Business Case Development for IT-project

2020-2021 (2B)

Business Case Report

Business Case: Smart lighting For University of Twente

Group 5

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Summary

The report contains the business case analysis that discusses the implementation of smart lighting within the university, as well as its implications, advantages and disadvantages, performance indicators, and beneficiaries. Furthermore, a classification is done via the balanced scorecard approach to give a strategic layout of the business case.

Recent studies have shown that energy-efficient smart LED lighting systems provide a better visual comfort-working environment at a reduced energy consumption compared to existing lighting systems. Present daylighting systems are able to regulate the light intensities via communication technologies utilizing smart sensors. The use case for this business case is focused to contribute to user comfort and satisfaction, save energy by conserving it during less busy hours and increase security.

University campuses are places where thousands of people study or work daily. The university campuses are in communication with the cities in which they are located on tangible issues related to infrastructure, and on intangible issues such as social relations or innovation. The use of smart lighting will improve educational campuses and the quality of life of the inhabitants. It allows areas of educational control to monitor their students and those involved in university education. A smart campus allows a better coexistence between the university population and its surroundings, adequately manages the resources within the campus, and provides favourable places for learning (Willard, 2019).

Scope of the project

The Smart lighting system at the University of Twente campus involves campus buildings and campus streets. Although currently the streets of the university of twente campus have daylight sensors, in this business case the current system of the street sensors will be integrated along with the Smart lighting system. The system is a combination of hardware and software.

The main motivation is to achieve higher comfort and satisfaction from users(students and staff). That will be achieved with personalized scenes for every occasion: it can set the stage for your daily routine, studying, learning-context-based, theater salons, and night mode. Moreover, it can adjust brightness, CCT, and illuminance distribution dynamically according to the specific learning context. Studies have shown that there are effects of smart lighting leading to an increase in productivity along with reduced fatigue and more concentration (Willard, 2019). Moreover, the project would be conserving energy, as smart LED's use 75% less electricity compared to the normal bulbs.

Current situation

This business case is an upgrade proposed to the current system. The current situation was found out after reaching out to the Electrical Maintenance Contractor from the University of Twente, that most of the buildings in the campus are equipped with LED lighting. Though, they are only equipped with two technologies: motion detectors and daylight sensors.

We also got access to an important website for this business case: Energy Data at University of Twente (energydata.utwente.nl). After plotting the data regarding Electricity (Figure 1), that we got from the website mentioned above, we were able to identify some insights:

