Interreg Sudoe

TR@NSnet

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Report on THE demonstrator transferability

Partner Responsible

UPM - Universidad Politécnica de Madrid

Authors:

Guillermo del Campo (UPM)

Georges Zissis (UT3)

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Project Coordinator	George Zissis and Marie-Pierre Gleizes (Coordinators) | Lou Ackermann (Project Manager) lou.ackermann@univ-tlse3.fr
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Introduction

Tr@nsnet project aims to contribute to the Energy Transition (ET) challenge by defining a new Living Lab (LL) model in the context of Open Innovation (OI). The objective is to create a **generic and transferable model** of LLs so that it can also be used by universities.

The Tr@nsnet project is divided into 3 task groups (TG), with TG1 being oriented to study the processes of adaptation and transfer of different demonstrators from one environment to another, in order to capitalize on the definition of good practices and methods that will be considered in LL model definition.

The objective of activity 1.1 is to replicate the existing UT3 and UPM smart outdoor lighting systems at the other university campus. The UPM smart lighting system in Madrid is composed of an IoT solution based on 6loWPAN communications that allows the automated dimming of streetlights depending on illumination and presence detection. In Toulouse the streetlights are equipped with Kara sensors from Kawantech. These sensors are cameras that analyze objects moving along the street and communicate with each other to optimize public lighting.

This report presents the different tasks performed to implement the replications, including administrative, technical and acceptability issues motivated by end-users from different cultures.

Toulouse Lighting Demonstrator

Location of the demonstrator

The demonstration site on Toulouse campus (118 route de Narbonne, Toulouse) was chosen in collaboration with the University's technical services (SGE). This is the section of Hypatie Street that runs along the building 2A (amphitheatres of Chemistry "Grignard" and "Le Chatelier") on both sides of the barrier delimiting the central part of the campus. Figure 1 shows the exact location of the demonstrator on the campus plan and one of the candelabras equipped with the Kara detector.

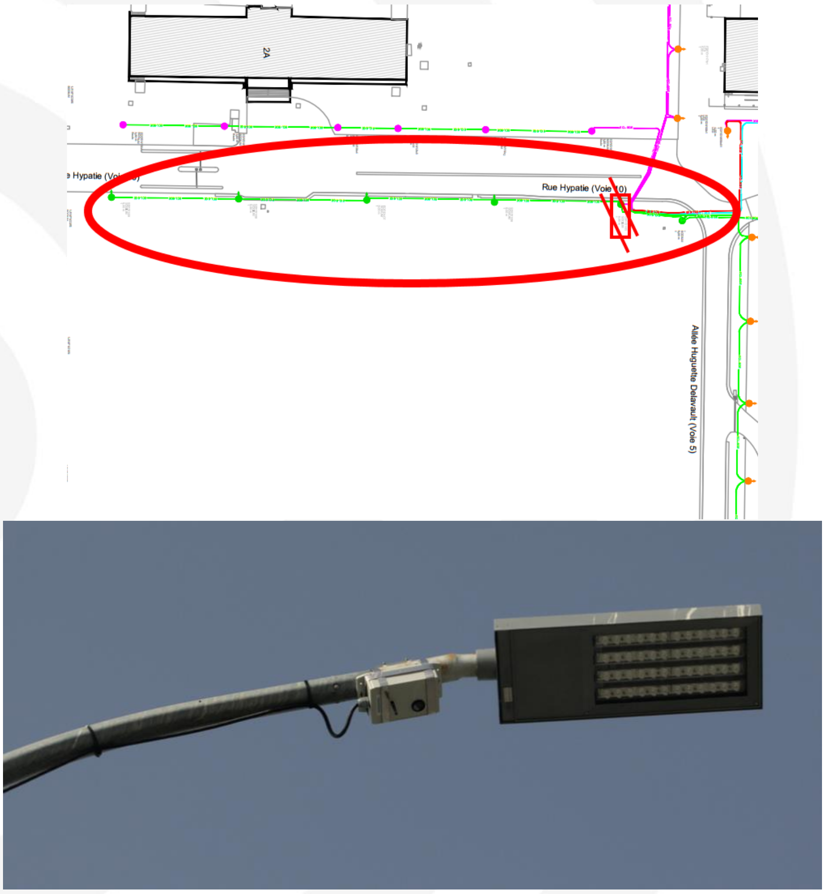
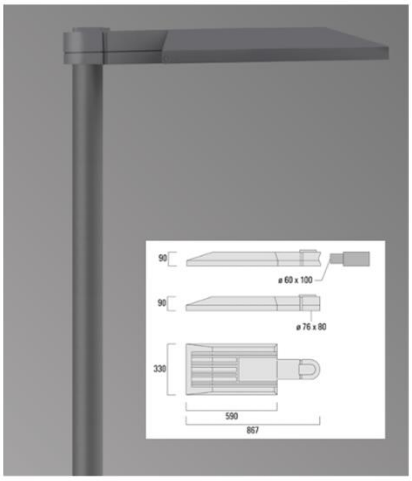


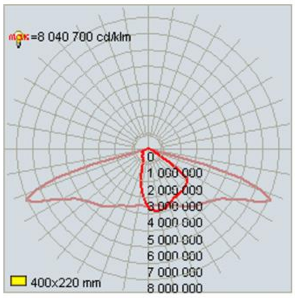
Figure 1: Location of the demonstrator on Toulouse campus and a candelabre equipped with the Kara detector.

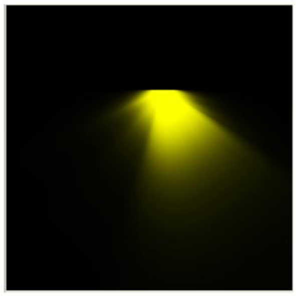
The equipment of the Toulouse demonstrator

The Toulouse demonstrator will combine the two technologies (Kara and BatStreetLight systems). Currently, the Kara system is operational, while the 2 BatStreetLight fixtures have been delivered, characterized and waiting for installation by subcontractor of the management and operations department (SGE).

The Kara system uses we-ef brand luminaires for road lighting equipped with a matrix of 48 LEDs powered at 1 050 mA corresponding to a nominal power of 108 W per candelabra. The luminaire is equipped with an integrated electronic driver without the possibility of dimming the power; however, the system allows switching on/off thanks to DALI signals. The colour temperature (CCT) of the LEDs is 3,000 K (warm white) and the colour-rendering index (CRI) is 70. The nominal luminous flux is 14 170 lm.
Figure 2 shows the head of the fixture, its photometry and its characteristics according to the manufacturer's catalogue.



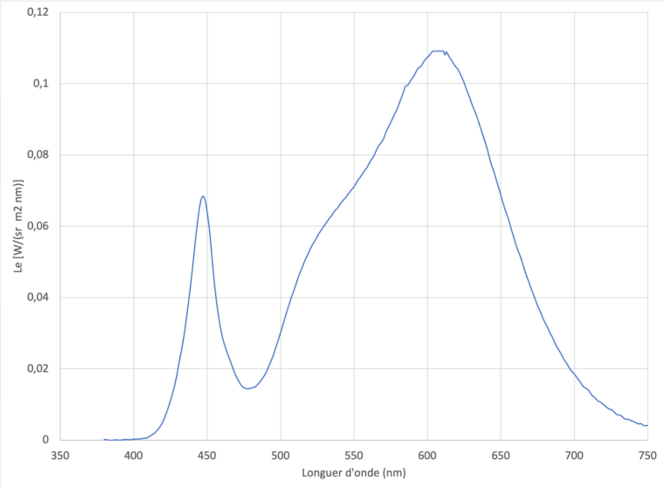




	Données Nominales	Données en sortie de luminaire
Température ambiante	85°C (Tj)	25°C (Ta)
Lumen par LED	448.5 lm	393.6 lm
Nombre de LED	36	36
Lumen total	16146 lm	14169.9 lm

Figure 2 : Les luminaires utilisés par le démonstrateur

We checked the spectro-colorimetric parameters of the luminaire. Figure 3 shows the spectrum obtained in the laboratory. We obtained a CCT of 3 035 K which in accordance with the manufacturer's declarations. The measurements show a CRI of 83, which is 16% higher than the declared value.



