system.

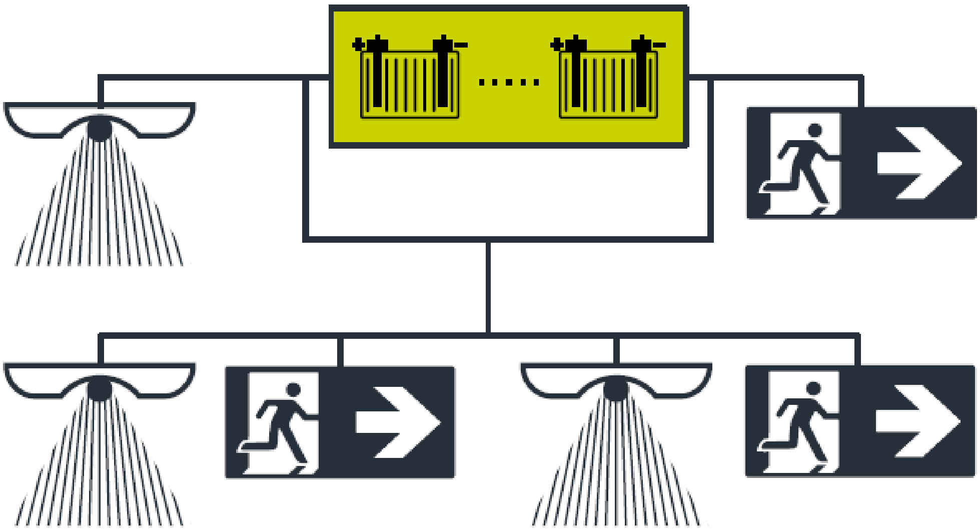

Figure 10: Central battery system[5]

To stipulate the size of the CBS the following calculations must be done:

- Determine the total power drawn by system: Usually the power drawn by the luminaire is given in the datasheet. From this, a simple multiplication is enough to obtain the total power consumption.
  For example, if one model of LED lamp consumes 3.9W and, in the building, there are 100 of the same devices, our total consumption will be 390W.

[5] https://www.eaton.com/gb/en-gb/markets/buildings/how-we-drive-building-efficiency-and-safety/safe-evacuation/evacuate/basics-emergency-lighting-systems.html, accessed on November 1st, 2023.

- Determine battery capacity: considering a 12V battery and the power calculated in the step above, it is possible to calculate the current in our system:

$$\frac{P}{V}=I \quad (3)$$

$$I=390\div12=32.5\text{A} \quad (4)$$

- Calculate the amount of energy charge in the battery (Ampere hours): In the case of emergency lights, the autonomy of the system is 1h, so the battery needs a 32.5Ah charge.
- Another important concept for LED lamps is inrush current (Baleja, 2015). It is the maximum momentary input current consumed by an electrical appliance when it is first activated. As any other power supply, LED drivers contain internal capacitors. These capacitors charge in less than a millisecond after power is applied to the typical LED driver. This rapid charging produces the inrush current. It doesn't directly affect CBS sizing, but repeated surges above the battery's rated output can damage the battery and shorten its life. It is therefore important to respect the inrush current limits of the CBS.

In addition to understanding the basic characteristics of self-contained and centralised emergency lighting systems, it is equally important to look at the aspects of testing and maintenance to ensure that these systems perform as expected when needed most (MAEd, 2022).

According to the EN 1838 standard, emergency lighting systems must have an autonomy of at least 1 hour to provide adequate lighting in the event of a power failure or emergency.

In terms of tenting and maintenance, the standard EN 50172 provides guidelines for assessing the duration of battery operation of emergency lighting systems. This duration can be assessed by several methods:

- **Switching off the mains supply:** A traditional approach to testing battery life is to deliberately cut the mains supply to simulate an emergency situation. During this test, the system's internal battery takes over and the length of time it provides lighting is measured.

- **Use self-test features:** Many modern emergency lighting systems are equipped with self-test features (Yarn, 2022). These features allow the system to automatically perform periodic tests to assess functionality and battery condition without external intervention. This self-diagnostic approach ensures that the system remains in optimum operating condition and can detect and report any problems promptly.
- **Use of central monitoring software:** In larger and more complex installations, central monitoring software can be used to monitor the status and performance of emergency lighting systems. This software provides a centralised platform for real-time monitoring, alerting and reporting to ensure that the entire system, including batteries, is functioning correctly.

These testing and maintenance procedures are essential to verify that emergency lighting systems meet the autonomy requirements of EN 1838 (Piantanida, 2023). Regular assessment and maintenance activities help to ensure system reliability and compliance with safety regulations, ultimately contributing to the safety of building occupants in critical situations.

3. CASE STUDY

In this chapter, we will delve into the step-by-step process of creating the emergency lighting system for the building, which serves as a practical application of the principles and standards discussed in previous chapters. The use of DIALux EVO - a state-of-the-art lighting design software that empowers professionals in the field of architecture, lighting design, and electrical engineering to create visually compelling and efficient lighting systems - plays a central role. This chapter illustrates how we used technology to design a compliant and effective emergency system.

The process begins by acquiring detailed blueprints of the structure in either .dwg or PDF format. These blueprints serve as the foundational documents for the subsequent design steps.

Using the advanced features of DIALux EVO the acquired blueprints are seamlessly imported. This step marks the initiation of the design phase, establishing the groundwork for subsequent actions.

Within the DIALux EVO platform, a new story is created to mirror the building's structure. Opting for the emergency light option, meticulous attention is given to drawing rooms and floors, aligning them precisely with the architectural layout provided by the blueprints.

The next critical step involves the strategic placement of chosen luminaires for the emergency lighting system. Utilizing photometry .ldt files, these luminaires are positioned within the designated areas of the building, ensuring optimal coverage and compliance with safety standards.

Simulations are then executed within DIALux EVO to evaluate the effectiveness and compliance of the lighting design. This step involves assessing the system's performance under various scenarios, considering factors such as escape routes and emergency scenarios.

Thorough scrutiny of the simulation results follows to ensure compliance with EN1838 standards, which dictate the requirements for emergency lighting systems. Verification is made to confirm that the designed system meets the specified safety and illumination criteria.

In cases where the simulation results do not align with EN1838 standards, adjustments to the design are made. This may involve modifying the disposition of luminaires, altering the number of lamps, or selecting different luminaire models to achieve compliance.

Upon confirming the validity and compliance of the design, a .dwg file is exported. This file contains information on the positioning of lamps and calculated light curves.

A results report is generated from DIALux EVO, documenting the outcomes of the simulations, compliance checks, and any design adjustments. This report serves as a vital record of the design process.

Transitioning to AutoCAD, the initial blueprints are merged with the .dwg file containing lamp positioning and light curves. This merging process provides a holistic view of the lighting design within the broader architectural context.

Leveraging pre-constructed AutoCAD blocks, luminaires are positioned according to the finalized design. This step ensures accuracy and consistency in implementing the lighting system.

EN1838 standards are incorporated into the design by carefully planning and implementing escape routes. Signaling lamps are strategically placed to guide occupants during emergency situations, ensuring a safe and efficient evacuation process.

A thorough count of the total number of luminaires used in the project is conducted. This final step provides a quantitative overview of the lighting system's scale and assists in logistical considerations for procurement and implementation.

The following flowchart summarizes the process that will be described.

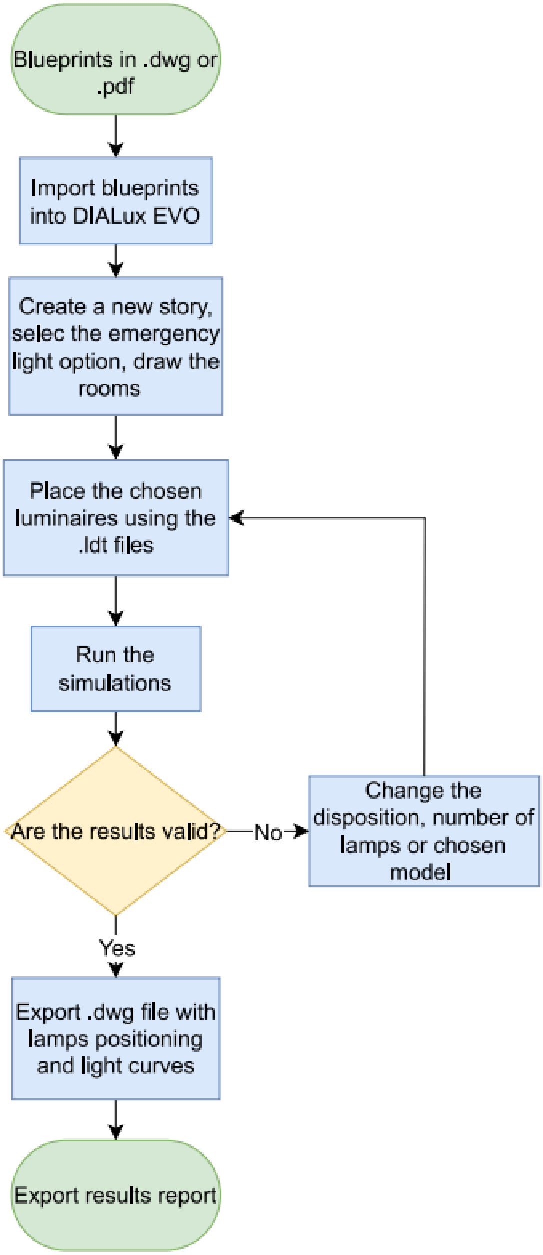

Figure 11: Process flowchart

3.1. Obtaining and Preparing Blueprints

Before starting the design process, it was essential to obtain accurate plans of the building. These formed the basis for the design of the emergency lighting system. They were received in PDF format.

