D4.1: EVALUATION AND MEASUREMENT OF THE INDUCED ENERGY SAVINGS ALLOWING THE COMPLETION OF A TECHNICAL "GUIDE OF APRON LIGHTING" - FINAL REPORT

OPTIMIZED DYNAMIC APRON LIGHTING

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Coordinator	Virginie Pasquier	ADP	06/02/2025	OK
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V01	28/01/2025	Initial version	A. Rodon (ADP)
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1 Introduction

In 2018, Groupe ADP wanted to produce a lighting guide for aprons, in order to ensure identical sizing and performance levels for the Group's airports.

This document initially presented the power supply principles and the performance to be achieved in terms of ground lighting. It also contained the control tools, then limited to *on/off control*.

The advent of LED lighting has made it possible to significantly develop light dimming. An update of the guide integrated this new control and monitoring method.

It was then necessary to question the control tools, to optimize both the environmental impact of lighting (consumption, maintenance, light pollution) and comfort on the aircraft stand (and, in fact, safety and security).

2 Final Report – Optimized Dynamic Apron Lighting

As part of the OLGA project, and more precisely task 4.1.1, this subject of control optimization was investigated: a broad benchmarking of existing solutions was carried out, followed by in situ tests, to finally choose the TWR data to ensure the actions of switching on, switching off and reducing the lighting levels on the aprons. The three steps are described below:

- **Step 1:** switch to LED lighting instead of High-Pressure Sodium, through a precise lighting study

The lighting study was carried out with Signify (through an existing tender), and lead to replace 184 HPS fixtures (unit power 400 W) to 40 LED fixtures (unit power 1498 W),

The consumed energy appeared then to be reduced by more than 35 %.

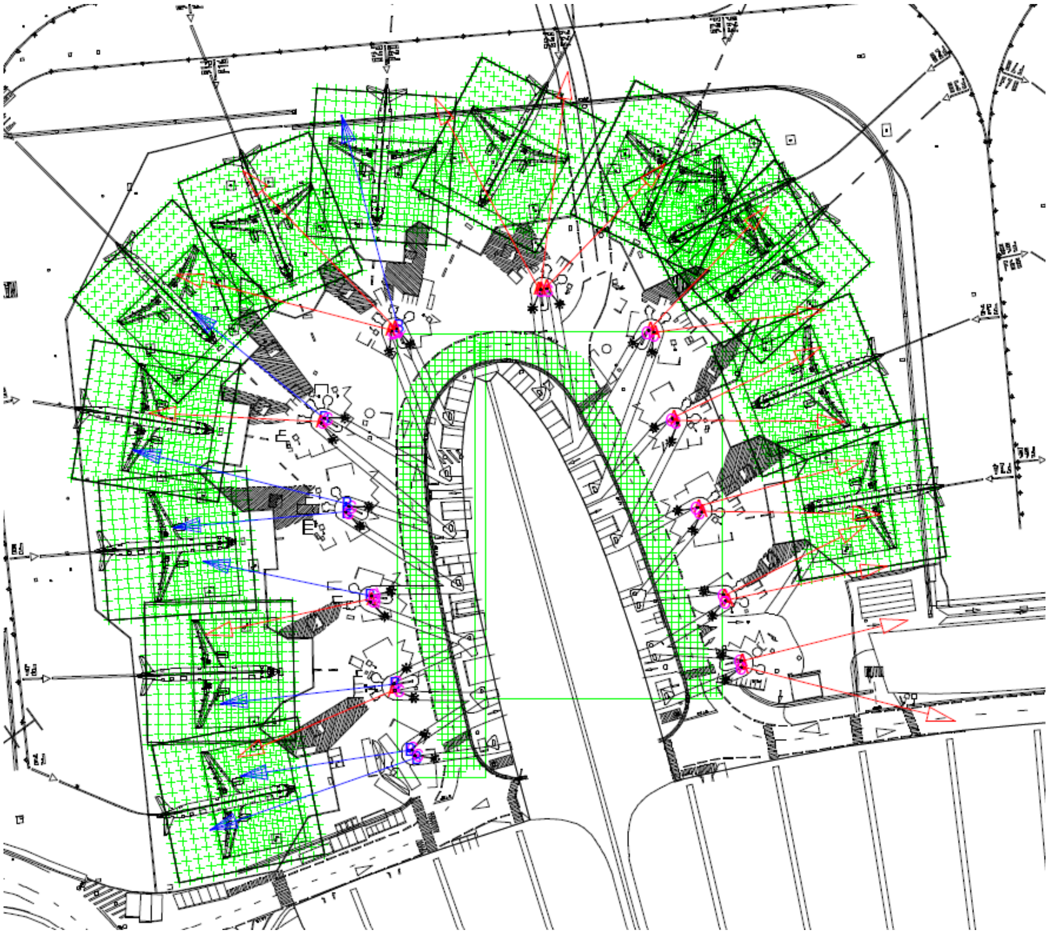

Figure 1: Lighting study with fixtures and calculation grids

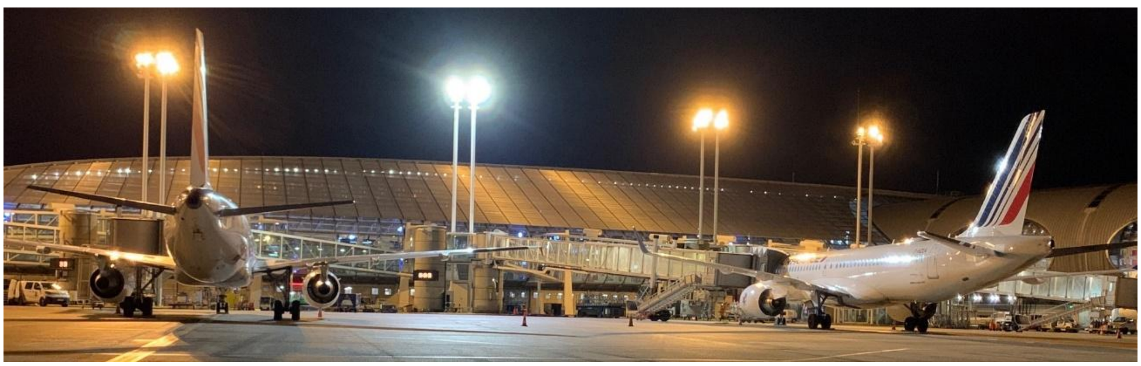

Figure 2: Terminal 2F first pole with LED fixtures

Figure 3: Terminal 2F poles with LED fixtures, and electrical cabinets

- **Step 2:** benchmark French and European airports, about the use of sensors (cameras, light and presence detector, …) and/or of TWR data, to pilot apron lighting

Discussions were lead with several airports, including French airports (Beauvais, Pau, Marseille, Ajaccio, Lyon) and a fellow-airport (Zagreb). Failure problems were raised with cameras (speed of vehicles, low visibility conditions, vibrations, …). The implementation of captors in the ground has also been tested in some airports, but feedback is bad through costs, maintenance constraints and weakness of equipment.

- **Step 3:** experiment and improve light optimization using TWR data, including, a measurement of energy impact:
  - HPS to LED lights: saving energy ~ 40 %,
  - "Common" lighting graduation: saving energy ~ 10 % more,
  - Optimized dynamic apron lighting through TWR data ~ 10 % more.

Figure 4: Final Terminal 2F LED apron lighting

An isolated presentation of this new control mode was not possible, since it would have been essential to redefine the regulatory and technical issues leading to these choices. It was thus decided to present these results through a new version of the apron lighting guide.

This version is intended not only to be used across the Group's airports, in France and other countries, but also to be shared widely with French and European airports, starting with Zagreb airport where a future replication of the system will take place.

3 Appendix: DESIGN GUIDE: AIRCRAFT STAND LIGHTING

Application date:
23/01/2025

Reference:
ECPTE/2025_01

DESIGN GUIDE:
AIRCRAFT STAND LIGHTING

Version	Date	Purpose of revision	Pages modified
01	12/06/2018	First publication	All
02	08/11/2024	Update – Smart control integration (OLGA)	All
02.2	23/01/2025	Internal ADP approval	21

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Contents

1. Introduction

1.1. Purpose

This document establishes the lighting functions required for aeronautical operations. Among other things, it sets out the general principles for installing and sizing the various equipment.