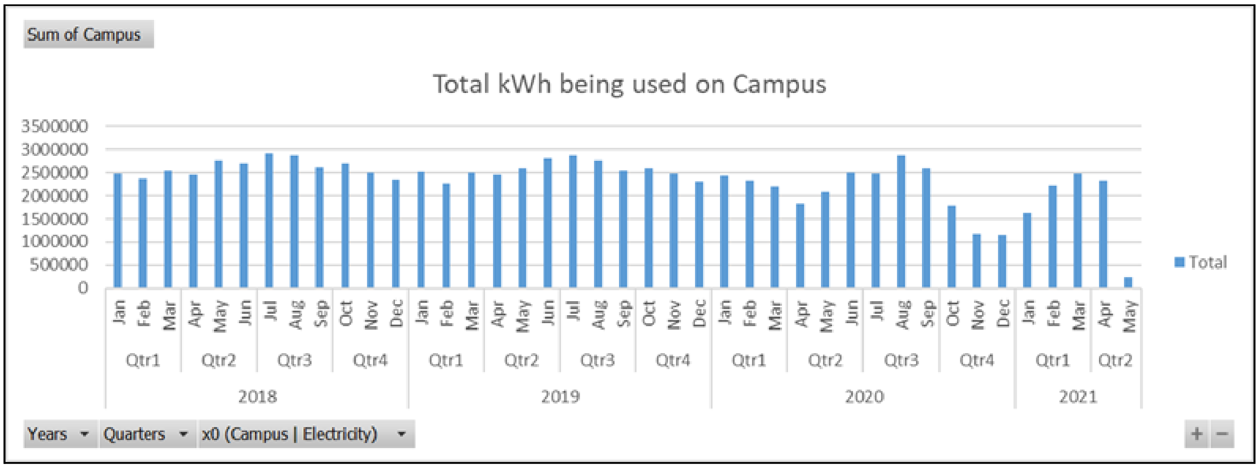

Figure 1: *Total kWh being used on Campus per month (source: Energy Data at UT)*

There is a clear drop in April 2020, compared to the previous years, which is probably related to the lack of use of the lecture rooms and other facilities on campus due to the lockdown measures that were put in place because of the COVID-19 pandemic. Moreover, the same could have happened in October, November and December of 2020, and January and February of 2021, since it could be the case that many students decided to go back to their parents houses, which would lead to less use of energy on campus.

That insight is helpful for us, because if we estimate our costs based only on the 2020 period, we would have a wrong estimation of costs, putting the project in danger.

Options Considered

Having in mind the facts discussed above we have two options for the focus of this project:

1. Changing the lights of the whole campus, upgrading the LED lights to smart LED and integrating the street lights in the light controlling system.
2. Changing the lights of specific rooms on campus, upgrading the LED lights to smart LED and integrating the street lights in the light controlling system.

Our Approach

The focus we have decided for this project is:

Changing the lights of specific rooms on campus, upgrading the LED lights to smart LED and integrating the street lights in the light controlling system.

The decision was made after knowing that the campus had already been replacing the incandescent light bulbs for LED lights. Therefore, changing the LED for smart LED in the whole campus would not have a high impact on the consumption of energy, for example. The benefit would not be as high as the costs that would be incurred.

Moreover, in order to have a central control of the rooms setting to improve student productivity and make the integration of the street lights to the lighting control system, that system would have to be built. In this case, that will also be a goal for this project.

Benefits

For University

1. Lower maintenance cost: Smart lighting has fewer maintenance requirements on the switches and controls as smart LED bulbs are used, which are connected to a central system. Smart LED and LED light bulbs have a longer lifespan than incandescent light bulbs. So the university could extend the maintenance cycle and save labor costs.

2. Enhance security: Increase safety on the campus, as smart lights help in detecting motion. Lights are activated when a sensor detects motion.

3. Saving electricity cost: Smart lighting systems will help the university to track savings on their lighting costs. When you use smart lighting, you can make sure to utilize lighting when you need it and avoid turning on the lights when the space is unoccupied.

4. Easy installation: For smart bulbs no installation or wiring is needed, their relatively low cost, wireless communication technology is built into the bulb including dimming or color-changing technology. Since the whole campus is equipped with wifi, the installation would be simplified.

For Users

We can consider all students, teachers and UT staff as users.

5. Personalized scenes for every occasion: it can set the stage for your daily routine, studying, learning-context-based, theater salons, and night mode. It can adjust brightness, CCT, and illuminance distribution dynamically according to the specific learning context. The LED driver control has four two-way ports. Each port can connect to a LED fixture's power driver, and its two-way controls the cool white LED and the warm white LED, respectively, by controlling the duty ratio of the power output to adjust the luminous level.

   Additionally, the suggested system also supports lighting mode and class schedule association. Users can control lighting mode in several ways such as control panel, remote control, software (e.g., APP, HTML5 page, WeChat) and voice command. The instruction is transmitted to the IoT gateway, then passed to the corresponding LED power controls by the gateway. The gateway gathers status of subordinate nodes and reports to the cloud. The cloud platform reflects the change of status on the UI. After the linkage is set, the system can automatically change lighting modes according to the current class context. (Sun, Zhang, Cao, 2020)