The first phase was to integrate the PDF designs into DIALux EVO. This step marked the start of the lighting system design process. Figure 12 shows the blueprint of the 2nd floor being used as a guide to draw the rooms for simulation. For better visualization, an enlarged version of the picture can be found in the appendix section.

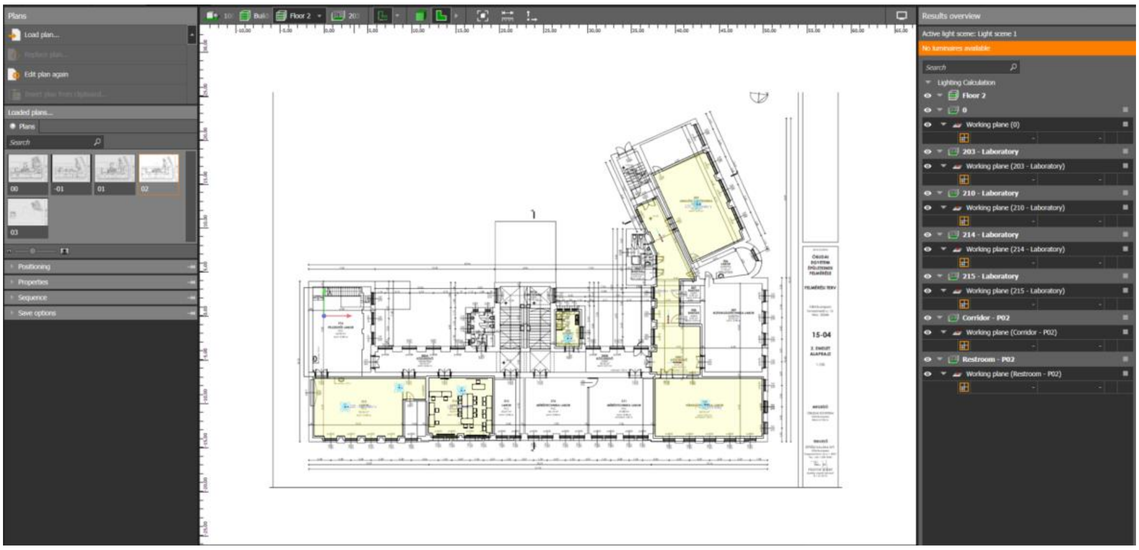

Figure 12: Blueprint of the 2nd floor imported to DIALux.

This integration procedure was executed for all floors within Building B, ensuring a comprehensive representation of the entire structure in the software. The successful incorporation of these blueprints lays the groundwork for the subsequent phases of the emergency lighting system design.

3.2. Drawing Floors and Rooms

Within DIALux EVO, the layout of the building was recreated by carefully designing floor plans and room layouts based on the imported blueprints. The software provided a range of tools and features that allowed the precise replication of the building's design.

This phase required attention to detail to ensure that room dimensions and architectural intricacies were accurately represented.
At this stage it is very important to have a well-drawn plan, especially the sectional views of the building.
The next images show individual classrooms and offices that have been recreated. They show 2D and 3D views of these spaces, as well as a 2D view of each floor. For better visualization, an enlarged version of the picture can be found in the appendix section.

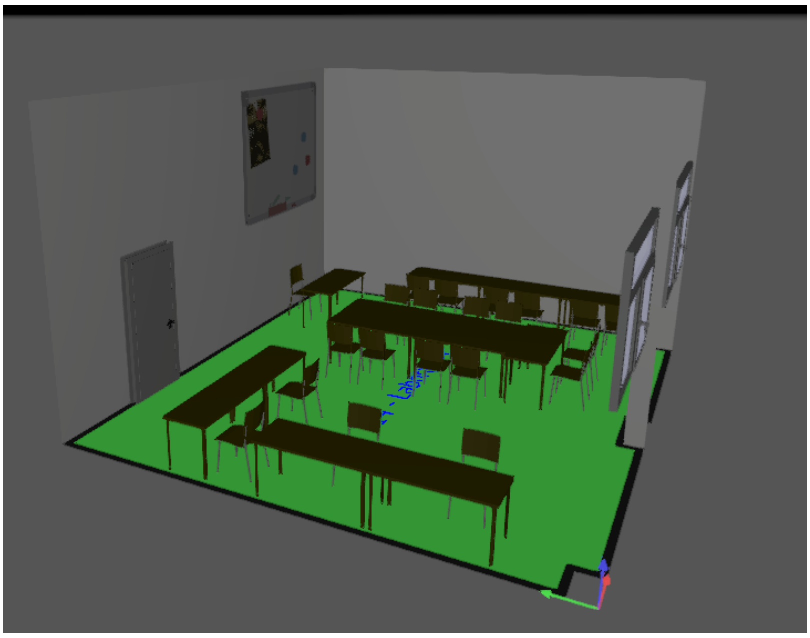

Figure 13: 3D drawing of room 21.

The following illustration shows how the blueprints are used as a guide for drawing the rooms. When importing these plans, it is possible to scale the drawings. Once the outline of the room has been drawn, it's possible to modify its height, the type of ceiling, to insert objects and to change the material and colour of the surfaces.

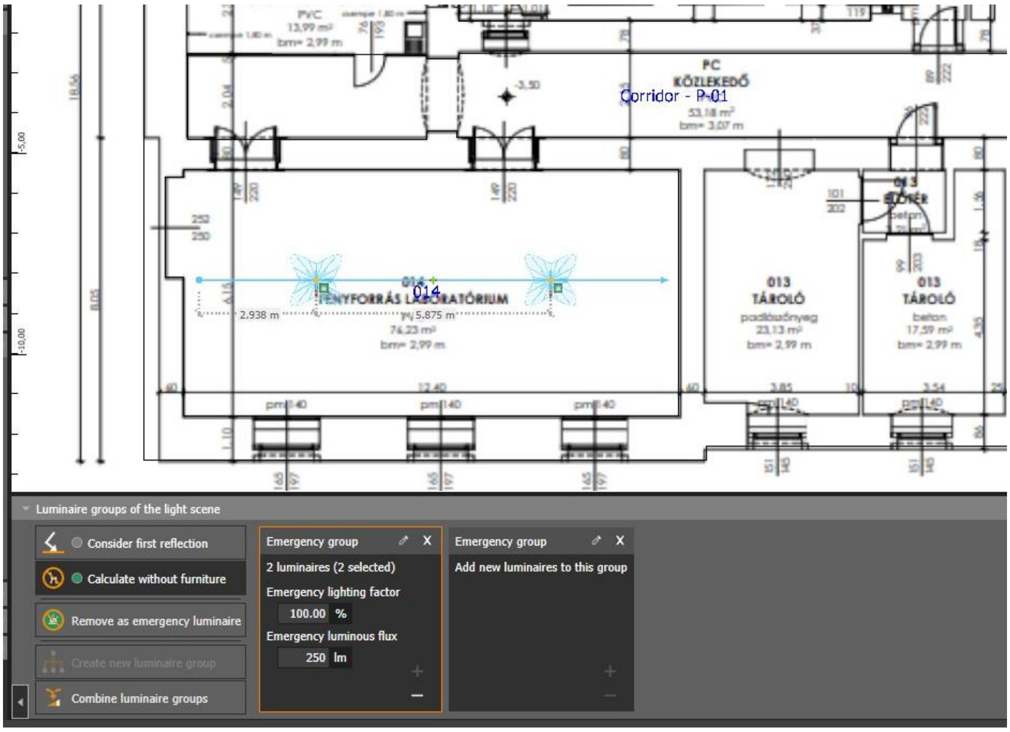

Figure 14: 2D view of ground floor and lighting curves

Next figure shows a 3D view of the lecture room 3. The platforms, chairs, and ramps were inserted as objects.