Please note that the installation specifications provided in this document are for guidance purposes only; other methods of installation may be considered if those recommended are not applicable.

1.2. Scope

The content of this document applies to permanent lighting installations, as opposed to temporary installations.

This document is intended for the departments responsible for the design, installation, maintenance and/or operation of lighting at airports and aerodromes.

1.3. Regulatory references

There are two types of international requirements in the field of visual aids and power supplies: those relating to aeronautical infrastructure, mainly governed by the International Civil Aviation Organization (ICAO), and those relating to electricity, in particular the International Electrotechnical Commission (IEC).

1.3.1. Texts relating to aeronautical infrastructure

International Civil Aviation Organization (ICAO)

- Annex 14 to the Convention on International Civil Aviation – Volume I Aerodrome Design and Operations
- Aerodrome Design Manual – Part 4 - Visual Aids (Doc 9157 AN/901)

European requirements in the field of visual aids and power supplies (EASA):

- Book 1, Chapter M “Visual aids for navigation” and Chapter S “Electrical systems” (“certification specifications”) and, more specifically, CS-ADR-DSN-M750
- Book 2, guidance material for airport design

1.3.2. Texts relating to lighting

European requirements for workplace lighting:

- NF EN 12464-2: Light and lighting – Lighting of workplaces – Part 2: outdoor workplaces
- French Employment Code
- Regulations on accessibility for disabled people to public buildings and areas, and facilities open to the public

1.3.3. Texts relating to electricity

French requirements for workplace lighting:

- NF C15-100-x series: low-voltage electrical installations
- NF C17-200: external electrical installations

1.3.4. Environmental issues

As far as possible, the project will comply with the requirements of the Decree of 27 December 2018 on the prevention, reduction and limitation of light pollution.

1.3.5. Cybersecurity

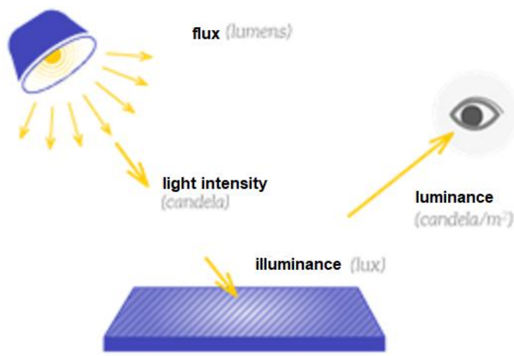
According to local instructions, the aerodrome/airport, operator or geographical area concerned.

1.4. General definitions

Luminous flux: [Lumen (lm)] Total quantity of light emitted by a light source in all directions, without specifying the distribution of the light.

Illuminance: [Lux (lx = lm/m²)] Refers to the quotient of luminous flux received by a surface by its area. It characterises the amount of light received per surface unit. There are different types of illuminance:

- Initial illuminance: the illuminance when the source is first activated
- Illuminance to be maintained: minimum illuminance before maintenance, which corresponds to the product of the initial illuminance and a depreciation factor
- Horizontal illuminance: the illuminance measured on a horizontal surface, on the ground or on an imaginary plane (luxmeter cell facing the sky)
- Vertical illuminance: the illuminance measured on a vertical surface, perpendicular to the ground. The luxmeter cell must be aimed in the right direction (pilot's eye, docking the boarding bridge walkway or freight vehicles, etc.). The same point can therefore be linked to several directions and, thus, to several vertical illuminance values



Light intensity: [Candela (cd)] Quantity of light emitted in a given direction. It is linked to glare.

Luminance: [cd/m²] Luminance is the visual sensation of the brightness of a surface. With equal illuminance, a very bright surface will have a high luminance, whereas a perfectly black surface would have zero luminance.

Uniformity: illuminance uniformity characterises the variations in illuminance level and is defined as the ratio between the minimum illuminance and the average illuminance observed in the area.

Light efficiency: [lm/W] Ratio between the luminous flux emitted and the electrical power of the source or luminaire.

1.5. Airport areas

Movement area: part of an aerodrome used for take-offs, landings and taxiing. It includes the manoeuvring area and aprons.

Manoeuvring area: part of an aerodrome used for take-offs, landings and taxiing. It excludes aprons.

Apron: an apron is a defined area on an aerodrome for aircraft to board and disembark passengers, load and unload mail or freight, refuel, park or undergo maintenance. Sufficient lighting must be provided to enable these tasks to be carried out safely and efficiently at night.

De-icing area: a de-icing area is an area used for de-icing aircraft.

Safety line: delimits the apron intended for use by ground vehicles and other refuelling and aircraft maintenance equipment, etc., to ensure a safe demarcation from aircraft within the manoeuvring area.

2. Objectives and regulations

2.1. Basic rules for lighting

2.1.1. General information

According to "ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting – 13.2.1":

- Assist the pilot in taxiing the aircraft into and out of the final parking position
- Provide lighting suitable for passengers to embark and disembark and for personnel to load and unload cargo, refuel and perform other apron service functions
- Maintain airport security

2.1.2. Control tower

According to "ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting – 13.3.7":

- The orientation of the floodlights must be designed so as not to interfere with air traffic controllers in the control towers

2.1.3. Pilot

According to "ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting – 13.3.7":

- The orientation of the floodlights must be designed so as not to interfere with pilots during landing and taxiing. They must be able to easily see runway lighting

2.2. Regulatory content

2.2.1. ICAO – Annex 14 – Volume 1 – Aerodromes – Aerodrome Design and Operations – July 2016

5.3.24.4 Recommendation – The average illuminance should be at least the following:

Aircraft parking stand:

- Horizontal illuminance – 20 lx, with a uniformity ratio (average intensity/minimum intensity) of no more than 4 to 1
- Vertical illuminance – 20 lx at a height of 2m above the apron in relevant directions

  Other areas:

- Horizontal illuminance – 50% of the average illuminance on the aircraft stands, with a uniformity ratio (average intensity/minimum intensity) of no more than 4 to 1

2.2.2. ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting

Airport security:

13.2.4 Illuminance should be sufficient to detect the presence of unauthorised persons on the apron and to enable the identification of personnel on or near aircraft stands.

2.2.3. ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting

Emergency lighting:

13.3.9 To cover the possibility of a power failure, it is recommended that provision be made for sufficient illumination to be available to ensure passenger safety.

2.2.4. EASA – CS-ADR-DSN – Issue 4 – December 2017 – Chapter M.750

(a) The purpose of apron floodlighting is to facilitate safe operations on an apron, on a de-icing/anti-icing facility, and on a designated isolated aircraft parking position intended to be used at night.

(b) Applicability: Apron floodlighting should be provided on an apron, as necessary on a de-icing/anti-icing facility, and on a designated isolated aircraft parking position intended to be used at night. Aprons primarily used for recreational flying need not be illuminated.

(c) Location: Apron floodlights should be located so as to provide adequate illumination on all apron service areas, with a minimum of glare to pilots of aircraft in flight and on the ground, aerodrome and apron controllers, and personnel on the apron. The arrangement and aiming of floodlights should be such that an aircraft stand receives light from two or more directions to minimise shadows.

(d) Characteristics:

(1) The spectral distribution of apron floodlights should be such that the colours used for aircraft marking connected with routine servicing, and for surface and obstacle marking, can be correctly identified.

(2) The average illuminance should be at least the following:

(i) Aircraft stand:

(A) Horizontal illuminance — 20 lux with a uniformity ratio (average to minimum) of not more than 4 to 1; and

(B) Vertical illuminance — 20 lux at a height of 2 m above the apron in relevant directions.

(ii) Other apron areas: horizontal illuminance — 50 % of the average illuminance on the aircraft stands with a uniformity ratio (average to minimum) of not more than 4 to 1.