Colour Rendering Index	
Reference Illuminant	Planckian radiator
CCT [K]	3053
R1	82,0
R2	88,3
R3	93,1
R4	82,6
R5	81,3
R6	84,5
R7	85,1
R8	65,0
R9	17,5
R10	72,2
R11	81,8
R12	67,2
R13	83,2
R14	95,6
R15	76,3
Ra	82,76

Figure 3 : Caractéristiques spectro-colorimétriques mesurées du luminaire du démonstrateur

The two BatStreetLight fixtures have been received in Toulouse and are waiting to be installed at the new section of demonstration that will include also the 2nd Kara generation in the frame of autOCampus regional program. The installation schedule is depending on SGE. The fixtures are equipped with individual BatStreetLight (BSL) communication devices with NEMA interface and IoT Presence Sensors with ZHAGA interface. Also, we received a BatLink router with Ethernet and Wi-Fi interfaces. Figure 4 shows the two fixtures received.

Figure 4 : The BatStreetLight fixtures received in Toulouse with the BSL communication device (right upper part) and IoT Presence Sensors (right lower part)

In the meantime, the LAPLACE laboratory verified the spectrophotometric characteristics of the fixtures. Figure 5, shows the spectrum obtained from the BatStreetLight fixtures.

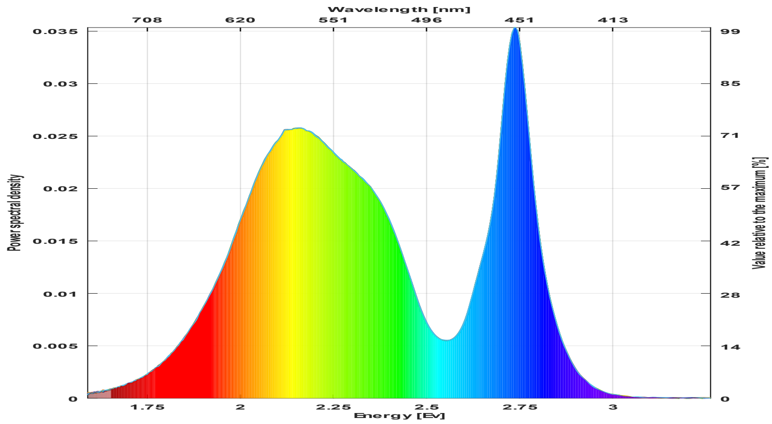


Figure 5 : Measured BatStreetLight fixture spectrum

The measurements shown a direct luminance of 1 533 cd/m², a dominant wavelength of 572±1 nm and CCT of 4 460±20 K (neutral white shade), the colour coordinates (x, y) are found to be (0,3593, 0,3794). The colour rendering index IRC is in the order of 70±2 which is acceptable for street lighting, however the R9 value is negative (-42,4) and this denotes a lack of red component in the spectrum.

Lighting simulation of the demonstrator site

Before proceeding with the installation of the demonstrator, LAPLACE carried out a preliminary simulation in DIALUX in order to validate the lighting compliance.
For this simulation we used the we-ef candelabras selected by the SGE installed in unilateral arrangement on poles 8 m high with a stock of 0,6 m long which carries the head of the luminaire with an inclination of 30 ° with respect to the ground, the candelabras are spaced 28 m apart.

To define the class of the street, following, we have applied the rules proposed by the EN 13201 standard and the recommendations of the AFE (French Association of Illuminating Engineers) which consider the frequentation of the lane and the speed of traffic. We therefore concluded that it was an S4 class street. For calculation purposes, we considered that the track is covered by an asphalt type R3 with an average level of wear (no specular reflection). A maintenance coefficient of 0,57, proposed by DIALUX, was considered in our calculations. Figure 6 shows the illuminance distribution and Figure 7 shows the luminance distribution.

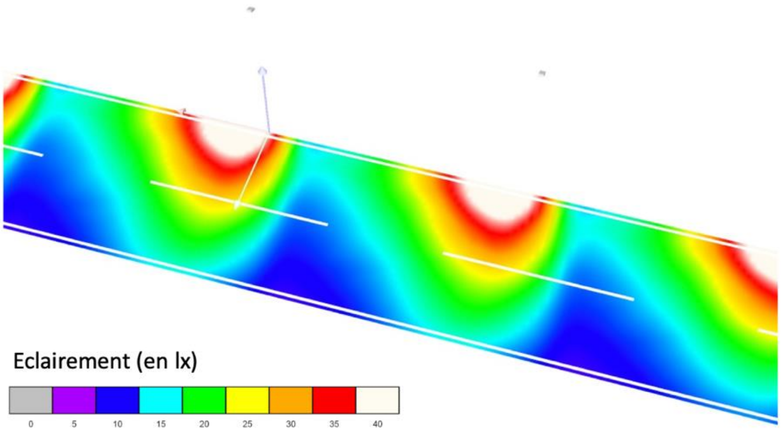


Figure 6 : Carte de la distribution des éclairements sur la chaussée simulée par DIALUX

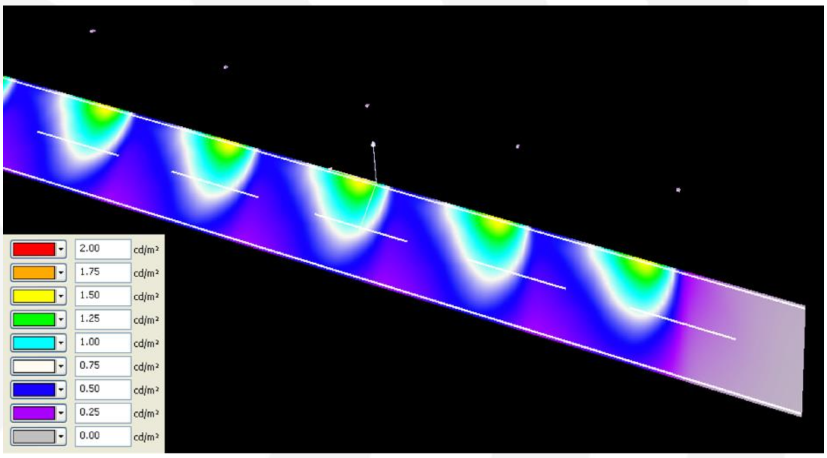


Figure 7 : Carte de la distribution des luminances sur la chaussée simulée par DIALUX

The simulation gives an average illuminance of 19,85 lx with a minimum illuminance of 8,82 lx. The values are relatively high compared to the recommendations of the standard for this type of street. However, as the demonstration track is illuminated by older luminaires using high pressure sodium (SHP) lamps with an average illuminance of 20 lx, it would not be desirable to create a significant contrast in illumination in the same street. Regarding the distribution of luminance, as shown in Figure 7 from the simulation, its level remains below 2 cd/m^2 which means that users will be in an environment whose mesopic vision will be preponderant. Under these conditions, the white light of the demonstrator offers an increased level of visual comfort and allows a better recognition of potential obstacles on the track, thus contributing to the safety of traffic and people.

Lighting conformity assessment

To evaluate the lighting compliance of the demonstrator, we carried out an in-situ measurement campaign and at the same time compared our results with those obtained in parts bordering the demonstrator still using conventional lamps (high pressure sodium).
This measurement campaign was carried out on the entire Hypatie Street of the Campus. This road connects a main road (ring road-avenue de Rangueil) east and the campus parking lot. There are 2 types of luminaires used in this section:

- We-ef LED luminaires equipped with the 1st generation of Kawantech's Kara system
- Old-fashion luminaires equipped with High Pressure Sodium discharge (HPS) lamps

Figure 8 gives an overview of the section studied and shows the measured values of the illuminance on the ground. The values obtained on the demonstrator side are on average 20% higher than those obtained by HPS candelabras and despite the fact that the latter are lower and that the nominal power of their lamps is 50% higher than that of LED candelabras.