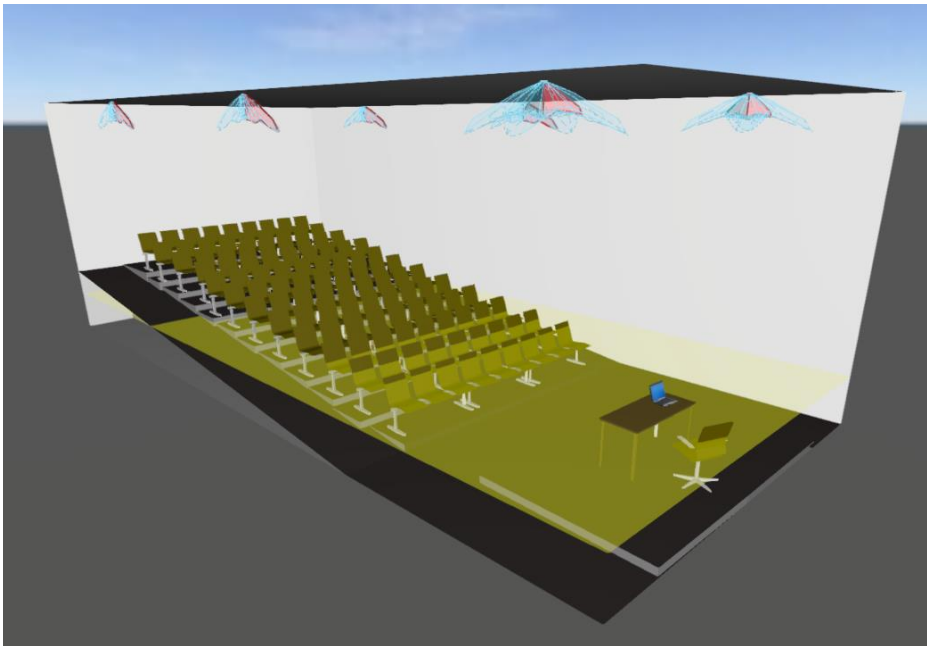

Figure 15: 3D drawing of the lecture room 3, with fixtures and calculation plane.

A model of the central staircase in the building was also created in a separate DIALux file, as shown in Figures 16, 17 and 18. These simulations show the floors from ground to 3rd and the corridors.

Only the stair flights and landings from ground to first floor were included in the calculations, as the results can be extrapolated for the other flights.

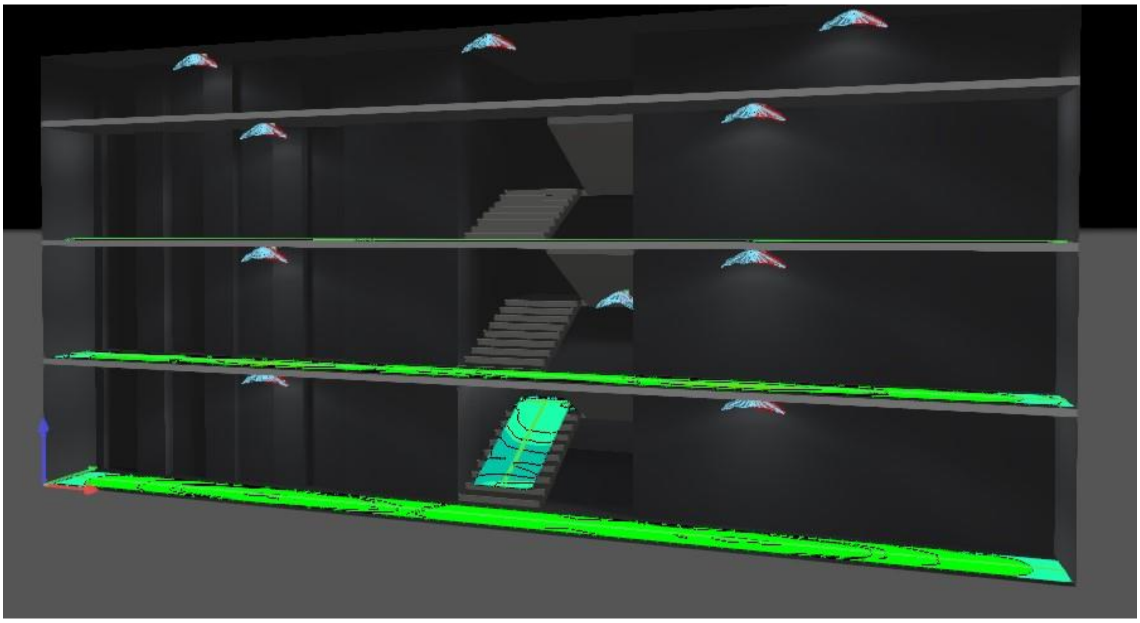

Figure 16: 3D view of central stairs and corridors

DIALux also allows side and front views of modelled spaces, as shown in figures 17 and 18.

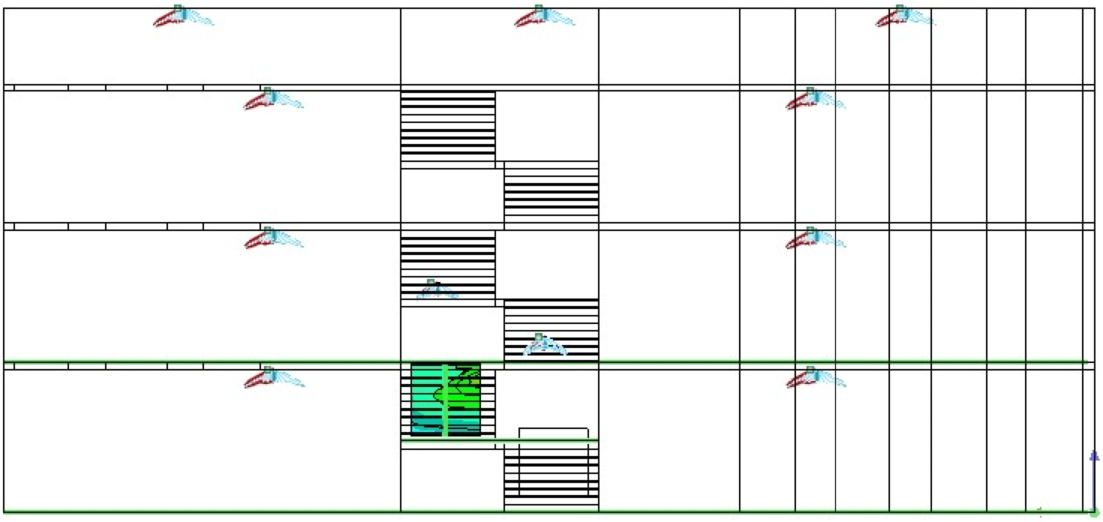

Figure 17: 2D front view of central stairs and corridors

Using the 2D views, the 3rd floor is constructed differently to the other floors. For this reason, it is not possible to replicate the same lamp positioning as on the other levels.

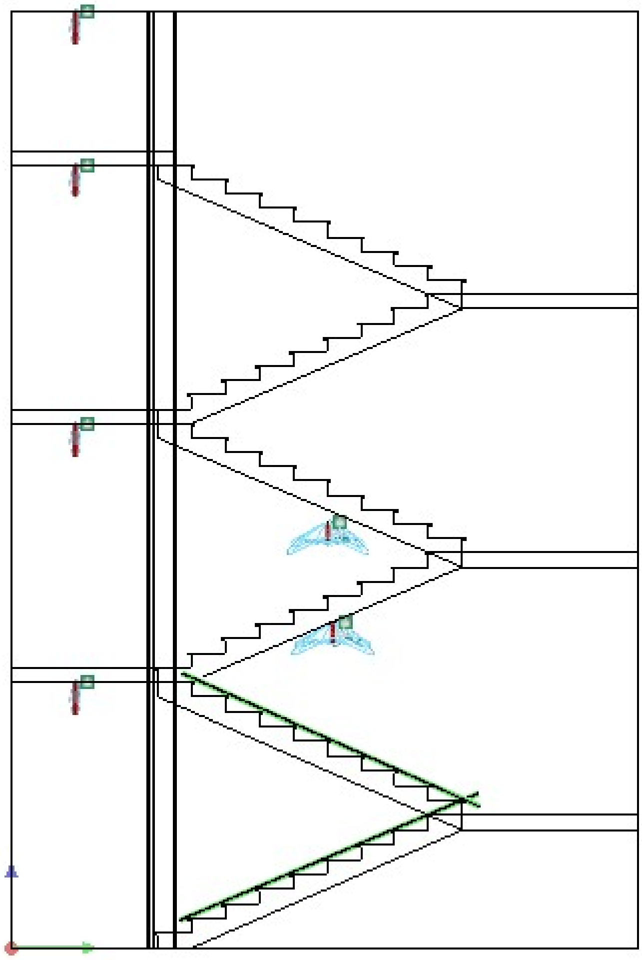

Figure 18: 2D side view of central stairs and corridors

3.3. Lighting Calculations, Fixture Positioning and Simulations

The next stage was the installation of DIALux EVO luminaires, including exit signs, escape route lighting and critical area lighting.

The luminaires chosen for the simulations were Eaton's GuideLed SL 13811 and GuideLed SL 13821 (Eaton, 2023). Both are self-contained, recessed ceiling mounting luminaires, for universal use, with maintained and non-maintained solutions and freely configurable for 1h, 3h or 8h operation. For this case study, 1h operation is sufficient to comply with the standard. The photometry can be found on the company's website.