2.2.5. EN 12464-2 Standard: Lighting of outdoor workplaces:

Ref. no.	Type of area, task or activity	$\bar{E}_m$ lx		U_o	R_{GL}	R_a	Specific requirements
		required[a]	modified[b]				
General							Direct light in the direction of the control tower and landing aircraft shall be avoided. Direct light emitted above horizontal from floodlights should be restricted to the minimum.
12.1	Hangar apron	20	–	0,10	55	40	
12.2	Terminal apron	20	–	0,25	50	40	Daylight hours may require higher lighting levels.
12.3	Loading areas	20	30	0,25	50	40	Localised lighting with $\bar{E}_m$ = 50 lx can be used for reading labels.
12.4	Fuel depot	50	–	0,25	50	70	
12.5	Aircraft maintenance stands	200	300	0,50	45	70	

NOTE For aircraft stand, see EASA chapter CS ADR-DSN.M.750 Apron floodlighting or ICAO, Annex 14.

[a] Required: minimum value.

[b] Modified: considers common context modifiers in 5.3.3.

Explanation of the table:

- **Column 1** lists the **reference** number for each area, task or activity.
- **Column 2** lists those **tasks areas or activities areas**, for which specific requirements are given. If the particular task or activity is not listed, the values given for a similar, comparable situation should be adopted.
- **Column 3** gives the **required maintained illuminance** $\bar{E}_m$ on the reference surface (see 5.3) for the area, task or activity given in Column 2.
- **Column 4** gives the **modified maintained illuminance** $\bar{E}_m$ considering common context modifiers when the visual conditions differ from the normal assumptions (see 5.3.3) on the reference surface (see 5.3) for the outdoor (area) in which the task or activity from Column 2 is performed.
- **Column 5** gives the **minimum illuminance uniformity** U_o on the reference surface (see 5.3.6) for the area, task or activity given in Column 2.
- **Column 6** gives the **Glare Rating limits** (R_{GL}) where these are applicable to the situations listed in Column 2 (see 5.4)
- **Column 7** gives the **minimum colour rendering indices** (R_a) (see 5.7.3) for the situation listed in Column 2.
- **Column 8** gives **specific requirements** for the situations listed in Column 2.

2.2.6. Decree of 27 December 2018 – Light pollution

This text includes a series of measures to reduce the impact of outdoor lighting on light pollution.

A request for clarification of the scope of application was made within Groupe ADP in June 2019; the response provided by the Ministry of Ecological and Inclusive Transition confirms that parking area lighting installations are, due to their nature, outside the scope of the directive because they are related to operational safety.

However, it is necessary to consider certain recommendations of this text, namely:

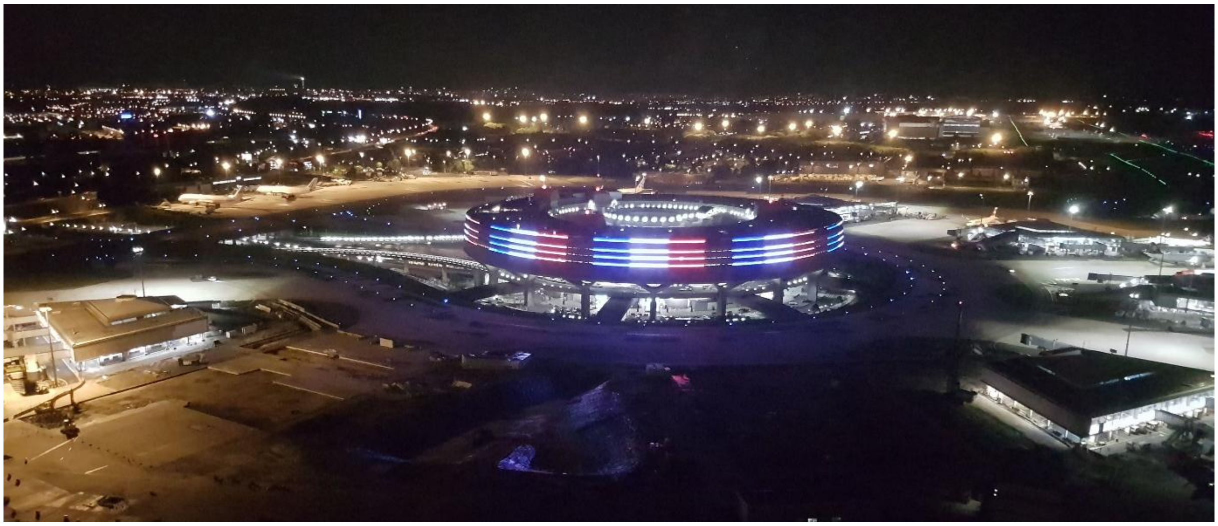
- Limiting the colour temperature to 3000K (Article 3, Paragraph 2 – Point 3)
- No luminous flux may be emitted beyond the horizontal (Article 3, Paragraph 2 – Point 1)

It should be noted that the greatest contribution to light pollution from aircraft parking stand lighting comes from light reflecting off the light pavement (concrete). Reducing the luminous flux and optimising control are therefore major challenges in reducing light pollution at airports.

3. General information on LED technology

3.1. Introduction

As part of the drive to optimise energy consumption and given the range of products on offer from manufacturers, LED technology has become the preferred choice for aircraft parking areas, gradually and definitively replacing high-pressure sodium technology.



This technology provides optimised light control. As such, the introduction of “smart” control (as opposed to a simple on/off switch) leads to additional energy savings and optimised lighting conditions.

3.2. Energy benefits and new challenges

The switch to LED technology and the introduction of smart lighting will both save energy and reduce maintenance costs.

LED technology:

- Offers greater floodlight efficiency (compared with fixtures fitted with high-pressure sodium or metal halide lamps)
- Significantly increases lifespan, while reducing associated maintenance costs and impacts on aircraft stand operations
- Responds to the obsolescence of high-pressure sodium lamps (no longer produced)

Smart lighting:

- Reduces energy consumption
- Reduces luminous flux, and therefore light pollution, when on-stand operations allow (see following sections)
- Increases the lifespan of LEDs

Experiments have been carried out to compare energy savings at constant lighting levels after switching to LED technology and smart lighting. The results, which incorporate the latest tests carried out as part of the OLGA project *, and more specifically task WP4.1.1 *"Optimised Dynamic Apron Lighting",* are summarised in the table below:

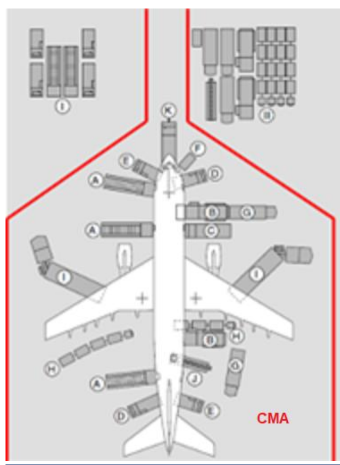
Old technology	Replaced by	Energy saving
Old model high-pressure sodium lamps	LED	50%
New model high-pressure sodium lamps	LED	20%
Constant lighting controlled manually or automatically	Smart lighting (dynamic apron lighting) (see 6.2.1.2)	20-30% extra
Smart lighting (dynamic apron lighting)	Optimised smart lighting (optimised dynamic apron lighting) (see 6.2.1.3)	Up to 20% extra

** OLGA : hOListic & Green Airports (OLGA) is a Horizon 2020 project that aims to reduce the environmental impact of the aviation sector. It develops innovative and sustainable solutions to reduce CO2 emissions,* *optimise energy efficiency, preserve biodiversity, and improve air quality and waste management while involving the entire aviation value chain.*

4. Aprons

4.1. Apron areas

Controlled movement area (CMA): a CMA only exists when an aircraft is present at its parking position. This area may be marked with a red line edged in white. International rules set out the procedures for accessing this area for all airside vehicles, which are supplemented by airport operating regulations that may set out special cases.



Airside service area: this is the area between the CMA and the end of the apron.