Figure 8: Street section studied for lighting conformity assessment and distribution of illuminances

The illuminance values obtained are 6 to 7 times higher than those imposed by lighting standards for this type of secondary road. ($E_{max;st}$=5 lx). Therefore, we can conclude that the way is overlit. It would therefore be desirable to lower the level of illumination. However, this was not possible in the demonstrator space otherwise it would create a glaring imbalance compared to the illuminances generated by the old HPS system, and it could become dangerous. Subsequently, we were interested in the visual comfort of road users.

Figure 9 gives an overview of the section studied and shows the measured values of luminance (amount related to glare and visibility). Although the luminance of the demonstrator candelabras is almost double that obtained by the HPS candelabras, the latter because of their height are closer to driver's line of sight (FOV point), pedestrians or cyclists moving in the area and therefore are more dazzling than the demonstrator candelabras.

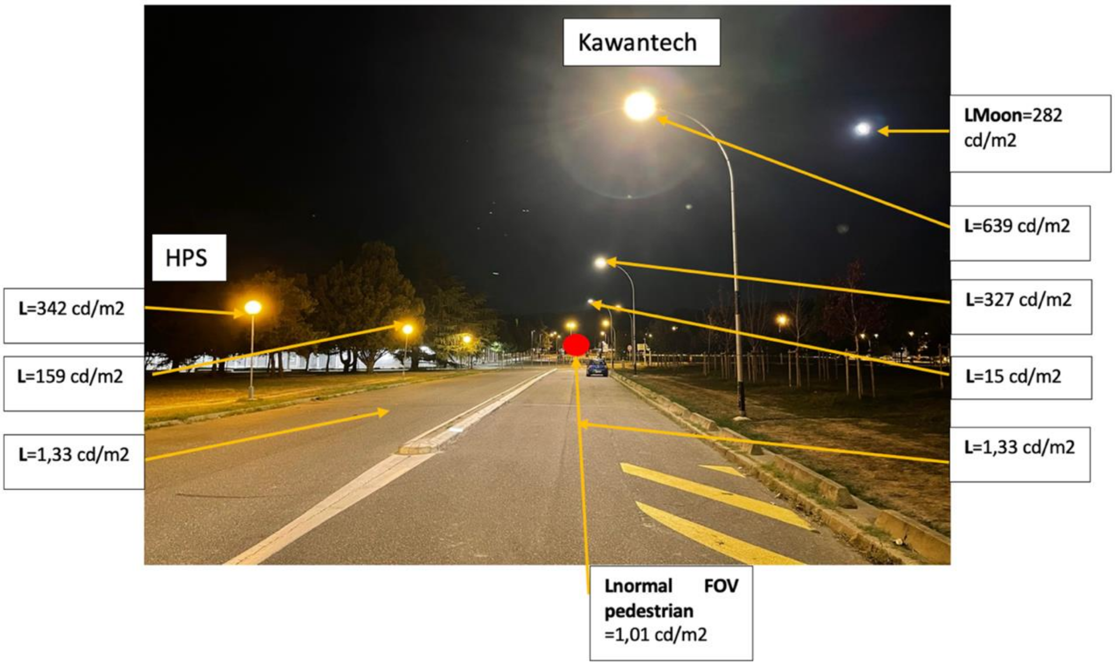


Figure 9: Luminance measured on the track section studied

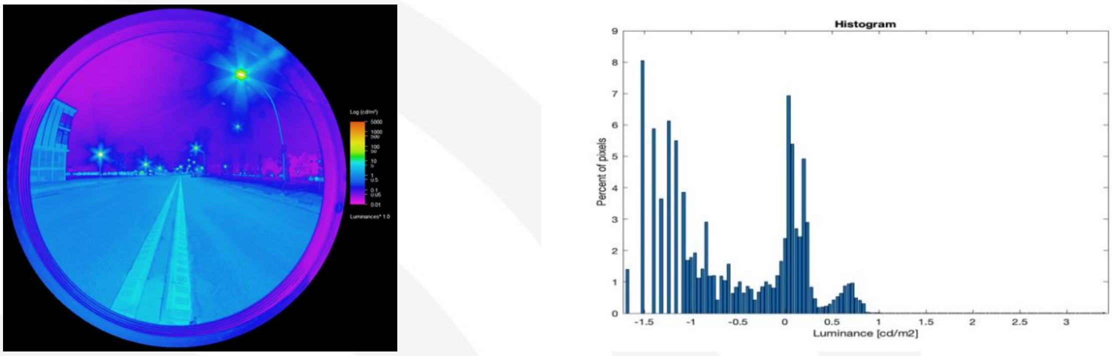
Note that old-fashion "globe" candelabras that emit yellow-pink light have a luminance and an apparent size similar to the moon and therefore they may attract more insects than the demonstrator candelabras that have a wider light spectrum and a colour temperature similar to that of HPS.

The luminance at road level is similar between (1,33 cd/m^2) related to the reflection of light is almost identical between the two systems. Finally, the luminance contrast between the point of fixation of the eye (FOV) and the luminance of the pavement (c = 0,75) is perfectly compatible with the recommendations in force and allows easy identification of potential obstacles on the track.

Note in passing that the measured values of illuminance and luminance are consistent with our initial simulations using the DIALUX software.

To ensure the absence of visual disturbances for users, we carried out a more detailed evaluation of the spatial distributions of luminance.

Figure 10(a) gives a luminance chart of the entire section obtained by a PhotoLux 3.1 video-photo-luminancemeter, while Figure 10(b) gives the luminance distribution.



(a) (b)

Figure 10: (a) Luminance map obtained by PhotoLux 3.1 with a fisheye lens, (b) Luminance distribution obtained by statistical analysis of PhotoLux 3.1 measurements

Thanks to the logarithm function of the device processing software, we can show different levels of luminance (high, medium and low) in the visual scene.

Figure 11 shows the luminance maps obtained after treatment and Table 1 summarizes our results.