This model was chosen for its good luminous flux, 210lm and 204lm, and discreet design. Ideal for environments such as universities, hotels, shops, hospitals, etc. This model is a LED self-cointained lamp, that uses Li-Ion battery, with IP41 and IK03 ratings.

The model used for signalling is the Crystalway from the same manufacturer. It is available in 20m and 30m distance viewing versions. The 20m version was chosen for this project. This lamp has a LED strip as its light source, uses a lithium battery and has IP42 and IK04 ratings.

Figure 19: Guideled lamp[6]

Figure 20: Crystalway lamp for signalling[7]

DIALux EVO facilitated the complex process of calculating and simulating the lighting. The software was used to perform detailed calculations to ensure that the proposed

[6] https://www.eaton.com/hu/hu-hu/catalog/emergency-lighting/self-contained-guideled-sl.html, accessed on November 1st, 2023.

[7] https://www.eaton.com/hu/hu-hu/catalog/emergency-lighting/self-contained-crystalway.html, accessed on November 1st, 2023.

lighting design was in compliance with safety and emergency lighting standards. Parameters, standards and guidelines were meticulously applied within the software to confirm that the design complied with regulations.

Figure 22 shows Lecture Room 3 on the ground floor, it's scape routes (both ramps and the area around the teacher's desk) and the light curves.

Since the ramps were considered as scape routes there will be a measurement for the central line, for the margins, and a check for the contrast ratio.

For instance, the next figure shows a section of the escape route. Calculations are made along the green line (called the centre line) and the 1m wide central band running along this green line.

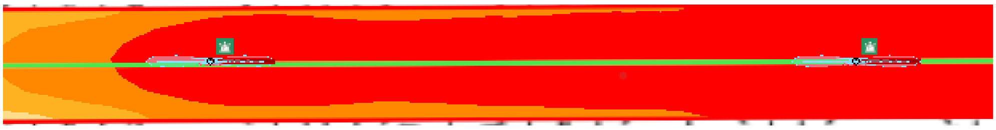

Figure 21: Central line of escape routes

The detailed results will be shown in the figure 23.

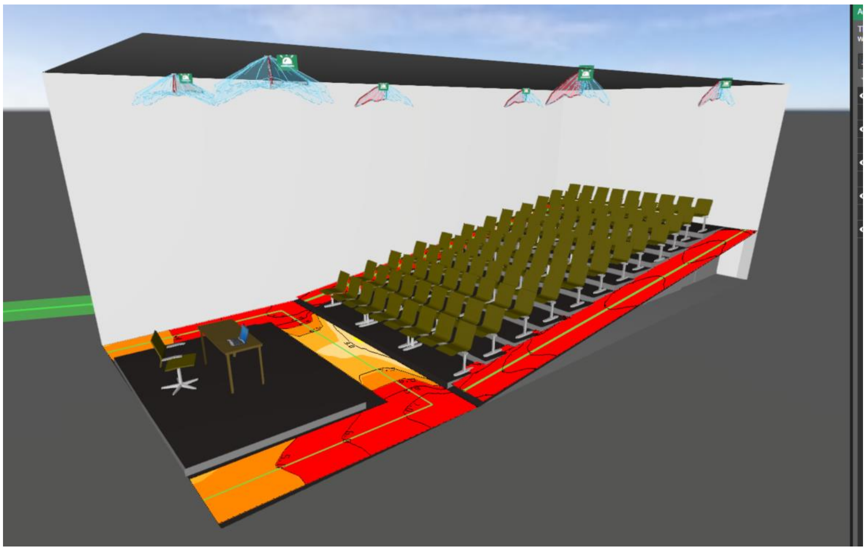

Figure 22: Lighting results on lecture room 3

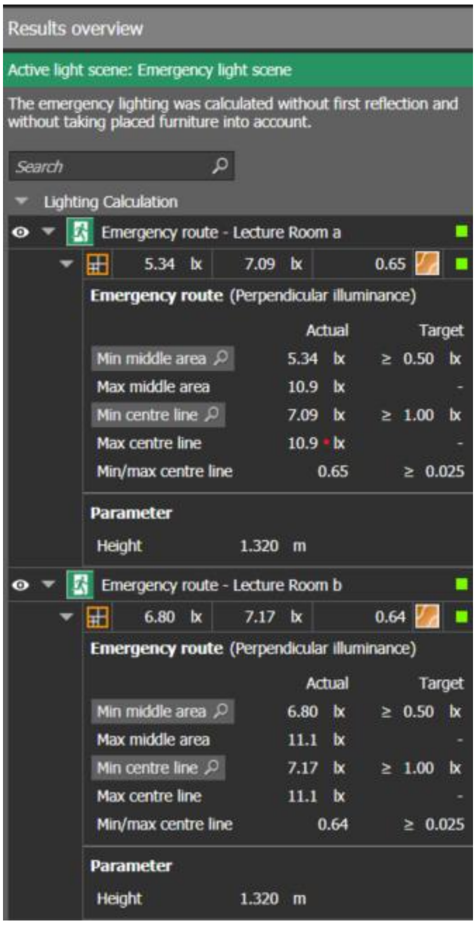

Figure 23: detailed light results for room 3

On the other hand, classrooms like the room 115 are considered anti-panic areas, so the detailed light results show only the minimum levels and the check for the contrast ratio (figures 24 and 25).

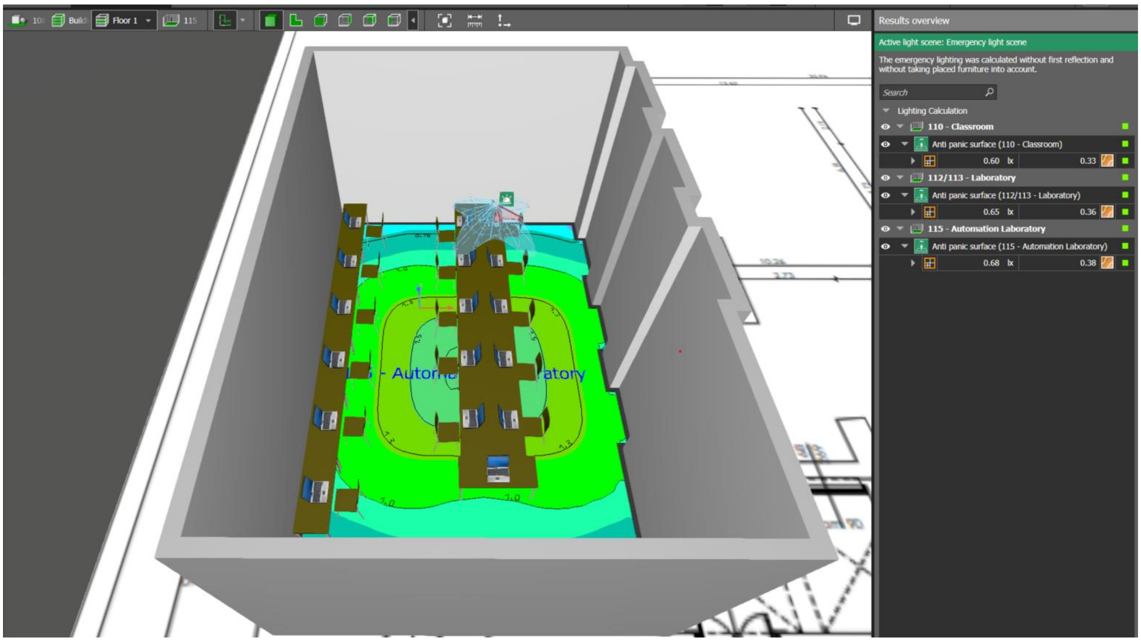

Figure 24: 3d view of 1st floor - room 115 and light results

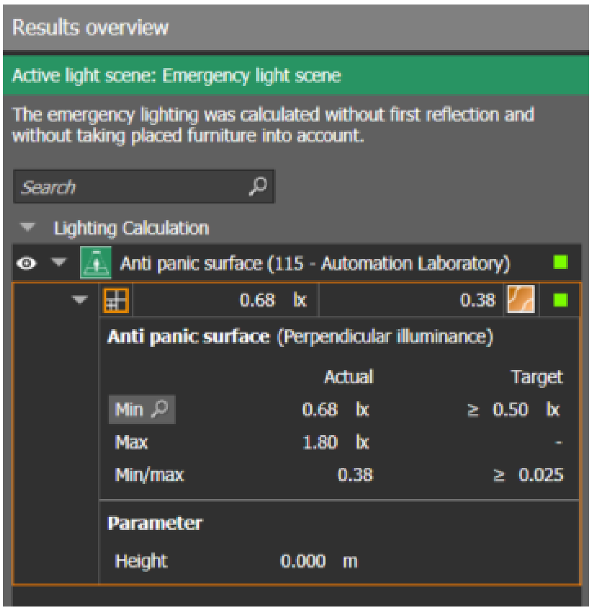

Figure 25: Detailed results of room 115

3.4. Importing into AutoCAD, positioning the signalling lamps

Once the lighting design and calculations had been completed in DIALux EVO, the next stage was to transfer the results to AutoCAD. This integration allowed for further precision and detail in the implementation of the emergency lighting system.