4.2. Positioning and orientation of lighting

4.2.1. Choice of location and height of floodlights

4.2.1.1. Physical characteristics:

ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting – 13.4.2:

The ultimate choice of the location and height of the floodlights depends upon:

a) Dimensions of apron(s)

b) Arrangement of aircraft stands

c) Taxiway arrangement and traffic scheme

d) Adjacent areas and buildings, especially control tower(s)

e) Location and status of runway(s) and helicopter landing areas

4.2.1.2. Glare:

ICAO – Aerodrome Design Manual – Part 4 – Visual Aids – Chapter 13 Apron Lighting – 13.3.8:

To minimise direct and indirect glare as much as possible:

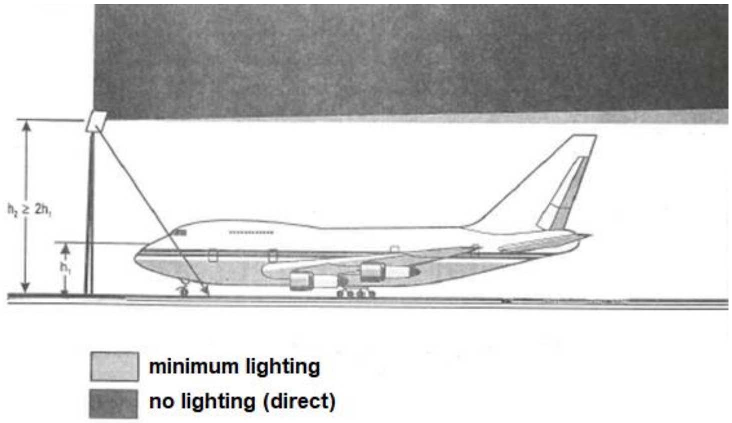
Regulation: the mounting height should be at least two times the eye height of pilots.

For example, on a Boeing 747 or A380, the pilots' eyes are at a height of 8m, so masts must be at least 16m high.

Stakeholder recommendations: as high as possible, subject to maintenance and accessibility constraints.

Issue: always check aeronautical and radioelectric easement constraints at the start of the design phase, which can have an impact on height limits.

Practical application: on average, Groupe ADP installs masts of between 20-35 metres tall, unless there are problems with easements.

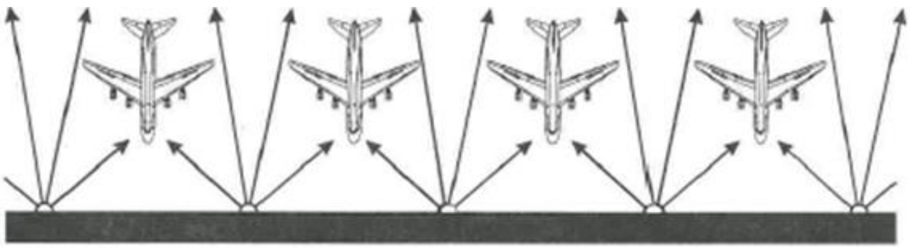


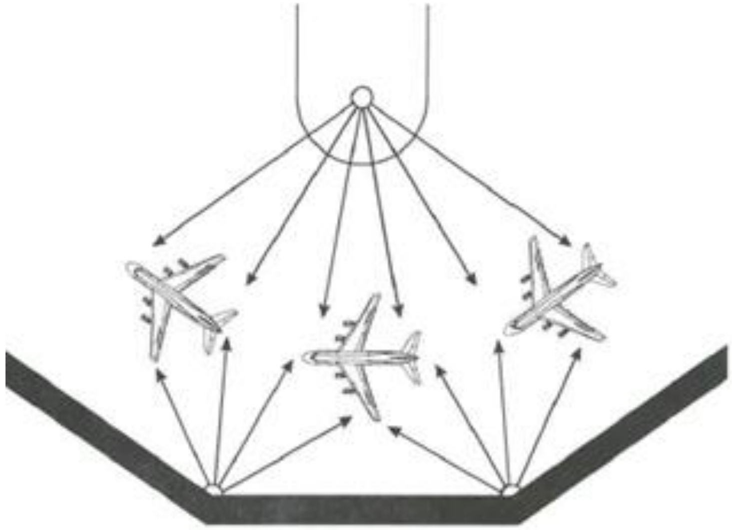
The taller masts are, the more the luminous flux from the floodlights is directed towards the ground: this guarantees (although calculations and measurements can be carried out when the lighting is designed and/or commissioned) a reduction in light pollution, mainly due to the absence of luminous flux emitted above the horizontal. It also provides a higher level of illuminance behind the apron.

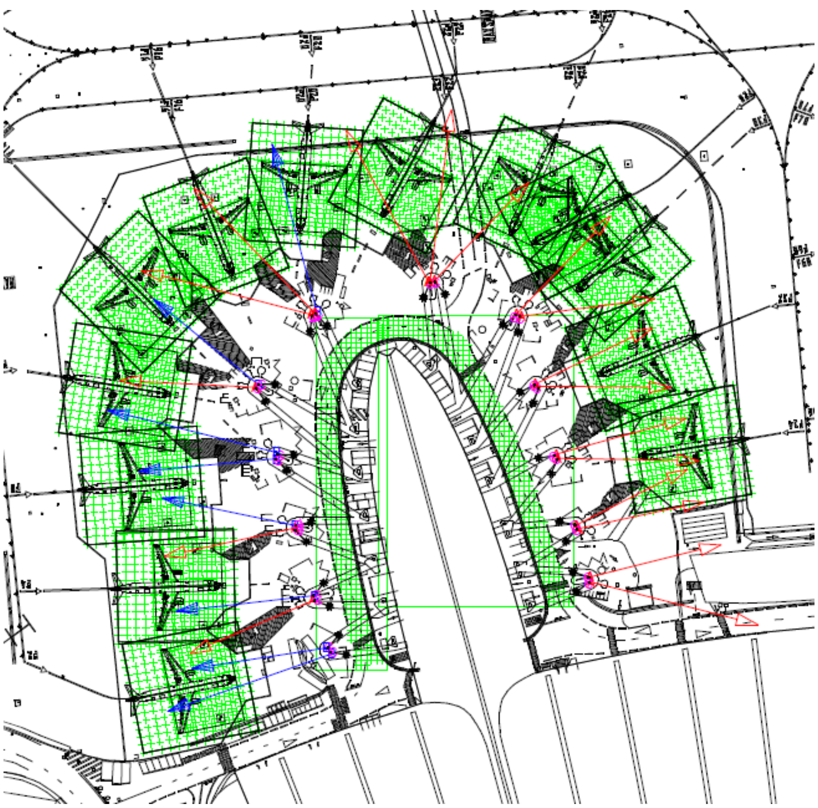
4.2.1.3. Positioning

The position of lighting poles depends on a number of factors, not least the configuration of the areas where they will be installed:

- Dimensions of apron(s)
- Arrangement of aircraft stands
- Adjacent areas and runways







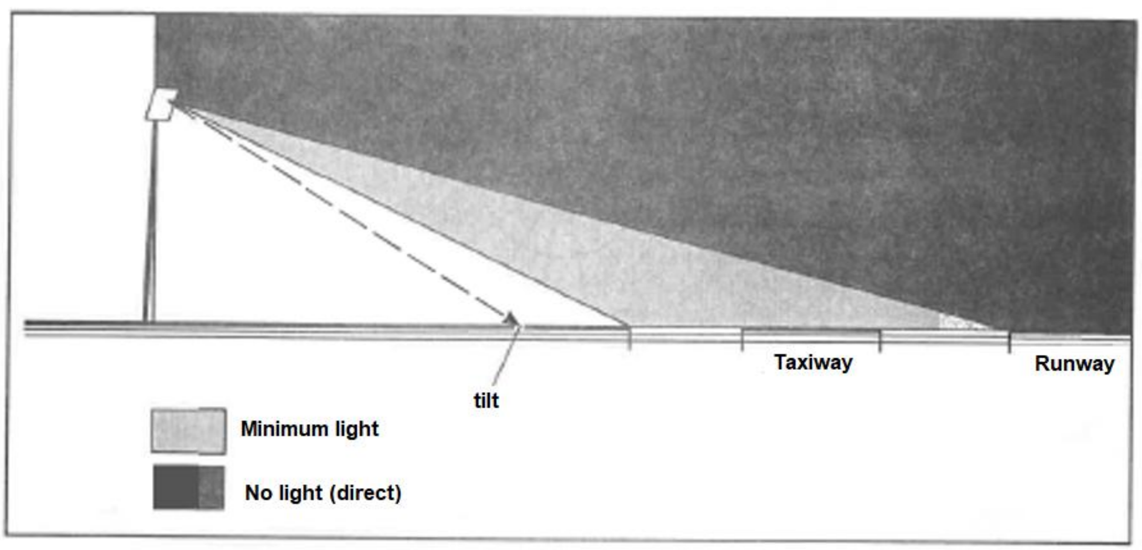
For straight aprons, masts should be positioned between aircraft stands (as shown in the first image) in order to allow overlapping of light and to limit the casting of shadows.