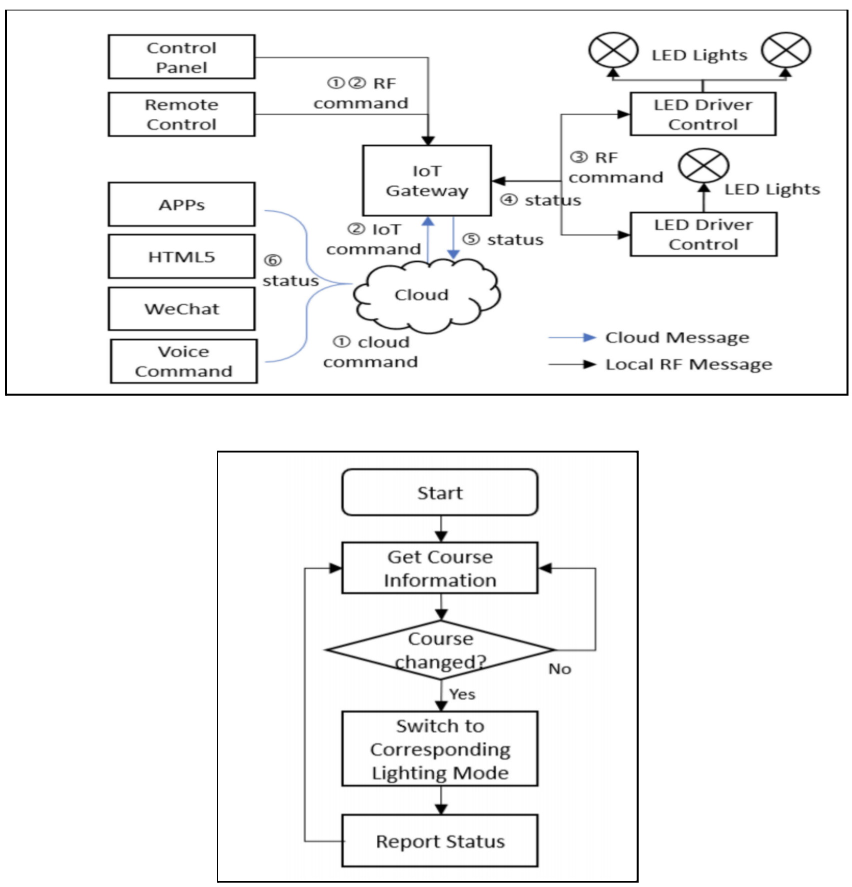

Figure 2: *Flowcharts of lighting mode switching with class schedules*

6. Lighting can affect productivity: using the right lighting will contribute to the improvements in wellbeing, functioning and work performance of the users (Mills, Tomkins & Schlangen, 2007). LED lighting is able to boost focus, assist in concentration and relaxation and improve overall mood and behavior in students. Daylighting has been shown to improve mood, mental performance, alertness, and brain activity, while decreasing depression, stress, sadness, and violent behavior. Therefore, with the smart LED lighting system, the controllers would be able to simulate daylight (Willard, 2019).

7. Safety during evening activities and nighttime transitions between dorms, educational and recreational buildings is essential. Since the street lights would be connected to the central control system, any defects or light failing would be quickly detected.

8. Sync and play music/voice with smart light bulb speakers: Smart Wifi and Flux Smart Bluetooth LED Light Bulbs speakers can be used to play music, video of lectures in any room of campus by transmitting voice commands to a smart hub. It can be used in theoretical classes, amphi salona, gyms.

For Environment

The natural environment can be affected by a company's activities and, through channels such as climate change, can have an effect upon the company.

9. Energy efficient and Eco Friendly: using this system can save a lot in energy usage, particularly when you use LED lights with dimmers. It is adjustable when it does not need full brightness from a light bulb, and the dimmer can cut down on energy usage to reduce electricity bills.

10. The amazing lifespan of Smart Bulbs: A longer life span means lower carbon emissions. LED Lights last up to six times longer than other types of lights, reducing the requirement for frequent replacements. This results in using fewer lights and hence fewer resources are needed for manufacturing processes, packaging materials and transportation.

11. LED Lights have a smaller carbon footprint compared to incandescent bulbs: The power consumption is reduced which in turn decreases the carbon footprint on its usage. Since almost 830g of carbon equivalents are released in the consumption of 1KWh of electricity. It follows that carbon emissions can be reduced if electricity consumption is reduced.