The first step was to convert the existing PDF plans into .dwg files, ensuring that the data was in a format compatible with both DIALux EVO and AutoCAD. Figure 26 shows the blueprints exported.

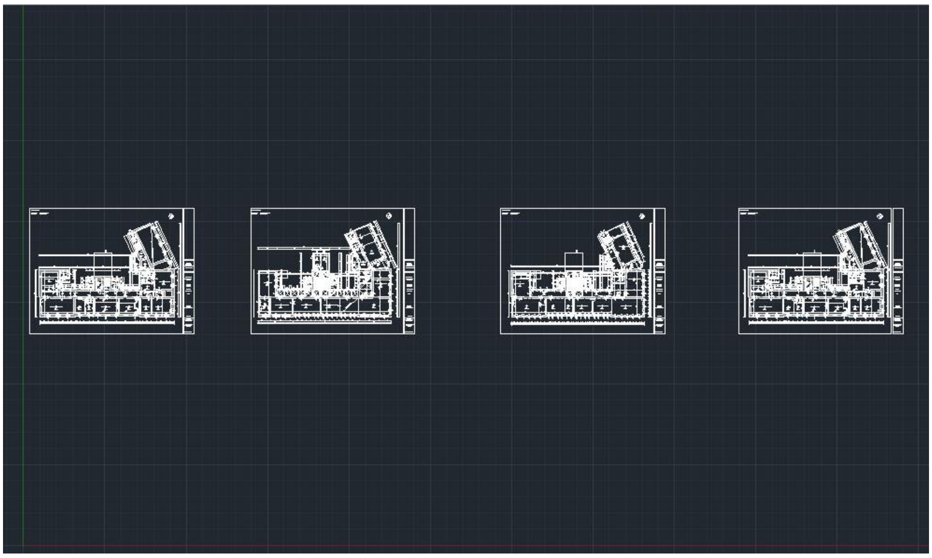

Figure 26: Plans imported into AutoCAD.

With the .dwg files in hand, the designed lighting layout was then exported from DIALux EVO to AutoCAD.

At this stage, the outputs generated by Decalux EVO and the existing architectural drawings were merged into a single AutoCAD .dwg file, as shown on figure 27. This fusion provided a comprehensive view of the lighting design within the architectural context of the building. For better visualization, an enlarged version of the picture can be found in the appendix section.

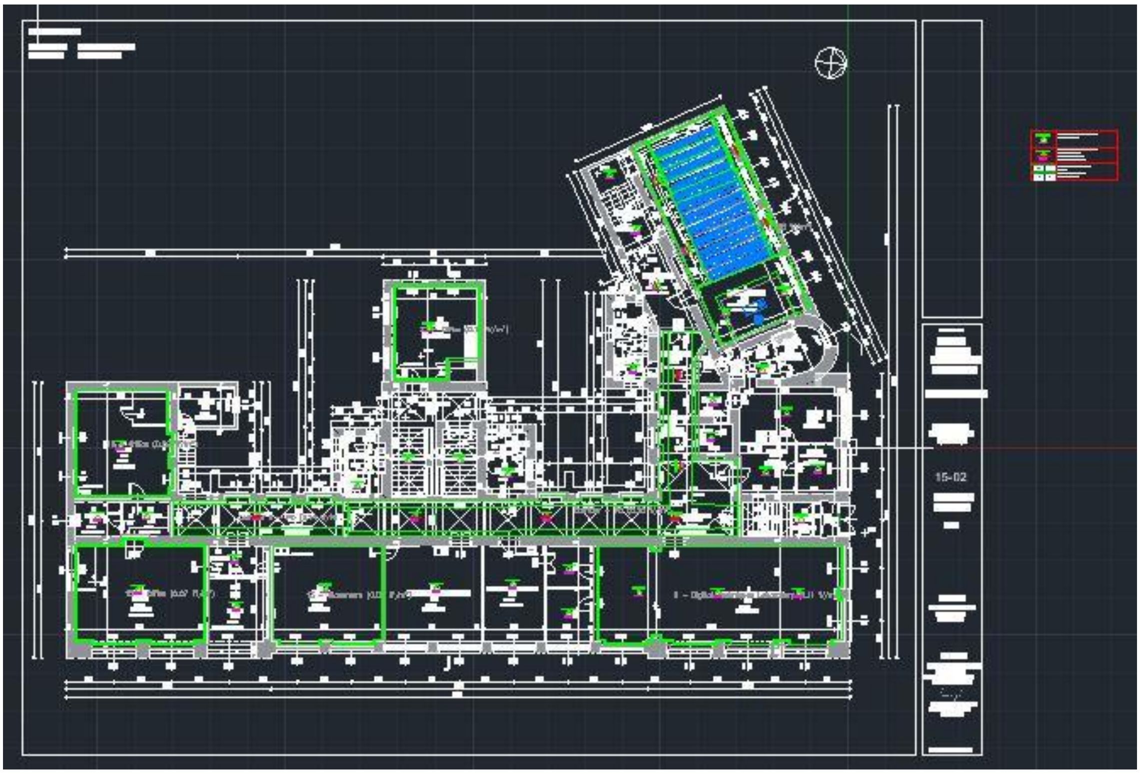

Figure 27: DIALux output and blueprint of ground floor were overlapped.

Lamps were positioned using pre-designed AutoCAD blocks (Figure 28) to represent the emergency and signalling lamps.

Figure 28: AutoCAD blocks

The design of the escape routes was also part of this phase. Placing the signal lamps in AutoCAD provided a clear visualisation of the routes to be followed in an emergency, ensuring the safety and rapid evacuation of the occupants. Figure 29 shows an example of how the signalling lamps can be positioned.

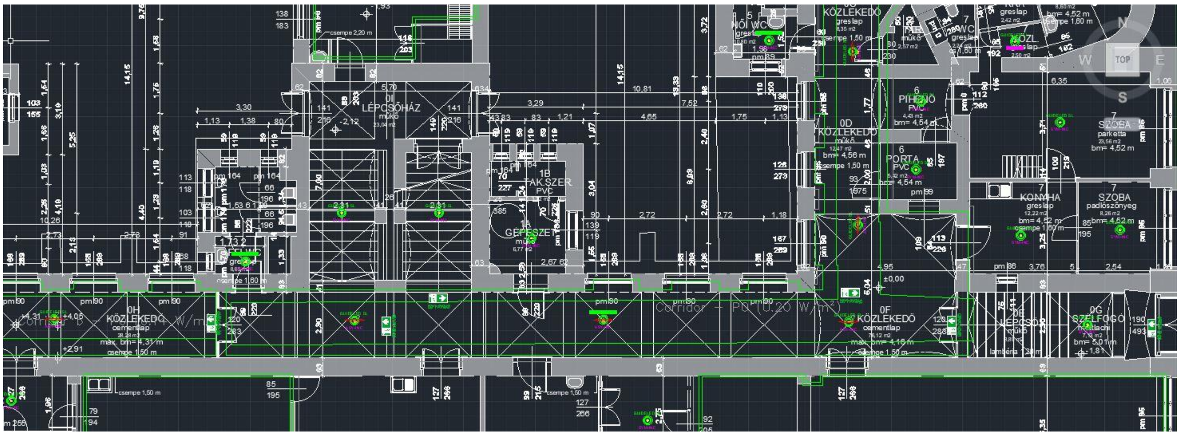

Figure 29: Positioning of signalling lamps

Taking sections of the figure 29 to showcase how the signalling logic was implemented. Figure 30 shows the exit door for the upper right corridor, guiding people from the lecture room 3.

Figure 30: Upper right corridor

Figure 31 shows the continuation of this corridor, leading to the building’s exit. One signalling lamp was placed in the middle of the entrance hall to indicate a direction change for the people coming from corridor 0D. Signalling lamps were also placed over the exit doors, before and after the stairs.