It is preferable to avoid placing masts directly in the centre of stands to avoid glare for pilots and to avoid constraining pushback. However, this arrangement is interesting from a technical and financial point of view, as it allows masts to also support the aircraft stand's identification panel and even the guidance system. However, it places too great a strain on pilot comfort when parking the aircraft and should therefore be avoided, if possible.

4.2.1.4. Orientation

The orientation of lighting depends on a number of factors:

- The optics of the chosen floodlight
- The layout of the area and, in particular, the positioning of parking areas
- Glare constraints
- The characteristics of the area to be lit



4.2.1.5. Number of floodlights per mast

The number of floodlights per mast depends on the configuration of the area and then on the photometric study, which determines the number of pieces of equipment needed to achieve required lighting levels.

The increased unit power of LED floodlights means that masts can now be fitted with just one or two floodlights (e.g. power now reaching 1500-1800W for standard products). It is essential to consider the consequences of reducing the number of floodlights as part of the design stage:

- Cost savings through a reduction in support constraints, the number of cables to be positioned in the mast shaft, the number of drivers and the volume of the mast foot cabinet
- Operational issues: in the event of a floodlight failure, immediate intervention required (stand(s) inoperable)
- Control issues: impossible to have conclusive, stand-by-stand control

4.2.1.6. Mast-to-aircraft and inter-mast distances

The required distance between masts and aircraft depends on where the aircraft's nose wheel stops (which varies across the airport).

The required distance between masts themselves depends on site constraints, aircraft types (code) and any other constraints resulting from the photometric study.

It is typically 60-70m.

4.3. Apron statuses

Apron areas can have four different statuses considered as use cases:

- Case 1 – Free stand: free and available parking stand (no CMA)
- Case 2 – Free stand awaiting parking: free parking stand (no CMA), but the stand has been allocated to an aircraft on approach
- Case 3 – Stand occupied with handling: stand with a parked aircraft (CMA), in addition to passenger boarding or disembarkation operations, loading or unloading of mail or freight, refuelling, maintenance or other services being carried out on this aircraft
- Case 4 – Stand occupied without handling: stand with a parked aircraft (CMA) but no ground handling operations being carried out on the aircraft

4.4. Apron illuminance (lux)

AREA	Terminal area – safety line		Airside service area	
ILLUMINANCE	Minimum at an altitude of 2m	Recommended for LED	Minimum	Optimal
Case 1 – Free stand	10	10	10	10
Case 2 – Free stand awaiting parking	20	30(1)	20	30(1)
Case 3 – Stand occupied with handling	20	30(1)	20	30(1)
Case 4 – Stand occupied without handling	10	10(2)	10(2)	10(2)

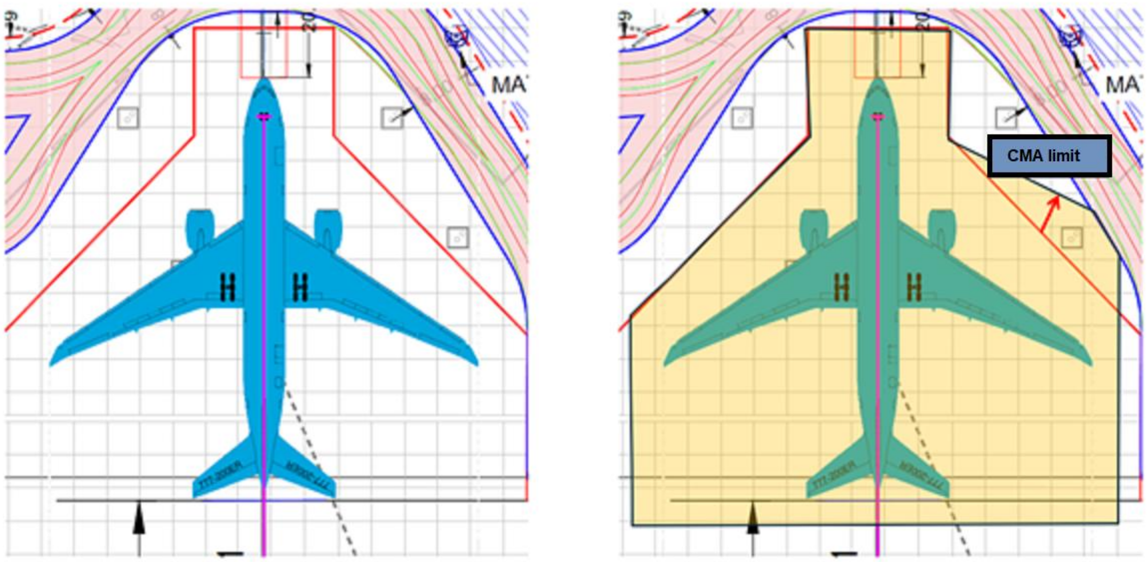
(1): Unless otherwise requested by operators.

(2): Barring any security constraints.

In the absence of any regulatory clarifications on the exact position of the calculation area in relation to the aircraft, using the entire aircraft as the calculation area is standard practice.

This illuminance calculation area must include the following parameters:

- Front: CMA line or 10m ahead
- Sides: 5m (code C) or 7.5m (code E), except for more restrictive configurations, such as de-icing on parking stands
- Back: safety line or 5m behind the tail



4.5. Lighting level readings

4.5.1. Lighting studies to be carried out or commissioned

Regulatory approval is carried out against the grid located 2m above ground level.

In practice, approval at ground level is sufficient, and compliance with lighting levels at ground level (and uniformity) guarantees compliance at 2m above ground level.

However, in order to comply exactly with EASA requirements, it is recommended that you ask the manufacturer and/or supplier of the lighting equipment for:

1. A study of the illuminance to be maintained, 2m above ground level
2. A study of the illuminance to be maintained, at ground level
3. A study of the initial illuminance, at ground level

The first study ensures EASA compliance.

The second will be useful for monitoring compliance of the installation over its lifespan.

The third will compare the readings with the theoretical values.

4.5.2. Initial readings upon commissioning

These readings should be carried out by an approved body in order to ensure a neutral position vis-à-vis the operator and other companies concerned (airlines, ground handling service providers, government departments).

They may be preceded by a simplified series of readings, by the prime contractor or works company, at a few positions, to ensure that the calibration is consistent between the in situ installation and the theoretical study.

It is also advisable to obtain a lighting study with the layout of concrete slabs and signage markings in the background. This makes it easier to create the mesh of measurement points.

4.5.3. Regular compliance approval

These readings must be taken regularly, at intervals of between 3-5 years, unless an event relating to lighting quality is reported.

They must demonstrate compliance with the lighting levels to be maintained (study 3).

5. De-icing areas

5.1. De-icing areas

De-icing area: the part of an aerodrome where aircraft are de-iced. These areas are generally close to the runways. Aircraft and de-icers are simultaneously present in these areas.