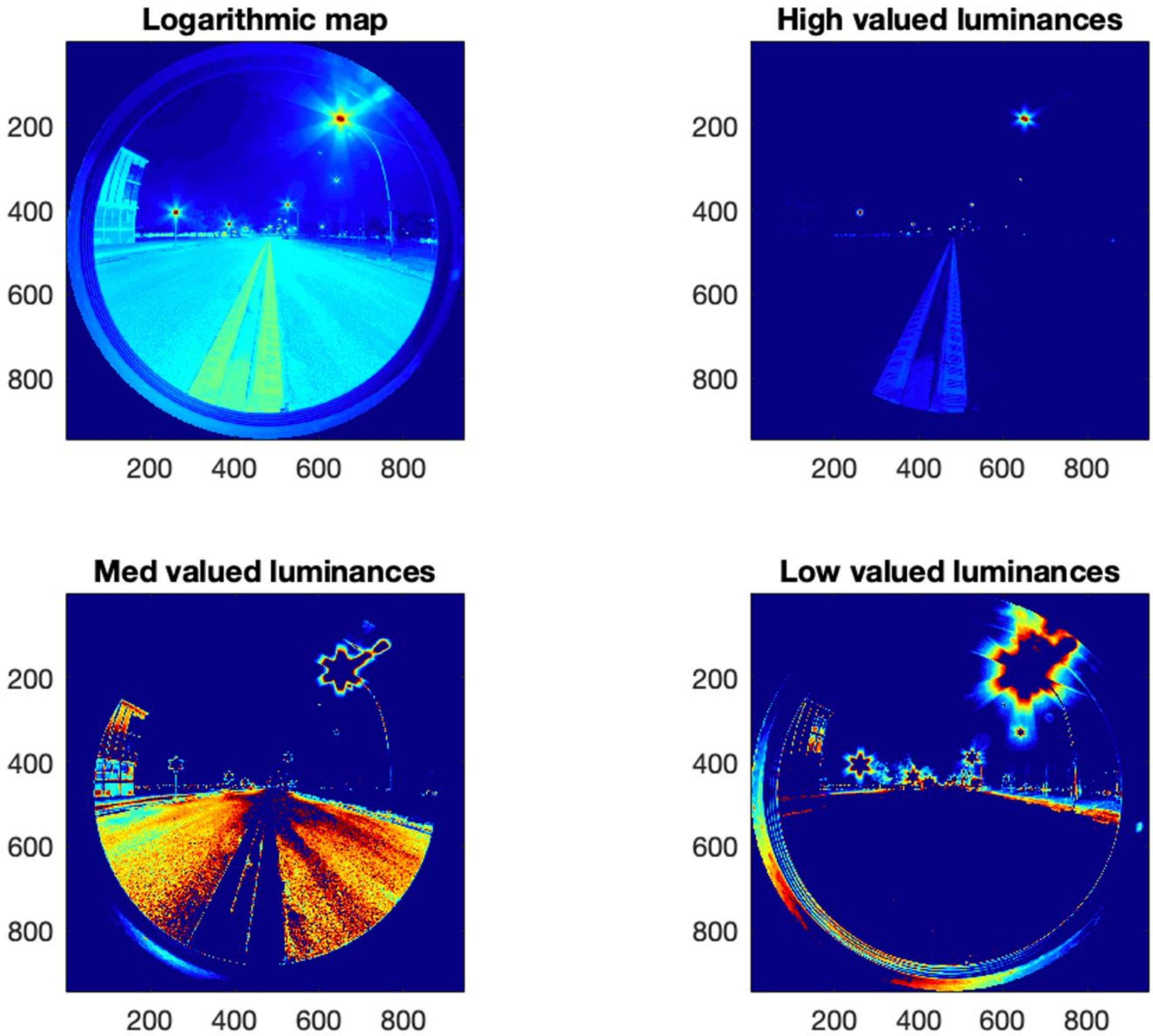


Figure 11: Luminance maps after logarithmic data processing.

Table 1 : Analysis of luminance levels

H = High level of luminance [log(L) between 0,85 and 0,35]	These luminance levels are troublesome for the pedestrian. The greatest luminance can be perceived at the head of the nearest demonstrator luminaire. We can also see bright spots in other luminaires. In this photo we can see a sidewalk in the middle of the road. It's also overlit, but this prevents potential accidents.
M = Average luminance level [log(L) between 0,35 and -0,3]	In this case, the measurement is influenced by the high values of average luminance. It can be seen mainly on the road. The scene is saturated because of the optical phenomenon. We can admit that there is a sufficient contrast in front of the user

	(3 m). In the normal field of vision of the pedestrian, we cannot distinguish a contrast between the sidewalk and the ground, it could be annoying especially on the HPS side or the phenomenon seems to be more pronounced.
L = Low luminance level [log(L) between -0,3 and -1,1]	Values below 0,06 cd/m^2 luminance (log(L)<-1.2) are considered noise and play no role in the visibility assessment.

To better understand the results, we showed, in Figure 12 the average luminance, L_{av}>5 cd/m^2) and mesopic (L_{av}<5 cd/m^2). This was also predicted by our DIALUX simulations. Now, we can conclude that the vision of users who imprint this section in "mesopic" mode and we know that in these conditions white light offers better visual comfort and that it allows to use the reaction time in case of obstacle on the track.

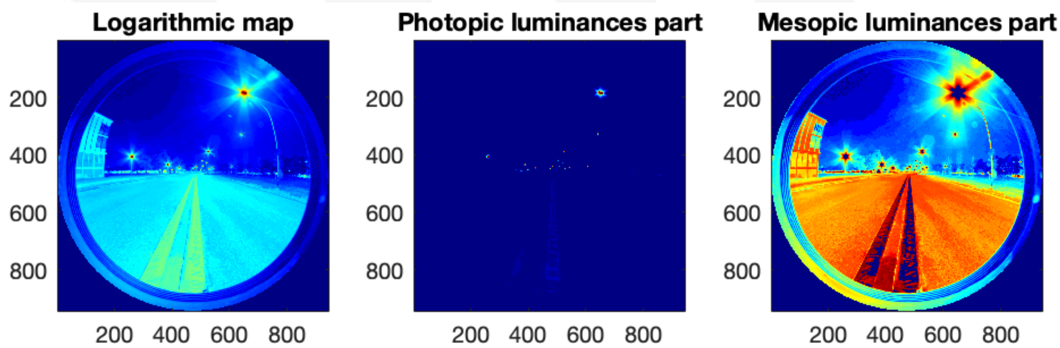


Figure 12 : Luminance map in phototopic and mesopic vision mode

End-user satisfaction study

LAPLACE has developed a satisfaction study of lighting conditions on the campus of the Toulouse III University in the form of an on-line questionnaire using the LimeSurvey software.

This study is intended for campus users, i.e. students and staff, although accessible to occasional visitors. The primary objective was to collect their perception of lighting on campus in order to be able to adapt it according to the needs of users.

The secondary objective was to make these audiences aware of our institution's research actions aimed at improving user comfort, reducing the campus' electricity consumption and the impact of its lighting system on the biotope that constitutes its urban green space.

Since it went online, we have received a total of 148 responses. Figure 13 shows the categories of users who responded to the questionnaire, 64,19% of them have been attending campus for more than one year (Figure 14). More than 68% of respondents live off campus.

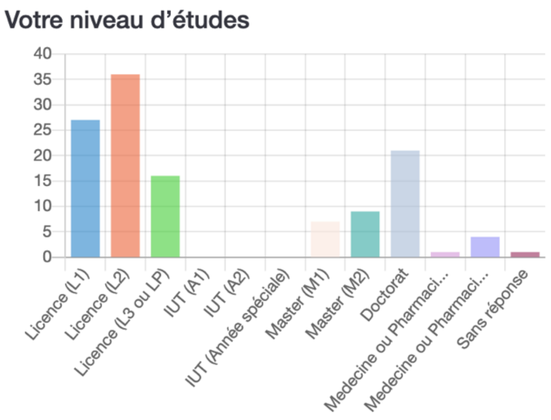


Figure 13 : Categories of users who responded to the questionnaire

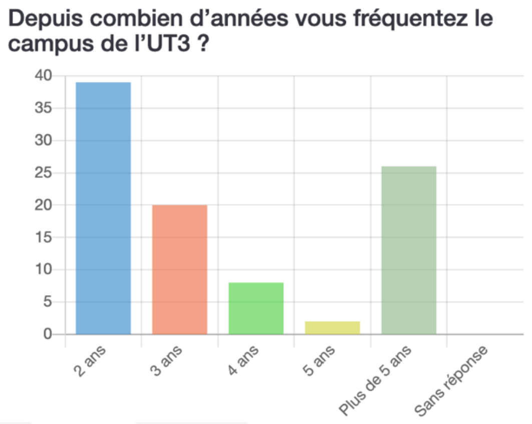


Figure 14 : Categories of users who responded to the questionnaire

The majority (39%) attend campus all week Monday to Friday. More than 50% arrive in the morning around 7:30 am (many classes start at 7:45 am) and 64% leave campus around 7:00 pm or later (Figure 15)