Performance Indicators - Balanced Scorecard

The balanced scorecard is a tool developed by Kaplan and Norton, it is widely used for the management of companies and projects, because of the numerous benefits it brings. First, it helps in creating a holistic view of the problem at hand. Second, it helps in improving performance, as well as measuring it (Kaplan & Norton, 2014). By separating in four different perspectives (Financial, Customer, Internal Process and Learning and Growth), the management tool helps to choose the best measures in order to reach the specified goals (Spider Strategies, n.d.).

Financial

In order to have a "healthy" company/project it is important to look at the financial perspective, taking in consideration all the usual measures such as profitability, growth, and shareholder value, but also other angles that are commonly overlooked. For this project, the following financial measures were selected:

1. Electrical Energy Efficiency ratio: This indicator is selected to measure how efficiently the system operates. It could help us to measure the maintenance cost.

    EEER is the consumed electrical energy in kWh per ton of product

    EEER = kwh/ton of product

2. Average maintenance cost per lighting unit: Costs incurred in the maintenance of the lights and the automated system. This could work together with EEER.

3. Operational cost benefits in remote control: The cost of operation can be determined with functional meters to track the electricity usage. Comparing the bills before implementation with the proposed smart control for the lighting gives the benefit value.

4. Maintenance cost over asset value: This matrix is set up to evaluate the cost performance of the whole system.

5. Total maintenance cost by replacement value of production equipment value.

6. Productivity and Saving: The importance of productive lighting for real estate and its efficient use is up to 10 times higher than for energy savings. It improves efficiency and generates

savings in e.g. cleaning, maintenance, life cycle and service costs. The key impact of productive lighting is the effect on people, through which it is up to 100 times more beneficial than energy savings alone. Its added value for business includes higher work safety, productivity, efficiency and quality, reduced errors. With the lighting systems in all of the buildings.

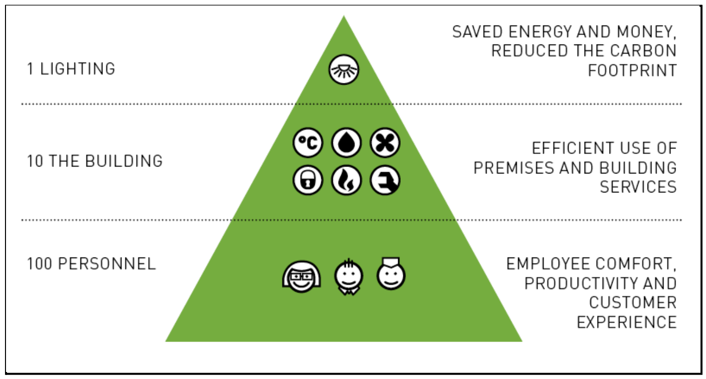

Figure 3: *Productivity and Saving*

UT has saved 75 percent in lighting energy and gained 20 percent in productivity. Reading speed is improved by up to 5% under LED lights and accuracy increases, too. For example, a study in Massachusetts has shown improvement in work performance due to LED lighting retrofit (Srivastava, Cochran Hameen, Loftness, 2013):