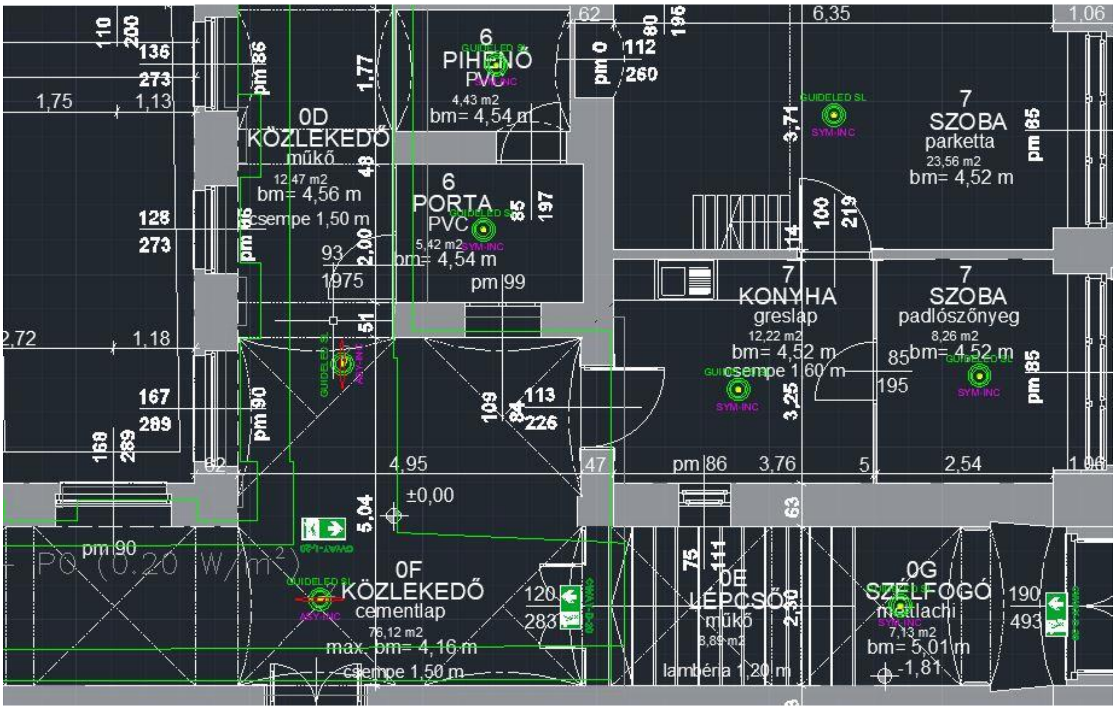

Figure 31: entrance hall and exit door.

The staircase signalling is shown on figure 32.

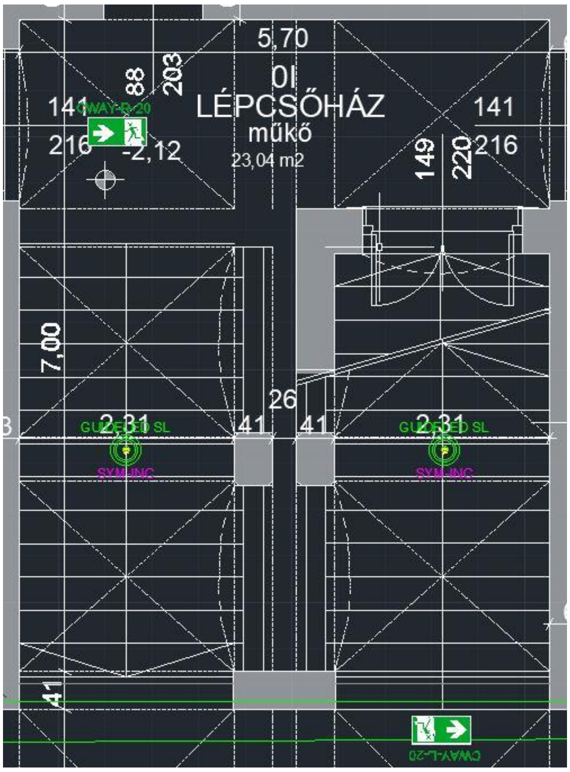

Figure 32: Staircase signalling on ground floor.

In this case, the changes of direction were indicated, as well as the direction of the exit door.

Finally, for the left side corridor, there is a signalling lamp over the exit door.

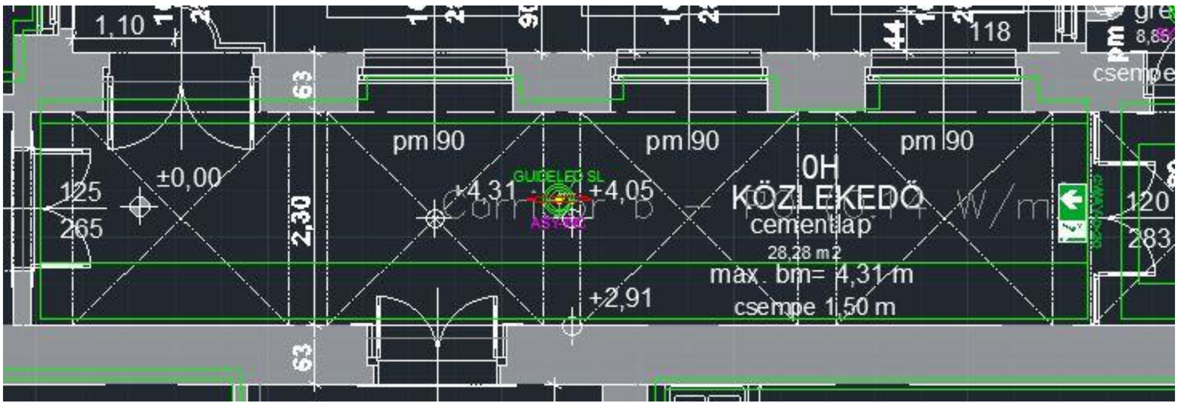

Figure 33: Left side corridor

Taking advantage to the previously shown blocks, an AutoCAD BCOUNT function was used. This allowed the exact number of luminaires required for each floor to be counted.

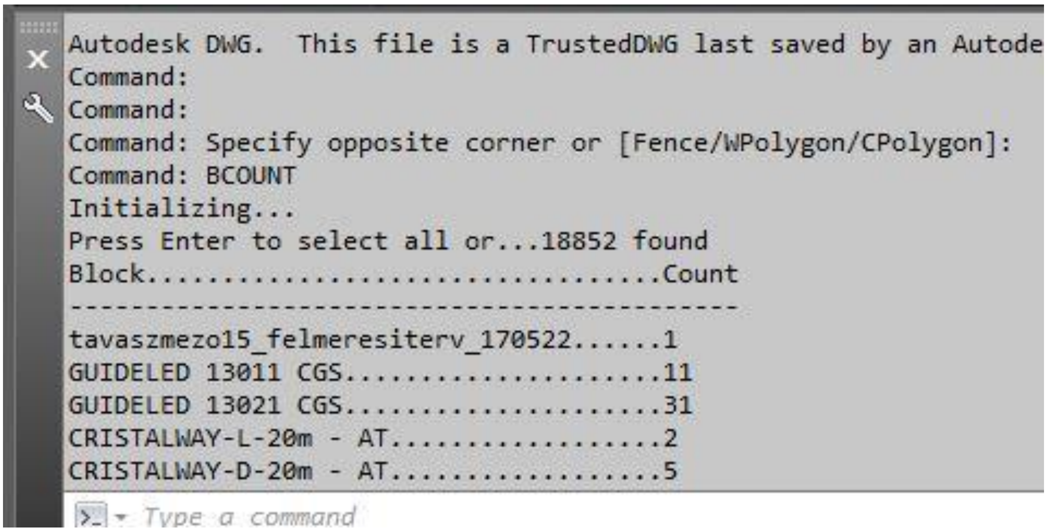

Figure 34: BCOUNT on AutoCAD

The results are shown in the tables below. It provides a clear breakdown of the luminaires required for each floor.

Table 1 gives a summary of the total number of luminaires by model, split by floor. Table 2 shows the total number of luminaires used in the whole building, broken down by model.

Floor -01	
Model	**Number of devices**
GUIDELED 13011 CGS	5
GUIDELED 13021 CGS	25
CRISTALWAY 20m	7
Floor 00	
Model	**Number of devices**
GUIDELED 13011 CGS	11
GUIDELED 13021 CGS	31
CRISTALWAY 20m	7
Floor 01	
Model	**Number of devices**
GUIDELED 13011 CGS	24
GUIDELED 13021 CGS	6
CRISTALWAY 20m	6
Floor 02	
Model	**Number of devices**
GUIDELED 13011 CGS	6
GUIDELED 13021 CGS	20
CRISTALWAY 20m	5
Floor 03	
Model	**Number of devices**
GUIDELED 13011 CGS	6
GUIDELED 13021 CGS	3
CRISTALWAY 20m	3

Table 1: Number and model of devices per floor

GUIDELED 13011 CGS	52
GUIDELED 13021 CGS	85
CRISTALWAY 20m	28

Table 2: Total number of luminaires by model

In contemplating the broader implications for the entire faculty, the consideration of a centralized versus self-contained system underscored a thoughtful approach to cost-effectiveness. The conclusion drawn from the total number of devices used in Building B suggests that a centralized system may not be economically justified, pointing towards the recommendation of a self-contained system with centralized monitoring for its practicality and efficiency.

This subsection's endeavors have not only contributed to the successful implementation of the emergency lighting system in Building B but also laid a foundation for scalable and adaptable solutions in similar contexts, demonstrating the symbiotic relationship between advanced lighting design tools and the architectural environment.

4. COMPARISON BETWEEN PROPOSED SYSTEM AND ACTUAL STATE OF THE BUILDING

As part of this case study, it is important to compare the current state of the building with the proposed system. Doing so allows one to see the improvements that the new system brings, as well as the challenges that need to be overcome.

The results of the comparison between the current state of safety signage and the proposed system will be presented in this section. The analysis is based on the following criteria:

- **Effectiveness**: Is the system effective in terms of guidance and warning of potential hazards?
- **Compliance**: Is the current system in compliance with EN1838?