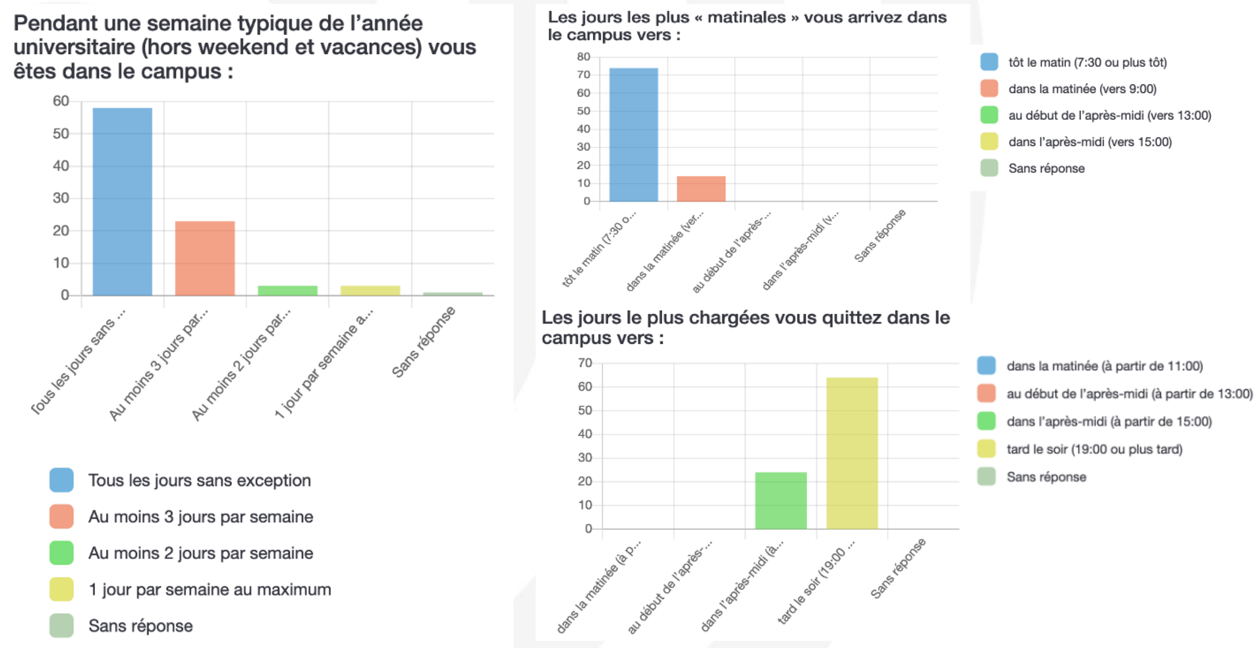


Figure 15 : Campus attendance days and times

Just over half of users (52%) arrive by metro while 35% on foot or by bike. The majority of the flow of users passes through the main entrance of the campus (118 route de Narbonne). The overwhelming majority of users mainly attend the FSI education area (buildings U1, U2, U3, U4, U6-MRL). The answer is more nuanced regarding the University's "service" buildings (Figure 16).

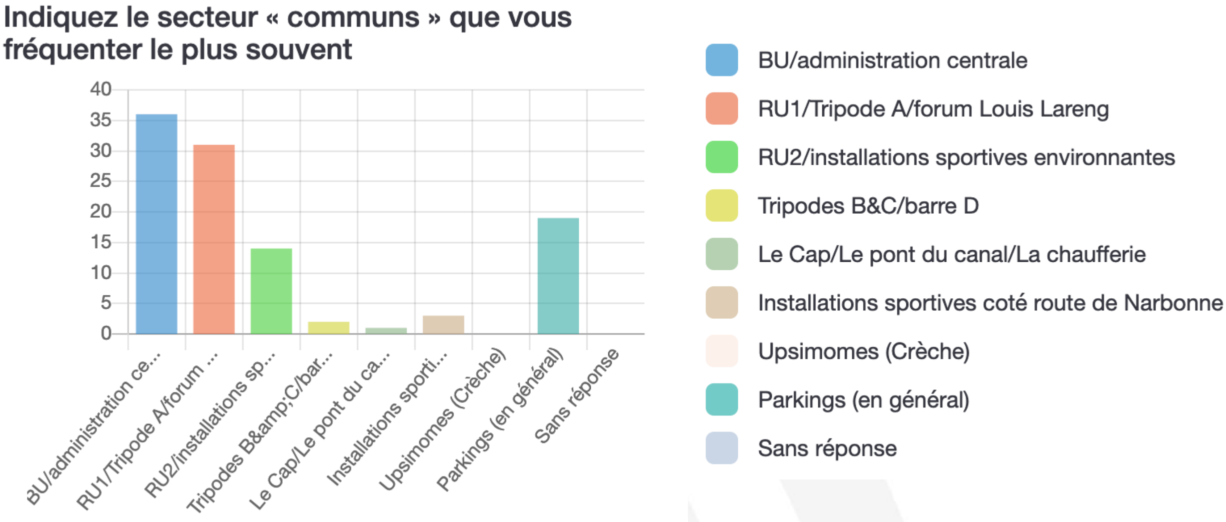


Figure 16 : Attendance at campus "service" buildings.

With regard to campus attendance outside normal school hours, 42% of respondents say they spend either regularly (50%) or occasionally (50%) on campus in the evening, on weekends or during holidays (the answers are evenly distributed over these three periods).

To the question "How do you judge the overall level of illumination (amount of light) of the campus?" users seem to be generally satisfied (Figure 17). As shown in Figure 18, among respondents 55% chart the atmosphere as "neutral" and 18% as pleasant. The remaining 27% consider it twilight or even gloomy (7%). However, 73% of all consider themselves to feel safe when travelling around campus at night. As much as the positive response is clear in the building sectors (education or services), it is more nuanced when it comes to car parks (Figure 19).

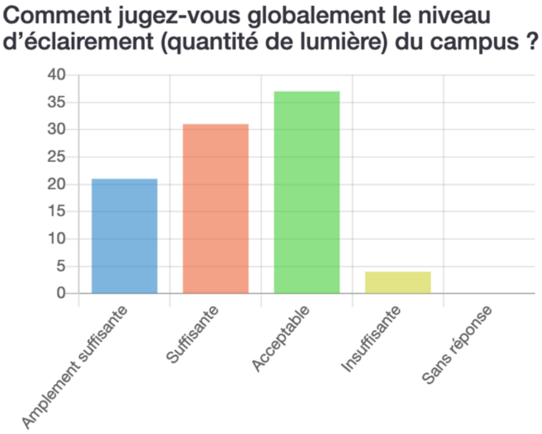


Figure 17 : Satisfaction des usages concernant l'éclairage du campus

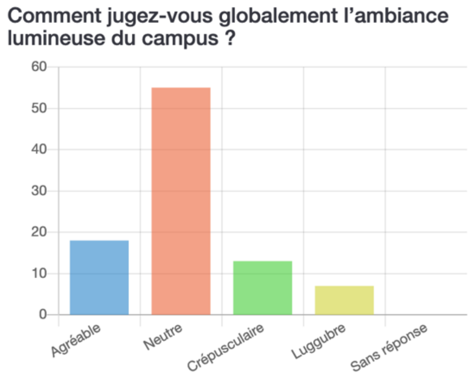


Figure 18 : Impression des usagers de l'ambiance lumineuse

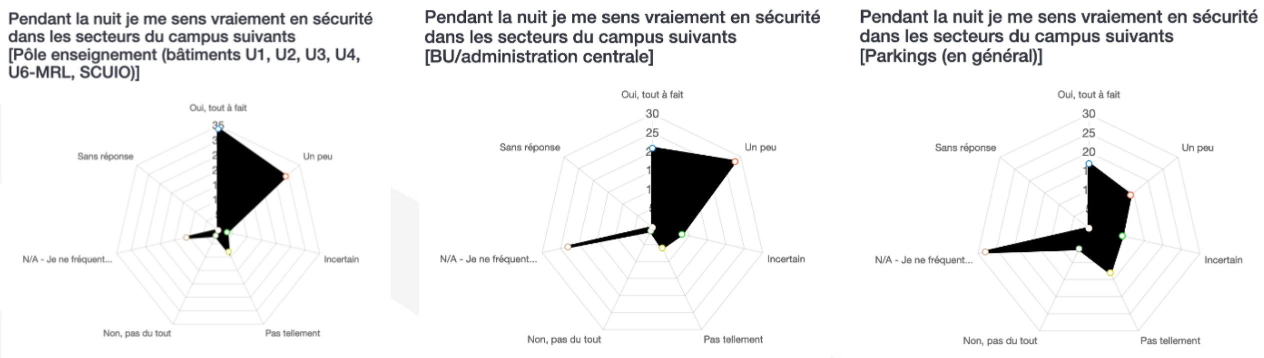


Figure 19 : Feeling safe at night in the FSI education area (left), central buildings (middle) and car parks (right)

To the question "Do you think that the current lighting of the campus can have a considerable impact on the environment and/or the ecosystem?" the answer is mostly positive (62%) against 16% of people who do not see cause and effect... As shown in Figure 20 users think that lighting has a very strong impact mainly on the alteration of the ecosystem by attracting/repelling nocturnal insects/animals, closely followed by light pollution of the night sky while the indirect production of greenhouse gases comes in 3rd position but associated answers on the level of its severity are quite uncertain.