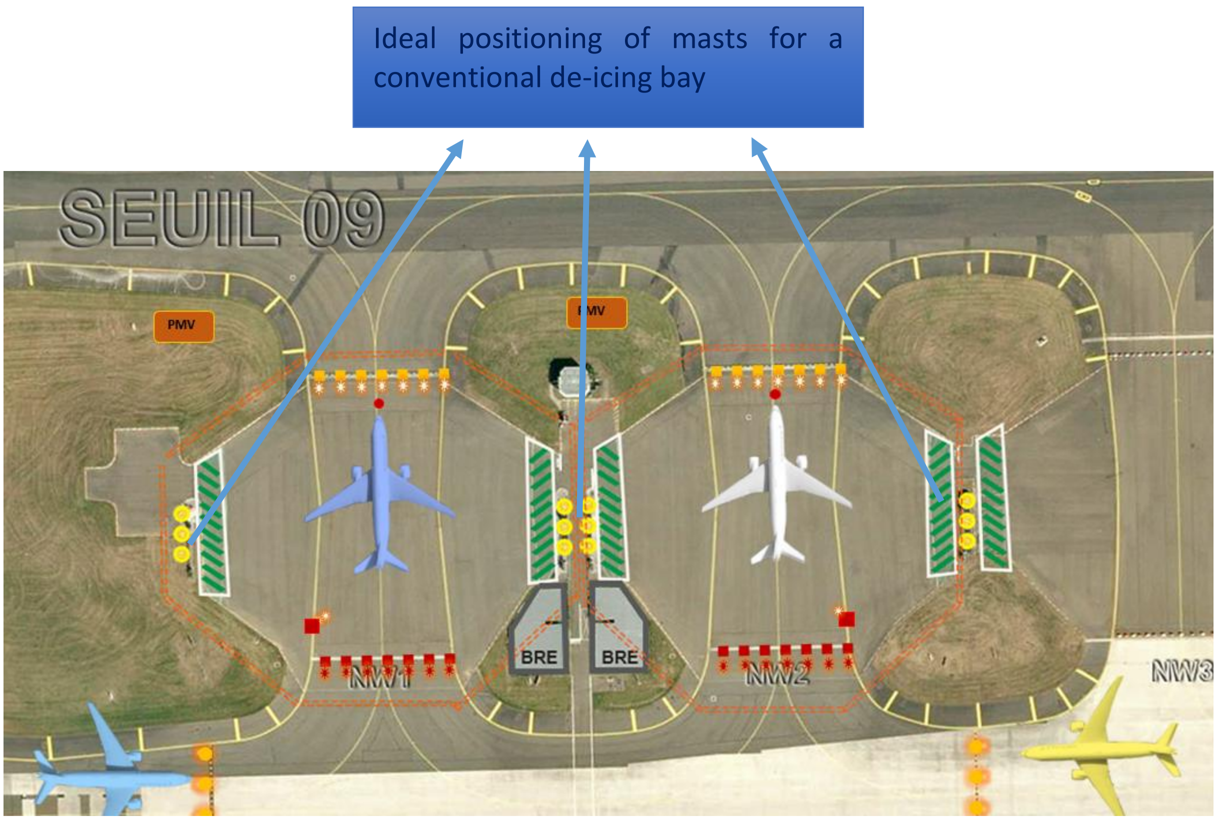
5.2. Positioning of lighting

Masts for de-icing areas must be positioned, if the location allows, on either side of the aircraft wings and outside the de-icer fallback areas.

As mentioned in paragraph 4.2.1.2, masts must be at least twice the height of the pilots' eyes.

Within de-icing areas, masts are generally fixed. Where there are radioelectric easements, they can be tilted and raised only when these areas are in use. Particular attention must therefore be paid to:

- Securing tilting movements
- The issue of tilting vibrations (impact on electrical and electronic components), especially if the lights are switched on or recently switched off (heat, increased risk to components)



5.3. De-icing area statuses

De-icing areas can have two different statuses considered as use cases:

CASE 1 – Active stand de-icing/awaiting aircraft: stand in the process of de-icing an aircraft, or about to do so. In other words, a de-icing team is stationed there

CASE 2 – Inactive stand: stand where no de-icing action is planned (no de-icing team is stationed there)

5.4. De-icing area illuminance (lux)

AREA	De-icing areas	
ILLUMINANCE	Minimum height of 2m	Optimum value
CASE 1 – Active stand de-icing/awaiting aircraft	20	30
CASE 2 – Inactive stand	0	0

6. Power supply/control/feedback

6.1. Electricity supply

6.1.1. Normal and emergency power supply for lighting

Floodlights must be powered from two separate networks:

- A normal network
- A back-up network, i.e. one that provides a continuous power supply in the event of the absence of the normal network (dedicated safety groups, inverters, etc.). The duration of back-up supplies (i.e. batteries for an inverter) must be consistent with operating needs and constraints, and the characteristics of the normal network

The normal network should provide approximately 80% of normal lighting on the lighting mast.

The back-up network will ensure a level of a few lux (3, 5, 10, to be established with the operator and depending on the characteristics and environment of the stand) on the aircraft stand, in order to ensure the safe evacuation of personnel or equipment in the event of a lighting failure during aircraft operations.

The power supply can be secured by:

- A back-up network at central level (terminal, production plant), for lighting. An high-quality (HQ) network can be used for equipment other than floodlights
- An inverter/battery set, with a minimum autonomy of 30 minutes (note the constraint on the sizing of cables and protections, which must be designed for both power supply modes and with a reduced short-circuit current in emergency mode)

If the operation of the aircraft stands concerned is highly critical, the proportion of equipment supplied by a back-up network may be increased.

Please note that the number of lights (see 4.2.1.5) has an impact on the choice of back-up power supplies, leaving the designer little room for manoeuvre if more than 20% security is required (since this would result in a totally secure power supply for the lights, with a financial and technical impact on production sources (batteries, sizing of networks in relation to short-circuit current, etc.).

The minimum lighting requirements for video surveillance must also be analysed regarding the performance of the cameras either present or planned for the area.

6.1.2. Pole cabinets

Pole foot cabinets are fitted with power and control equipment in accordance with standard diagrams to facilitate maintenance operations and reduce installation costs.

Regarding the potential failures of LED equipment (80-90% of issues are linked to electronic equipment), drivers should be positioned in cabinets at the foot of masts.

Regardless of the lighting method chosen, it is further recommended that a button be fitted at the foot of every mast to force lighting to 100%, with cut-off a time delay, to meet personal safety requirements while, at the same time, deploying smart lighting. This provision must be accompanied by the introduction or updating of dedicated operating instructions.

6.1.3. Location of cabinets and distances between cabinets and masts

Electrical cabinets should preferably be attached to masts with the doors opening opposite to prevailing winds, with a clamp fitted between cabinets and masts to limit cabinet vibration.

If a cabinet needs to be offset, an analysis must be carried out with the lighting manufacturer to ensure that the distance between the driver and the lights allows adequate activation and communication.

6.1.4. Other power supplies

Mast foot cabinets contain certain pieces of equipment dedicated to controlling the installation and providing feedback: PLCs, copper/fibre optic switches, etc. …). A secure electricity supply must be provided for this equipment.

6.2. Lighting control and feedback

Controlling the installation is essential for both operational and energy reasons. Ideally, the airport/aerodrome operator should be able to know the status of lighting installations at all times, so as to guarantee the operability of aircraft stands and the safety of operations.

Three control modes are presented below, from the simplest to the most precise. Decisions must be made with a “multi-criteria” approach:

- Aircraft stand operating mode (e.g. active area all night vs. aircraft stands mainly used in the evening and early morning)
- Financial issues
- Existing installation (presence of cables and/or PLCs allowing the installation to be easily upgraded)
- Ability to carry out electronic/IT maintenance, updating and re-configuring installations

6.2.1. Control mode descriptions

6.2.1.1. On/off management

Simple control by switching the general circuit (i.e. the entire lighting installation) on and off, using a contactor controlled by an operator, an astronomical timer or a luminosity detector.

Extremely robust and low maintenance costs.

Lack of control and feedback.

6.2.1.2. Programmed switch-off during non-operating hours

This mode is only possible with LEDs, as it takes advantage of the ease of dimming the lights to reduce energy consumption. It also requires a communications network and DALI *(digital addressable lighting interface*) drivers, given 0-10V or 1-10V technologies are becoming obsolete.

Timetable:

- Switches on at 100% at dusk, using an astronomical clock or luminosity detector
- Reduces to 30% at a predefined time, corresponding, for example, to a curfew (30-minute margin), operating stoppages at a terminal, nighttime work operations, etc.
- Increases to 100% at a predefined time, symmetrical to the elements described above
- Switches off at dawn

Highly robust, with the possibility of local forcing (via a forced activation button at the foot of the mast). Increased robustness in terms of operability, by ensuring positive safety upon activation, i.e. 100% commissioning in the event of a loss of communication on the drivers.