It is important to note that the current safety signaling is not internally illuminated. This is a requirement of EN 1838.

The lack of backlighting on current signs poses a significant hazard in the event of a fire (Kang, 2010). Fire smoke, for example, can quickly obscure visibility, making it difficult for occupants to see exit signs or emergency instructions. Internally illuminated signage, on the other hand, remains visible in dim or smoky conditions, ensuring occupants can navigate effectively to safety.

In the event of a fire, lack of visibility can lead to disorientation and panic. This can increase the risk of injury or death. The implementation of backlighting on signalling devices is not only a requirement of EN1838, it is also a critical safety measure that can save lives. Figure 35 shows an example of fire device signaling, that should be internally illuminated. This type of signaling was not foreseen in this study since the fire plans were not present in the blueprints.

Figure 35: Pictogram for fire devices on building B

First point of comparison is the corridor adjacent to lecture room 3, on ground floor. Both approaches can be implemented. They are effective and clear. The actual design for the pictograms implements a logic of wall-mounting the signalling, at eye level. This can be observed throughout all the figures used in this section. The logic implemented in the proposed design puts the signalling over exit doors in escape routes, conforming with the EN 1838 guidelines.

Figure 36: Corridor 0B

For the two doors leading to the exit of the builting, both approches foresee signaling before and after the stairs, complying with the standards. The only difference, again, was the choice of doing so by inserting the pictograms over the doors or at eye level.

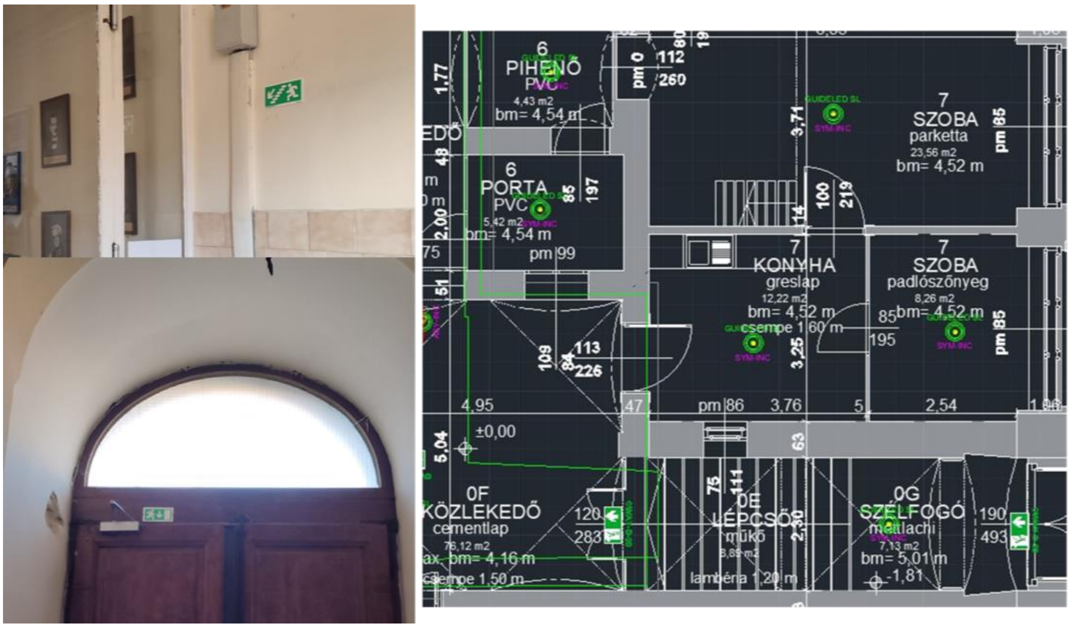

Figure 37: Building exit

The staircase signalling is similar in both the actual and proposed designs. Both show the change of direction as they should. The actual design uses a wall mounting solution whereas the proposed design uses a ceiling mounting option.

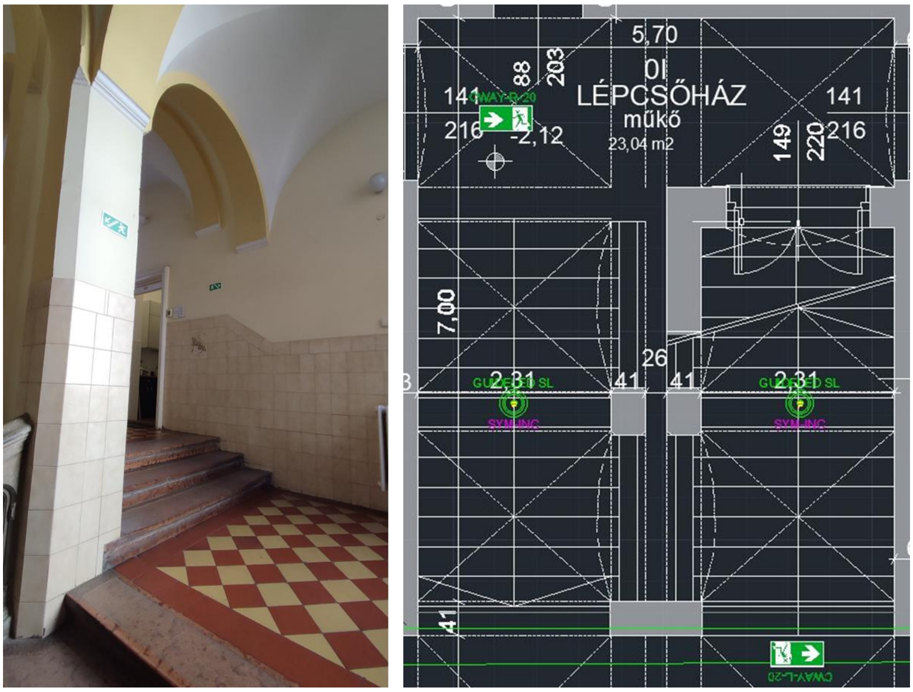

Figure 38:comparison on the staircase

In conclusion, the existing design falls short in terms of effectiveness and compliance with EN1838 standards. While the arrangement of pictograms is well-executed and bears similarity to the proposed design, the absence of internally illuminated devices renders it ineffective during emergencies, particularly in low-light or smoky conditions. The proposed system, with its adherence to EN1838 guidelines, not only rectifies this deficiency but also emerges as a critical safety measure capable of significantly mitigating risks during emergencies. This nuanced comparison underscores the imperative need for enhanced safety features in building design and reaffirms the importance of complying with established standards for the well-being of occupants in emergency situations.

5. FUTURE WORK

As the study on emergency lighting systems and their design and implementation concludes, there are several avenues for future exploration and improvement in this field.

- Integration of Adaptive Signaling Lamps: Some companies have already started implementing adaptive technology, where signaling lamps dynamically change pictograms based on real-time information about the nature and location of the emergency. Exploring and refining these adaptive features can significantly enhance the responsiveness and effectiveness of emergency guidance systems.

- Integration of Smart Technologies: Integrating smart technologies and Internet of Things (IoT) capabilities into emergency lighting systems. This could involve incorporating sensors for real-time monitoring of occupancy, environmental conditions, and system health. Smart emergency lighting systems could dynamically adjust illumination based on real-time data, enhancing energy efficiency and responsiveness during emergencies.

- Energy-Efficient Technologies: Continued research into energy-efficient lighting technologies is essential. Exploring advancements in LED technology, energy storage solutions, and sustainable power sources can contribute to the development of emergency lighting systems that are both environmentally friendly and cost-effective.

- International Collaboration on Standards: Given the global nature of building construction and safety standards, future efforts could be directed towards fostering international collaboration for the development and harmonization of emergency lighting standards. This could lead to more universally applicable guidelines that enhance safety across diverse regions and building types.

In summary, the future work in the field of emergency lighting systems should focus on harnessing emerging technologies, improving design methodologies, and understanding the evolving needs of occupants in emergency situations. By addressing these aspects, researchers and practitioners can contribute to the ongoing evolution of safety standards and the development of more effective, responsive, and sustainable emergency lighting solutions.

CONCLUSION

This thesis has undertaken a comprehensive exploration of emergency lighting systems, encompassing their significance, adherence to standards, design intricacies, and practical implementation. Beginning with a recognition of the crucial role emergency lighting plays in ensuring occupant safety during unforeseen disruptions to standard lighting.

Chapter 1, THE EN 1838 STANDARD, laid the groundwork for understanding emergency lighting, introducing critical standards and foundational concepts. The exploration of luminous metrics and safety space classifications provided a robust foundation for the subsequent chapters, setting the stage for the practical implementation of advanced lighting systems in architectural design. The principles established in this chapter serve as a guidline, emphasizing not only the technical intricacies of emergency lighting but also the imperative need for flexibility in adhering to diverse regional safety requirements.

Building upon this foundation, the second chapter delved into the technical nuances of emergency luminaires. The exploration of light distribution, including symmetrical, asymmetrical, and concentrated optics, provided insights into tailoring lighting solutions for diverse building areas. Additionally, the scrutiny of IP and IK ratings underscored the paramount importance of protection against environmental factors and mechanical impacts.