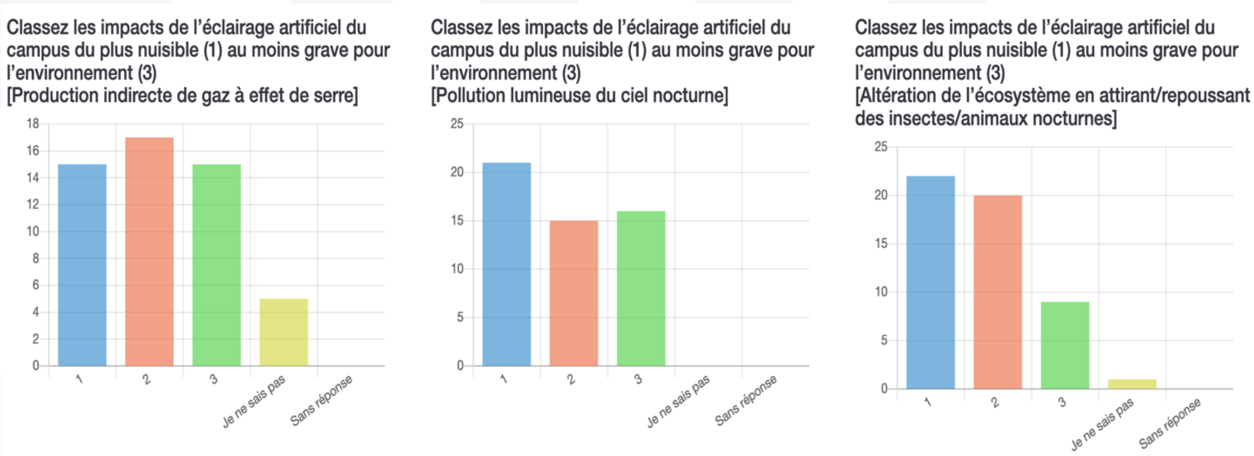


Figure 20 : Estimated environmental impacts of campus lighting.

Users consider that a system that illuminates on demand during off-peak hours is the most effective measure to limit the negative impacts of campus lighting (Figure 21).

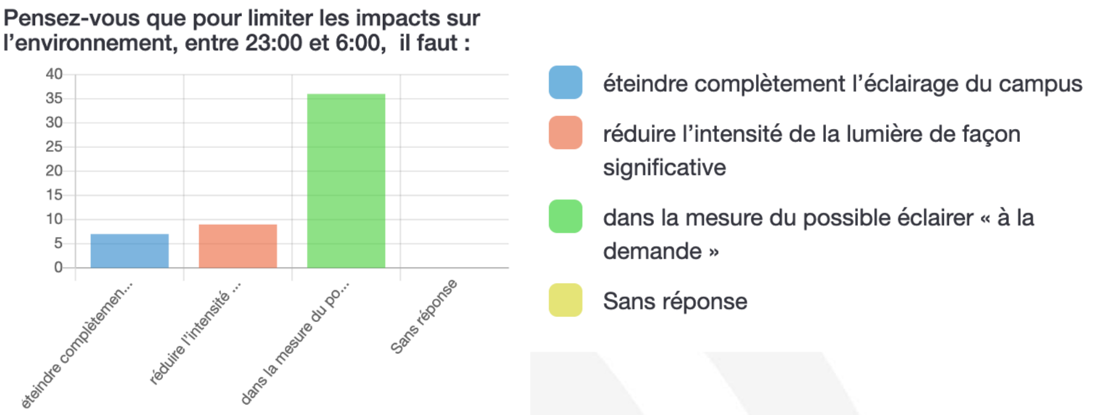


Figure 21 : User proposals to limit the negative impacts of campus lighting

Finally, we informed users that Toulouse 3 University participates in several research projects on the optimization of lighting systems and, subsequently, we asked them how they positioned themselves vis-à-vis these initiatives, as shown in Figure 22, the answer is "very favourably" at more than 83%. And to the question "Do you encourage the school principal to..." The answer is first "amplify these initiatives" followed by "continue to invest as much as possible in these activities" (Figure 23).

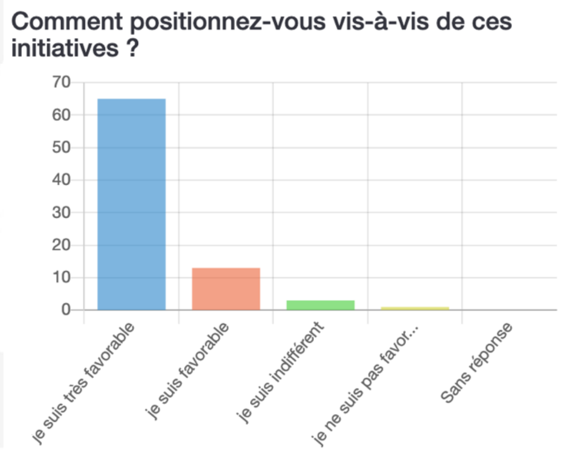


Figure 22 : Position of users concerning the institution's initiatives

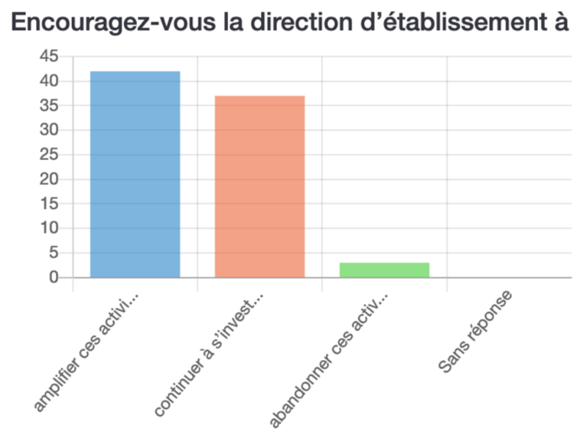


Figure 23 : What users advise the institution

The main conclusion of this survey is that users are aware of the impacts of campus lighting on the environment, energy and the biotope. They approve of the institution's involvement in research programs that aim to limit these impacts and they strongly encourage the institution's management to amplify these activities, including by using its own resources.

Madrid Lighting Demonstrator

Location of the demonstrator

The demonstration site on Madrid campus (Campus de Montegancedo sn, Pozuelo de Alarcon) was chosen in collaboration with the University's technical services (SGE). This is the section of the campus where is present a pedestrian path that connects different buildings and the sports facilities.
Figure 24 shows the exact location of the demonstrator on the campus plan, including the location of the new BSL version and the streetlight equipped with the Kara sensor.

Figure 24. Location of the Madrid Lighiting demonstrator and streetlights equipped with the BSL system.