Possibility of feedback.

Energy savings, compared with solution 1, can be calculated by counting the hours of lighting, assuming a reduction of 4 hours per night (0.30am to 4.30am).

In the case of 6.2.1.1, 4,000 hours of nighttime lighting are generally used for public lighting.

In the case of 6.2.1.2, with 365 x 4 = 1,460 hours at a 30%-reduction, the equivalent lighting time becomes:

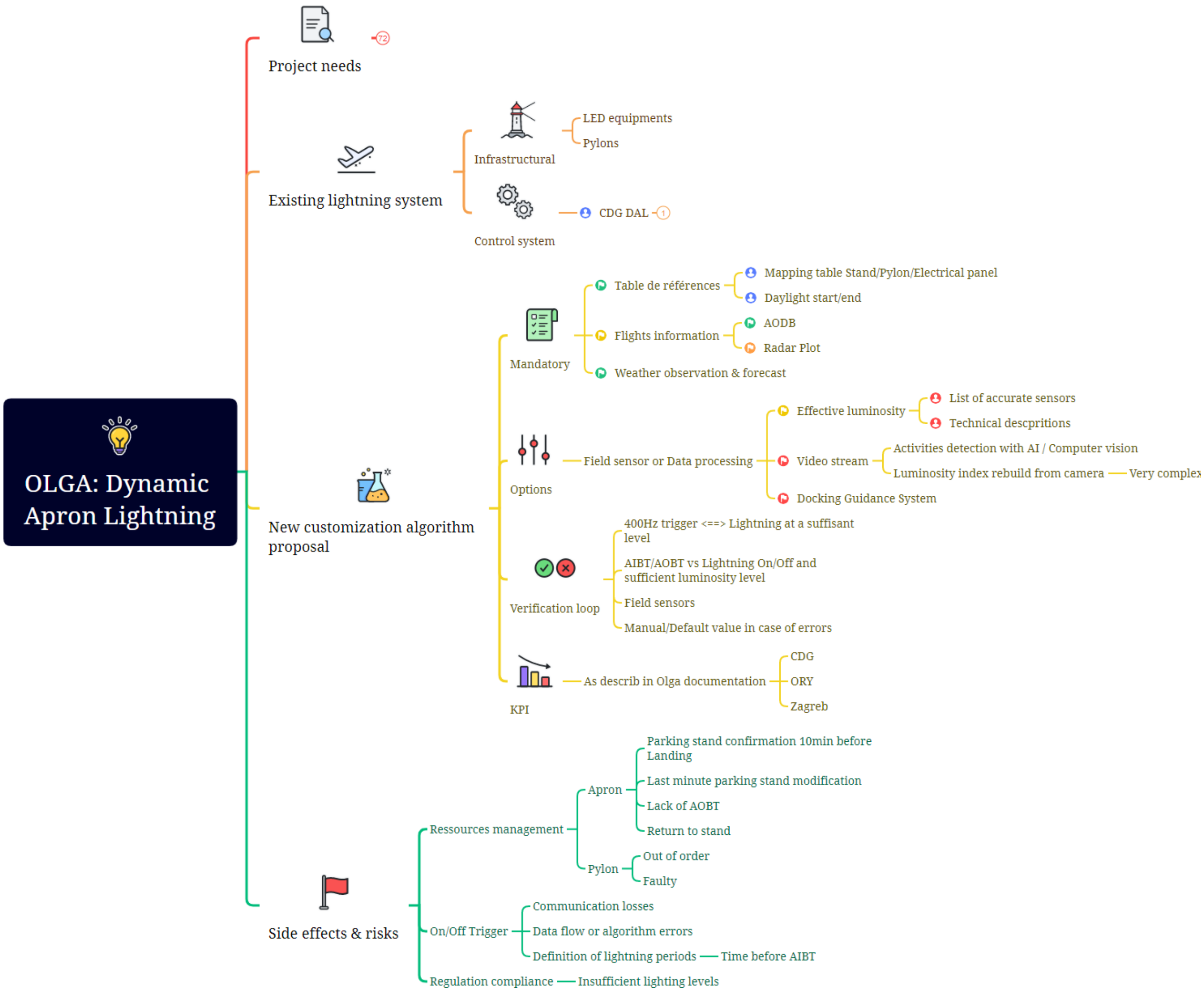
$$1460 \text{ x } 30\ \% + (4000 - 1460) \text{ x } 100\ \% = 2978 \text{ hours}$$

6.2.1.3. Optimised control

Work on this optimised control system was carried out as part of the "Optimised Dynamic Apron Lighting" project for the OLGA [1](Holistic & Green Airports) Consortium.

It was developed by the Engineering Division, the Paris-Charles de Gaulle Airside Division, and HubOne, and can be summarised in the following flowchart:

[1] ***OLGA project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement n° 101036871.***


OLGA: Dynamic Apron Lightning
Project needs
Existing lightning system
Infrastructural
LED equipments
Pylons
Control system
CDG DAL
New customization algorithm proposal
Mandatory
Table de références
Mapping table Stand/Pylon/Electrical panel
Daylight start/end
Flights information
AODB
Radar Plot
Weather observation & forecast
Options
Field sensor or Data processing
Effective luminosity
List of accurate sensors
Technical descpritions
Video stream
Activities detection with AI / Computer vision
Luminosity index rebuild from camera
Very complex
Docking Guidance System
Verification loop
400Hz trigger <==> Lightning at a suffisant level
AIBT/AOBT vs Lightning On/Off and sufficient luminosity level
Field sensors
Manual/Default value in case of errors
KPI
As describ in Olga documentation
CDG
ORY
Zagreb
Side effects & risks
Ressources management
Apron
Parking stand confirmation 10min before Landing
Last minute parking stand modification
Lack of AOBT
Return to stand
Pylon
Out of order
Faulty
On/Off Trigger
Communication losses
Data flow or algorithm errors
Definition of lightning periods
Time before AIBT
Regulation compliance
Insufficient lighting levels

The focus was on control methods, information sharing and sensors. The conclusions were then used to supplement the following sections.

This mode uses the main assumptions of the previous mode, leaving a base lighting level of 30%, rising to 100% only when an aircraft is present. In practice, the lighting is increased to 100% 10 minutes before and reduced to 30% 10 minutes after the theoretical parking and departure times.

Control information therefore comes from aeronautical data, via a dedicated gateway between this system and the lighting control process.

Lighting can also be applied to an individual aircraft stand rather than an entire apron. This requires an installation with a sufficiently small mesh (see number of floodlights per mast in 4.2.1.5) and precise settings linking each lighting unit to the stand(s) it lights.

6.2.1.4. Feedback

Feedback on lighting functionality should enable the operator to control lighting more effectively. The main requirement is to know the operating status, i.e. on/off/fault.

Accuracy then depends on the type of control implemented. It may be limited to electrical feeders (circuit breaker and/or contactor position), extend to electrical protection in cabinets, or be complete with operating information for each driver (i.e. each light).

In the case of a DALI system, only the information needed to operate the installation needs to be fed back (the DALI protocol offers a very large amount of information), including the operation and time stamps for switching off, switching on and switching to reduced mode as a minimum.

Finally, the frequency of interrogation between the monitoring system and the PLCs must be limited, as real-time information is not essential (latency of a few minutes is perfectly acceptable).

6.2.1.5. Other control options – sensors

As in Section 6.2.1.3, the OLGA project has made it possible to test several physical sensors, and to carry out comparisons with other French and European airports.

Solutions relating to the commissioning of 400Hz and guidance system detection were not retained. The former requires an estimate of duration before connection and after disconnection. The latter requires equipment on all aircraft stands and communication between the two processes. It has also been noted that switching to 100% lighting when pilots are aligned with the parking axis (guidance system detection) can create glare.

Ground-based sensor solutions are not appropriate because of the constraints on installation and maintenance operations. On the first point, crossing the hydrant network would be necessary (link between the foot of the mast and the far end of the stand).