Transitioning from theory to practice, the third chapter presented a detailed case study for the Kandó Kálmán Faculty building on Tavaszmező utca, creating an emergency lighting system for the faculty building. The meticulous methodology, incorporating the use of advanced tools like DIALux EVO, followed by the positioning of the luminaires in AutoCAD, culminating in the creation of escape route plans, showcased the integration of tools, standards, and architectural considerations in the practical implementation of emergency lighting.

Using AutoCAD's BCOUNT function, the number of luminaires required for each floor was accurately determined, providing an informed basis for final system implementation.

The fourth chapter undertook a critical comparative analysis between the proposed emergency lighting system and the existing state of the building. Assessing effectiveness and compliance with EN1838 standards, this section underscored deficiencies in the current system, emphasizing the imperative need for enhanced safety features in building design.

In conclusion, this work highlights the importance of adherence to safety standards and best practice in the design and implementation of emergency lighting systems. The integration of theoretical principles with a practical case study not only advances academic understanding but also underscores the evolving landscape of architectural design, where illumination during emergencies signifies a commitment to life and safety. As buildings become more complex and diverse, the role of emergency lighting stands as a testament to the unwavering commitment to creating environments that prioritize and safeguard human life. The imperative for safety in architectural design is not just a regulatory requirement; it is a profound commitment to ensuring that spaces, even in their darkest moments, can guide occupants to safety and security.

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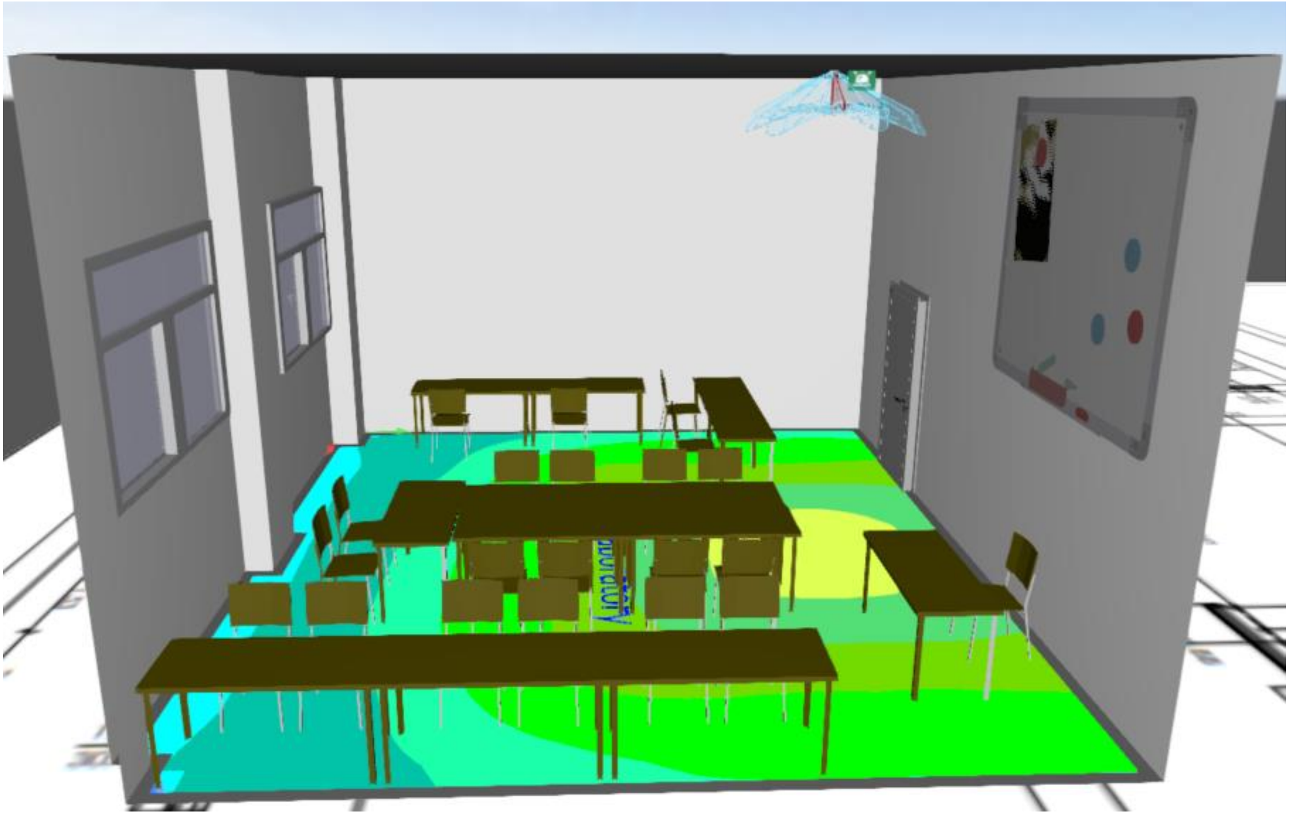
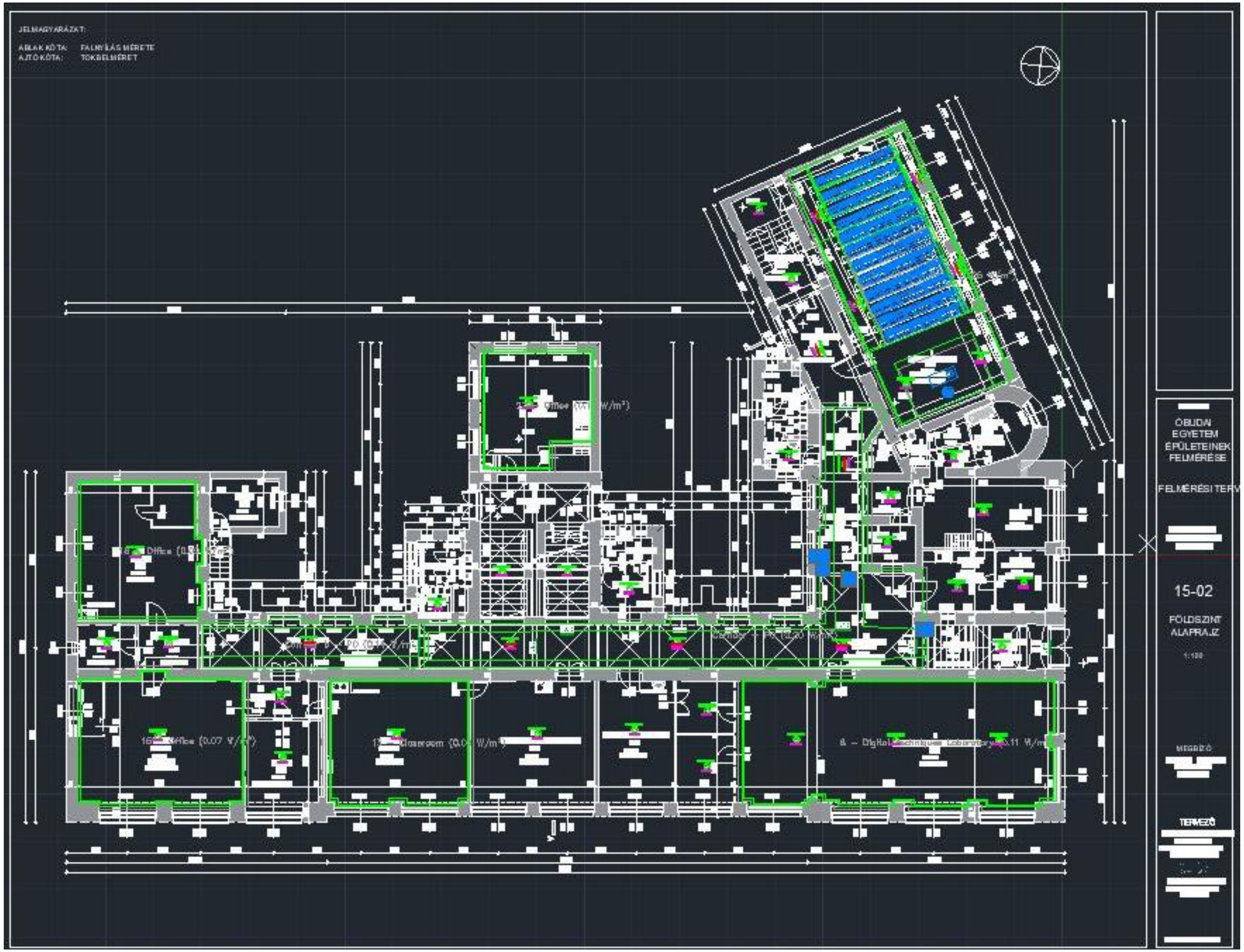
APPENDIX



Picture 1: 3D drawing of room 214

Picture 2: Blueprint of the 2nd floor imported to DIALux.



Picture 3: DIALux output and blueprint of ground floor were overlapped

More annexes are available at:

https://drive.google.com/drive/folders/1Cnr_g8RE2KDf7JMiU3OEkNrTUZddpjos?usp=sharing