The equipment of the Madrid demonstrator

The Madrid demonstrator will combine the two technologies (BatStreetLight and Kara systems). Both systems are operational and working together.
Every street light is equipped with a device called BSL (BatStreetLighiting) capable of controlling any illumination driver with a 1-10V interface. The BLS integrates a light sensor and multiple motion sensors, so that the street light is switched on only when needed and with the exact required level.
Through a wireless communications interface based on IEEE802.15.4 and 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) technologies, street lights can be easily connected to the Internet and externally controlled, defining every street light as an IoT (Internet of Things) node.
A management platform, which stores information from BSLs and offers monitoring and control applications, supervises the system.
An experimental implementation consisting of 69 street lights to cover the pedestrian areas and a parking lot at Montegancedo Two networks have been configured with

different physical channels to ensure reliability and load of the coordinating nodes to ensure response time. Devices have been programmed to switch on when detected illumination reach a threshold and not at a given time. In the on state, they work by default in low power mode (dimmed to 10%) unless presence is detected in which case, they gradually change to 100% and inform the neighbour lamppost in order to anticipate the lighting to the pedestrian before is detected. When presence is no longer detected, they gradually come back to the low power state.

Communication between BSL nodes is made directly (ad-hoc) and the system can operate in autonomous and manual mode. The BSL autonomous operation mode is based on a finite states machine.

- INIT state is the initial state reached after restarting the BSL.
- IDLE state is a stable state where the lamp is switched off because there is enough natural light: dimming level = 0%.
- STDALONE state is a stable state where the lamp is switched on due to lack of natural light. The dimming level remains invariant so that the luminosity measured is within the range THMIN±HYST. Whenever the system detects motion, it changes to the DETECTION state. In case any node receives a detection message from another BSL, it changes automatically to the NEIGHBOR state.
- In the DETECTION state the dimming is set to the maximum level during the set time DTOUT. After DTOUT, it returns to the previous state. If another motion detection takes place during DTOUT, the timer restarts. If a node receives a detection message from a BSL during DTOUT, it changes to the NEIGHBOR state.
- NEIGHBOR state works similarly to the DETECTION state: NTOUT instead of DTOUT and when a motion detection happens during NTOUT, the node changes to the DETECTION state.
- CONTROLLED state sets the manual mode allowing to change the dimming level remotely.
- ALARM state notifies an alert situation either when any physical damage or unexpected removal of sensors occurs.

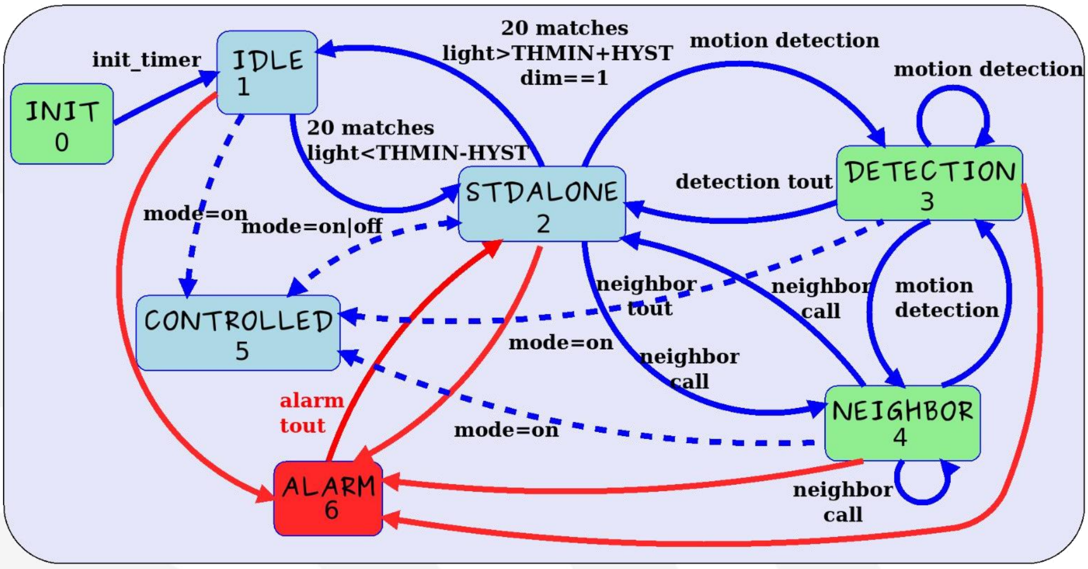


Figure 25. Autonomous mode states machine of BSL

Intelligence of the system is implemented through an algorithm that uses the measure of the luminosity reflected on the floor to decide the dimming level of the lamp.

1. Starting at night, after a certain number of periodic luminosity measures with a value lower than THMIN–HYST, the BSL switches from the IDLE to the STDALONE state.
2. During the STDALONE state, the light will be regulated so that the minimum light level (THMIN±HYST) is guaranteed.
3. When the luminosity level has been higher than THMAX+HYST during the day throughout a certain period of time, the system switches off.

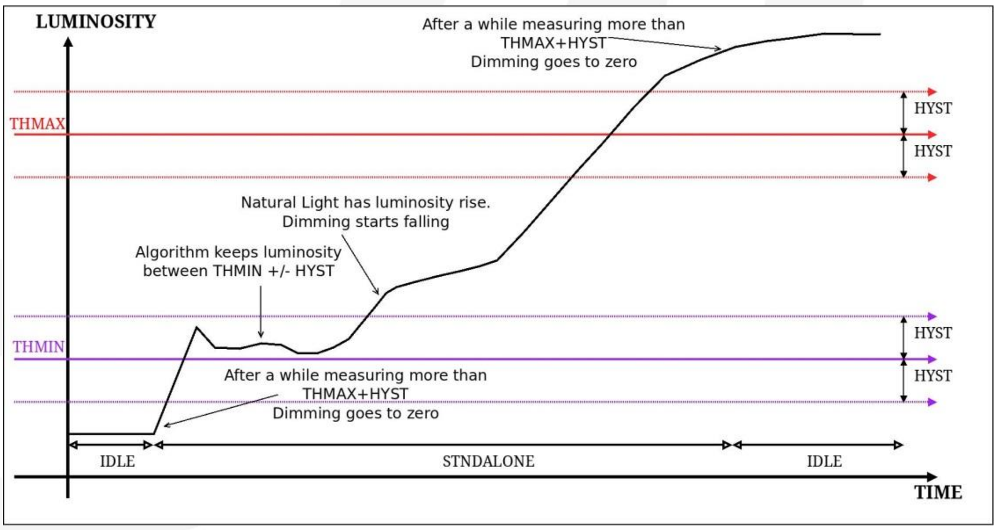


Figure 26. System behavior during the STDALONE state.

4. Starting in STDALONE state, when a detection or neighbor notification event happens, the system changes to DETECTION or NEIGHBOR state and try to maintain the illumination level within the range THMAX±HYST.
5. After a configurable timeout, the states machine goes back to the STDALONE state unless there are not more events during that period of time.

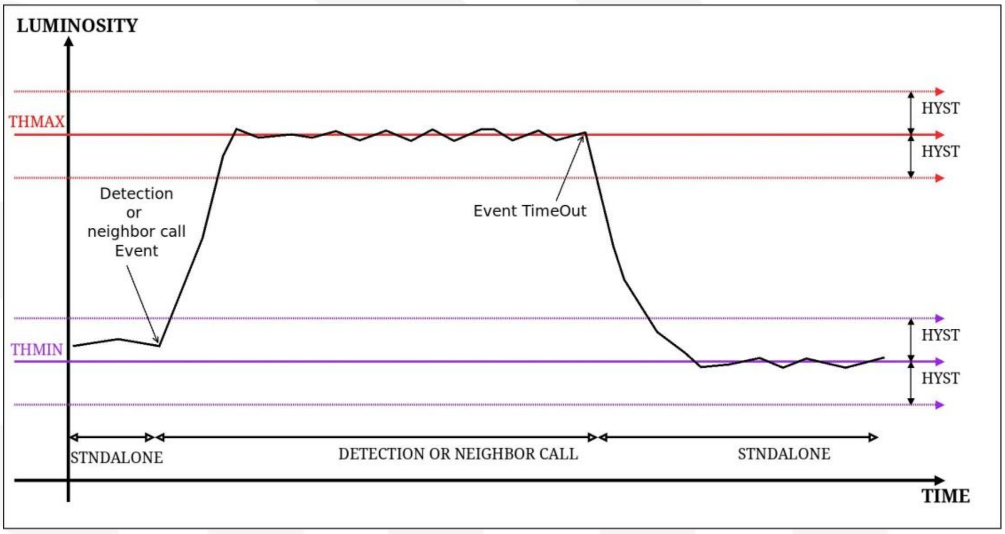


Figure 27. System behavior during the DETECTION and NEIGHBOR sates.