Finally, camera-based solutions, which were not tested at Paris-Charles de Gaulle as part of the OLGA project, were also not retained. Although these systems have a number of advantages (they can be shared with operational cameras, and the system is precise (depending on speed, vehicle/obstacle type, etc.)), they require regular maintenance and significant investment, and are ultimately not very effective (even inoperable) in adverse weather conditions (rain, snow, wind, LVP).

6.2.2. Wireless networks

Wireless connectivity (Bluetooth, LoRa, etc.) should be avoided for aircraft stand lighting control, given the risks relating to the integrity of the system (cybersecurity), the installation of sensors directly at floodlight level (maintenance with a major impact on operations) and the need to check for any disturbances caused by the frequencies used.

6.2.3. Wired networks – DALI

Wired systems are preferable because of their robustness and the physical protection of data.

The DALI system is the preferred choice, given the open nature of the protocol.

LED drivers are now all pre-equipped for this type of communication.

Communication is provided via a main PLC (“master cabinet”) and secondary PLCs controlled by the first (“slave cabinets”). Wago PLCs are used in the majority of cases.

A physical link must be created between the PLCs:

- If the distance between PLCs is less than 100m, the link can be made using an Ethernet cable,
- If the distance is greater than 100m, it must be made using optical fibre, which requires the use of upstream and downstream switches

A reflectometry test should be carried out before connecting PLCs to guarantee the continuity and performance of the fibre.

Implementing this kind of network requires in-house or external expertise (with guaranteed responsiveness) for updating information, correcting HMIs and troubleshooting.

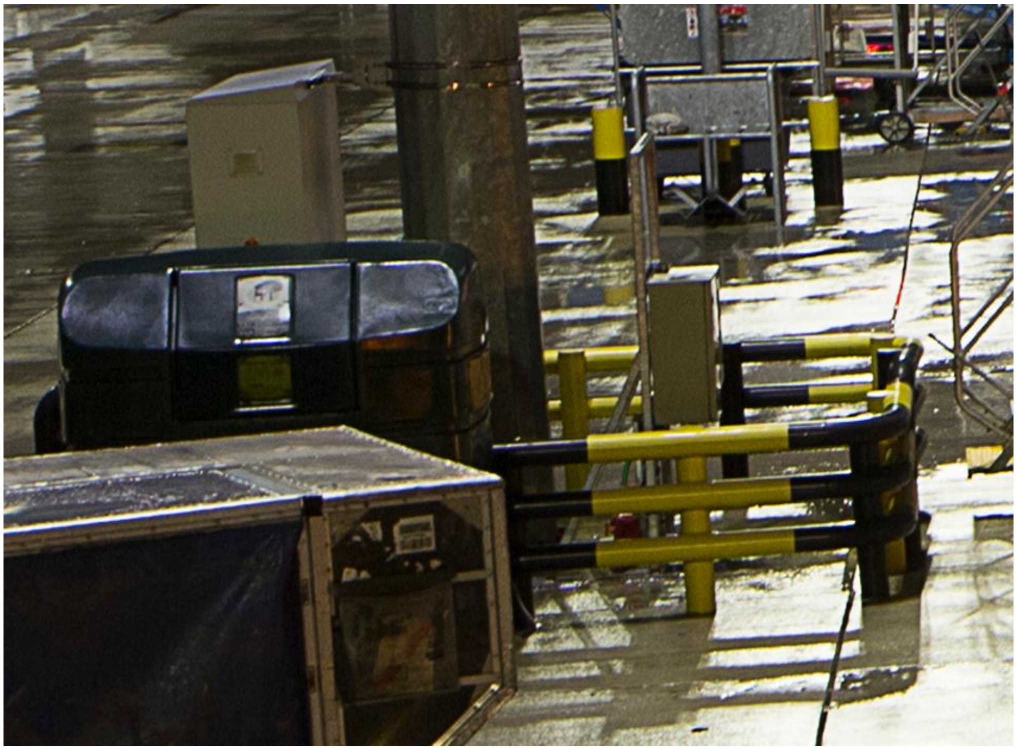
7. Mast foot protection and equipment

Mast and cabinet equipment must be protected against impacts.

Protection can be:

- Metallic
- Shape memory polymer

They should be painted red and white (sometimes yellow and black).



At the foot of the mast, a metal frame should be installed to support the various boxes, such as video surveillance, baggage recognition systems, guidance system/timer boxes, etc.

The protected area can also house the hydrant network's emergency stops and the guidance system control panels.

8. Other lighting

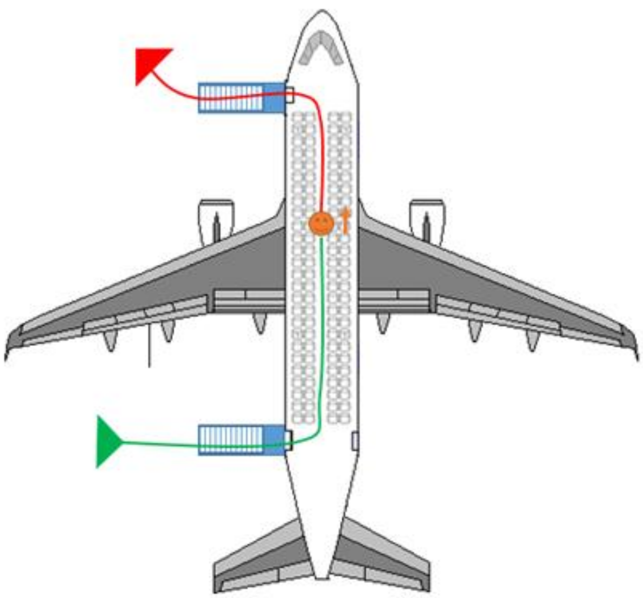
8.1. Additional mobile lighting

This type of lighting is rarely used, except in special cases:

- Lack of light on one side of the aircraft (baggage hold)
- Shadows being cast on the back of the wings

It is provided either by autonomous mobile systems or by electrical equipment. For the latter, a pre-equipment recessed socket (similar to 50/400Hz PCs) must be installed.

This lighting could be useful in the case of WIWO, but this process is limited to certain aircraft (B737 or A320, for example) for which the lighting conditions are generally good (in relation to the length of the aircraft).



This type of lighting also creates a significant risk of collision on the apron.

8.2. Lighting on roads near airports/aerodromes

Road lighting and obstacle lighting must be designed and installed in such a way as not to create ambiguity with aeronautical ground lighting.

Few details are given in the regulations or recommendations. However, the following principles should be respected:

- Incident lighting should not be installed close to or parallel with runways and taxiways

- The compatibility of mast heights should be analysed to avoid light interference on runways and taxiways

8.3. Stadium lighting near airports/aerodromes

This type of lighting must also be designed to avoid any discomfort to pilots.

For this type of space located on runway flightpaths or, more generally, in take-off and landing areas, a photometric study should be accompanied by a study of the luminance and light intensity emitted above stadia.

In the event of significant values similar to the limits described in the dedicated appendix, an analysis may be carried out in conjunction with air traffic control services. In any case, asymmetrical optics should be used, with sufficient mast height to direct the light towards the ground.

If in doubt, an analysis of light halos can be requested by the airport operator or even by the air traffic control services.

8.4. Architectural lighting near airports/aerodromes

The rules set out above must be respected when lighting façades using lighting fixed to the ground resulting in high luminance levels and high light intensities emitted directly into the sky.

Dynamic lighting systems should also be analysed to avoid any further disturbance caused by the colours, patterns and any strobe effects chosen.

8.5. Building site lighting

Building site lighting must be installed in such a way as not to interfere with pilots or control towers.

4 Table of acronyms

CMA	Controlled movement area	**LED**	Light Emitting Diode
DALI	Digital Addressable Lighting Interface	**LoRa**	Long Range (protocol)
HMI	Human Machine Interface	**LVP**	Low Visibility Protocol
HPS	High Pressure Sodium	**PLC**	Programmable Logic Controller
ICAO	International Civil Aviation Organization	**TWR**	Tower
IEC	International Electrotechnical Commission	**WIWO**	Walk-in / Walk-out