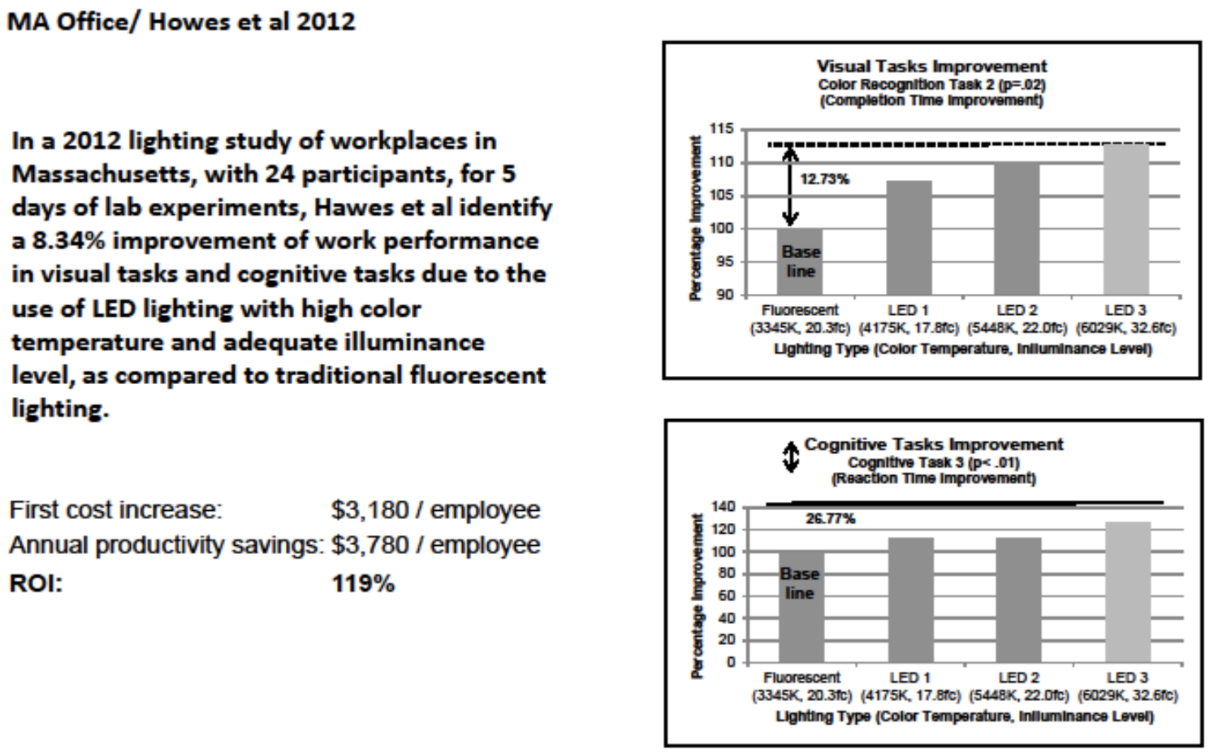

Figure 4: *Study showing improvement in work performance*

Customer

The customer perspective is related to the question: “How do customers see us?”. Therefore, the following measure was selected to monitor customer satisfaction.

7. Percentage (%) of students/employees satisfied with the Smart Lighting Service: This can be calculated by sending out surveys after the smart light system is implemented, for example, using the Likert scale.

8. Percentage (%) of students that noticed a change in their productivity when using the rooms with the smart lighting set up.

With the answer to this, it is possible to assure that some of the most important stakeholders are being taken into consideration with the project implementation.

Internal process

A sophisticated lighting control system is needed for the optimization of the lighting environment for different conditions. Moreover, in order to guarantee the effectiveness of the project the following measures could be considered:

9. % of total power that is "green" power: Green power is a subset of renewable energy and represents those renewable energy resources and technologies that provide the highest environmental benefit (Environmental Protection Agency, 2021).

10. Percentage (%) of energy saved per person: University will incur the percentage of energy being saved behind each person and can understand the difference before and after the smart lighting implementation.

11. Kilowatts of energy saved per person: University will have the costs calculations of electricity consumption before and after the implementation of smart lighting systems.

    The calculation can be done by subtracting the following PIs:

    a. Average electrical consumption before switching to smart lighting
    b. Average electrical consumption after switching to smart lighting

Learning and Growth

It is vital to develop new strategies to achieve energy saving for lighting while satisfying the illumination comfort of users.

The administrations can develop the necessary skills for maintaining and possible expansion of smart lighting in future. Furthermore, a support system can be considered and documenting all installation and execution steps can be helpful. Furthermore, in this project it can be added that:

12. R&D spent as % of revenue: University will have the cost of implementation and can understand the revenue trends based on the bills paid before and after implementation.

Benefit Model

In this section we will describe the modelling of the benefits of using Smart lighting systems based on the matrix by Ward et al. Benefits are modelled based on the aspects and on the type of activity that they perform.

They can be categorized into 4 aspects: Financial, Quantifiable, Measurable and Observable and into 3 kinds of activities: Doing New Things, Doing Things Better and Stop Doing Things. The first stage of using this matrix is to classify each expected benefit according to the main type of change that will be needed to realize it. “Doing New Things” lists all benefits that will add a new value,“Doing Things Better” consists of the existing activities that can be improved, whereas “Stop Doing Things” lists all the activities that don’t add any value.