The Kara sensor fromo Kawantech was received and tested in laboratory conditions before installing it in the outodoor location.

Figure 28. Kara sensor upon reception and final location in Campus.

Integration of BatStreetLighting and Kara systems

For the replication test of the Kawantech Kara system at UPM, a Wi-Fi network was deployed with the parameters provided by Kawantech. The Kara device was pre-configured to search for an IEEE 802.11 access point with SSID "KWTFRPolitecUniverMadrid123" and a specific password.

Once the device is connected to the network, we can access its control interface thanks to a web server incorporated in the device itself (Figure 29).

Figure 29. Home interface of the Kara sensor we GUI.

On this first page it can be observed the system's response to motion detections. Reactions to motion detection can be configured differently for the three different types of "things" that Kara's live image analysis algorithm recognises: people, cars and bicycles:

- Linear or logarithmic illumination increase - the latter more natural to human eyesight.
- Minimum and maximum allowable levels in case of absence and presence respectively
- Virtual presence hold time after real motion is no longer detected by the camera
- Illumination level in case of system failure
- Ramp-up and ramp-down time of absence-presence transitions

For the Kara system per se, the physical installation height of the camera must be configured, so that the algorithm considers the focal length of the lens when detecting presence. A detection zone can also be chosen by "drawing" it on a camera image or leaving it on automatic.

The system also allows other "neighbouring" streetlights to be alerted of detections, thus creating a virtual light path in the event of detecting people or bicycles, for example. This warning can be in a "cluster" manner, i.e. to all neighbouring luminaires, or in a "corridor" manner, i.e. in a linear path.

The system allows the connection of luminaires with DALI or 1-10 V control. In addition, statistics and detection data are sent periodically. LoRaWAN or Dash7 can be used for communication. With the Wi-Fi connection, it is possible, in addition to configuring the device, to view a live video stream of the camera and its detections - either in real image mode or detection "blobs" mode (Figure 30).

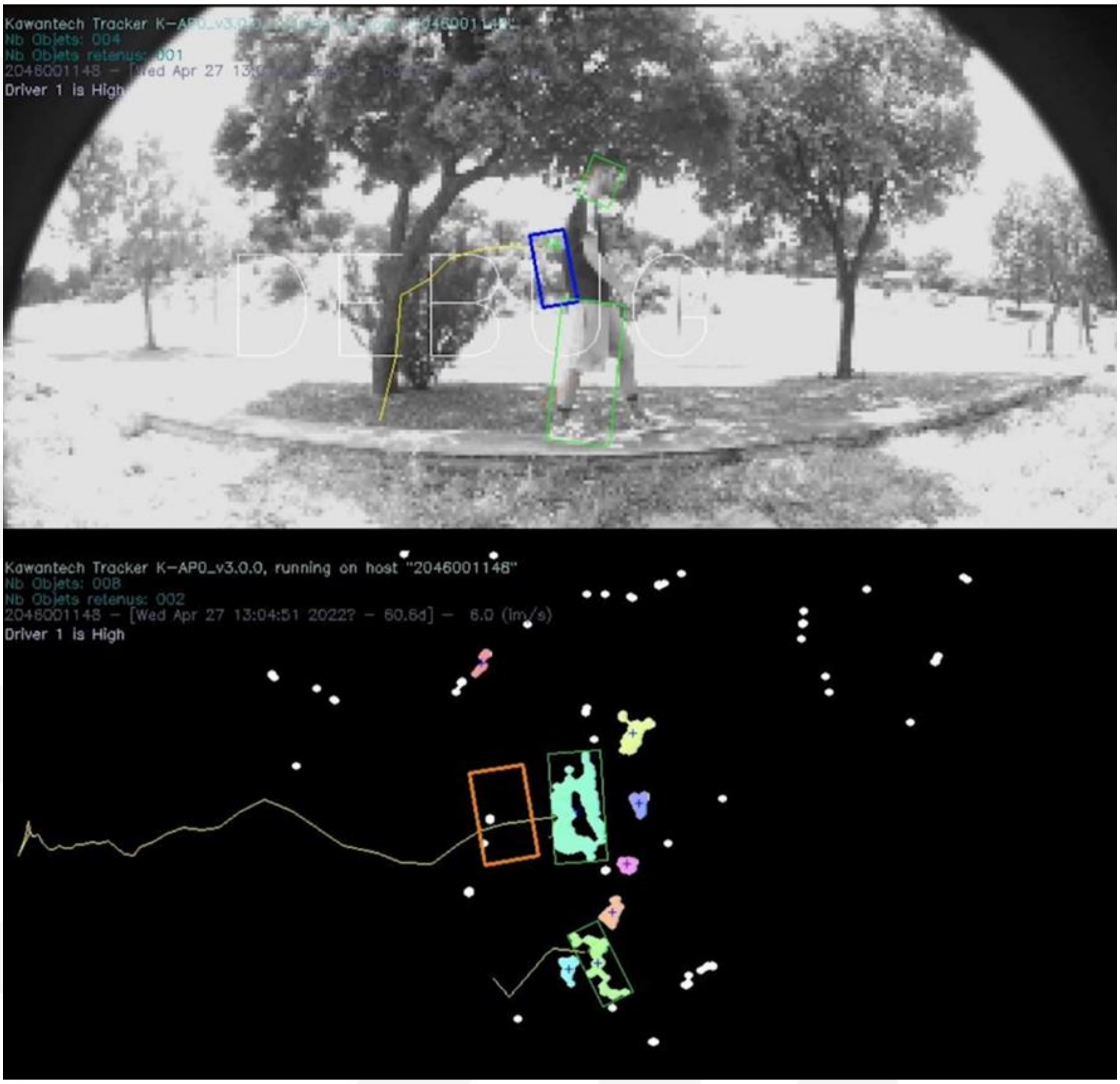


Figure 30. Video stream of the Kara system detecting a pedestrian.

The integration of Kara sensor with BSL system has been done in two different ways:

- Web scraping from the device's website, to know when the detections occurred in real time, storing the values in the BSL time series database (Graphite).
- By using a BatNet mote, connecting the 1-10 V output of Kara to an ADC of the mote, which sent the values to the BatNet Gateway.

Issues of the replication process

In general terms, the results achieved in this activity are in line with the initial hypothesis. However, the universities have faced unpredicted issues. In October 2022, and in the framework of TG3, FUNSEAM has conducted a survey to collect data from tasks developed by the universities in TG1 and TG2. The questionnaire asked the involved partners (UPM and UT3 in this activity) for information about the technical and the administrative difficulties they encountered when replicating the innovations.

As for the technical difficulties, UPM faced some complications regarding the use and configuration of the replication elements (the Kawantech sensor). On the other hand, UT3 found obstacles to understand the IoT communication protocols and adapt our data acquisition system. Both issues were solved during the project.

Regarding the administrative difficulties, the UPM noted that, in comparison with other project activities, as the cost of the elements for the replication was below 5.000 euros, the administrative process is easier. This answers for the Spanish regulation regarding the equipment acquisition for public bodies. On the other hand, UT3 has faced many barriers to obtain the authorizations to install the BatStreetLight system in the campus. Regulated by university equipment services, the process is very complex and takes large amount of time. Hopefully, it will be installed soon.