The table below (table 1) shows each of the measures in a more objective way. The method was developed by Ward et. al. (2008) and has the goal of providing a way of assessing each benefit in a more insightful and concise way.

Ward et al. / Building Better Business Cases for IT Investments			
	Doing New Things	**Doing Things Better**	**Stop Doing Things**
Financial	**Benefit**	**Benefit**	**Benefit**
		1. Lower the maintenance cost from lighting	
		2. Saving energy cost	
		Measure	
	Measure	1. The Electrical Energy Efficiency Ratio(Smart lighting) = kwh/ton of product - EEER(previous lighting system) 2. Average electrical consumption(before smart lighting) - Average electrical consumption(after smart lighting)	**Measure**
	Benefit Owner	**Benefit Owner** 1. University - Executive Board 2. University - Executive Board	**Benefit Owner**
Quantifiable	**Benefit**	**Benefit**	**Benefit**
		Using LED for smaller carbon footprint	
	Measure	**Measure**	**Measure**
		830g of carbon equivalents are released in the consumption of 1KWh of electricity	
	Benefit Owner	**Benefit Owner** - Students	**Benefit Owner**

Measurable	**Benefit -** 1. Adjust light to improve students performance 2. Employee wellbeing	**Benefit**	**Benefit**
	Measure 1. Surveys about student productivity in the rooms with the new set up. 2. Surveys can be taken after the implementation of Smart lighting system about employees wellbeing	**Measure**	**Measure**
	Benefit Owner - Users (Students and Staff)	**Benefit Owner**	**Benefit Owner**
Observable	**Benefit**	**Benefit**	**Benefit**
	Enhance security (motion sensor can detect every move inside the campus)	1. Encourage lighting sustainability 2. Easy installation	Stop using incandescent bulbs to reduce energy consumption
	Measure Numbers of suspicious behaviors detected	**Measure** 1. Future lighting upgrading cost 2. No installation or wiring (using wireless	**Measure** Number of incandescent bulbs divided by number of led lights
	Benefit Owner Students and Staff	**Benefit Owner -** 1. University - Executive Board 2. 1. University - Executive Board	**Benefit Owner** University - Executive Board

***Table 1** : Summary of Benefits*

Below we explain each of the table 1 sections in more detail.

- **Financial**

The financial perspective takes into consideration the factors that would impact the business case money wise and is able to be quantified (Ward et. al., 2007). We understand that lowering the maintenance cost for lighting and saving energy cost would have a great impact for the University, therefore they are benefits that are worth mentioning.

- **Quantifiable**

This perspective is used for the cases that can offer enough evidence in order to forecast the improvements or benefits that the project would bring (Ward et. al., 2007). Usage of smart lighting systems would require the use of smart LED bulbs for controllable lighting. This reduces the carbon footprint as it has been observed that the LED bulbs require lesser energy consumption in terms of electricity.

Experiments on calculating the energy consumption have pointed out an approximate value of 830g of Carbon being released for 1KWh of electricity. This immediately benefits every student around the environment of the smart lighting systems which indirectly leads to benefitting the people of the society.

- **Measurable**

  This perspective presents the benefits that can be measurable, although they do not provide a way of forecasting the future benefits the project would bring (Ward. et. al., 2007). The students will be benefited after the implementation of the smart lighting system in the campus. Studies have found that people working in LED lighting had faster reaction times, reduced fatigue and increased activity. And, as mentioned before, the light setting can improve students' performance and employee (staff, workers, etc.) productivity (Amerlux, 2018).

  Surveys regarding the students productivity could be used in order to quantify the enhancement in productivity during their studies.

- **Observable**

  At last, in this perspective it is only possible to measure to what extent the benefit was realized by using an agreed criteria (Ward et. al., 2007).

  The world is moving towards smart systems and using a smart lighting system is a wise choice for its interoperability with other systems. To provide maintenance, installation and upgrades in the future would be comparatively minimal as the major investment lies on the initial costs for establishment.

  This encourages the shift towards sustainable lighting technologies within universities. As the process is heavily reliant on software, it requires lesser expertise on hardware installations. This makes the implementation process easier for the university.

Cost Analysis

Cost Factors

Cost modelling and estimation analysis is done in order to ensure proper determination and understanding of all potential costs that would impact during the development and implementation of the project. This business case assumes a one-year deployment period and considers the project costs and benefits over a 15-year period compared to business-as-usual. All costs in the associated model are expressed in today's terms (i.e., approx real values).

Cost factors of systems life cycle

All calculations and estimations are related to the entire campus and its buildings.

1. **Planning (requirements, design)**

    - Smart LEDs should be selected from different manufacturers. The powers of LED range in variable categories can be selected based on type of use and different lighting classes. The photometric quantities of them should be measured.

    - The results of the measurements are saved as files and transferred to the DIALux lighting design software package. According to the results of the design calculations, cost analyses of the LEDs are calculated with the LCCA method.

        *Life-cycle cost analysis (LCCA) is a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system.

    - After the cost analyses, the LEDs with the minimum total cost will be procured.

2. **Initial development(build, test, deploy)**

    - The initial cost to buy a bulb, armatures or its connections.

    - Cost of smart control system

    - Cost for installation and implementation

- Cost of hardware replacement
- Staff and supervisors need to be involved to test and ensure the project stays on the right track.

3. **Production (operation, support, maintenance, shut-down)**

- Annual cost of repairs, replacement
- The reduction of the budget for maintenance for a system with LED connected to a smart control system is estimated to be 70 % by Philips and 87 % by Sala Heby Energi. The average of these numbers, 78.5 %, can be used.

Type of Costs

	Acquisition & Implementation Costs	**Operational Costs**	**Ongoing Change & Growth Costs**
Hardware Costs	- LED Smart Bulbs	- LED Smart Bulbs replacement	
Software Costs	- Smart Control System acquisition	- Smart Control System fees	
Personnel Costs	- Personnel hiring for system set up - Personnel hiring for hardware installation	- Training hours for system usage	- Personnel hiring for hardware maintenance - Personnel hiring for software maintenance
Computing Costs	- Cloud set up	- Monthly usage fees	- Migration costs
Other Costs		- Operation electrical energy	

		- Maintenance costs	

Table 2: *Type of costs*

By using the table above with the description of the type of costs involved in the project, the stakeholders are able to have a complete understanding over the possible ways that the project will require investing. By using this tool it is possible to predict and have a clear overview over the whole project life-cycle instead of only focusing on the implementation costs.

Total Cost of Ownership

Total Cost of Ownership (TCO) is a holistic view of costs that are related to all the expenses of owning, maintaining and developing a product. It considers all the costs over the complete lifecycle pre use, usable life and post usable life.

This technology is not obsolete until and unless there are any new innovations related to smart lighting systems in the upcoming future. Therefore, this financial analysis uses a period of 15 years to estimate the total cost that the project would involve.

Expected Costs

1. **Hardware**: For the hardware part, Smart LED's and its installation both are the initial expense and replacement costs over time. They would result in a total of €345,000 for the 15 years.

    a. Acquisition & Implementation Costs

        i. LED Smart Bulbs

        The cost of LEDs depends on some factors that change the price: manufacture, energy efficiency, Brightness/Light output, Colour temperature, Lifetime.

        Nevertheless, The new smart LED bulbs used with voice-controlled services cost anywhere from €33 to €82 per bulb depending on the manufacturer. In order to have a real estimation, we chose to use €50 as the price per smart LED.

Considering that 200 rooms from the university campus would be included in the project to have smart lighting, and that each room uses around 30 light bulbs, we would need around 6000 smart bulbs, totalling €300,000.

b. Operational Costs

i. Smart LED replacement: Most of the manufacturers offer a warranty for a number of years. Therefore, since the life-cycle of a smart LED bulb should be long, if it still fails during the warranty period it will be replaced at zero cost of the hardware part, otherwise the university has to assume that cost. Which we believe will not exceed 1% of the total installed smart bulbs, considering that the product's life span is between 15 to 25 years (Ledic, 2020), therefore it would result in less than €3000 in hardware costs per year.

2. **Software**: The street light control and management integration is one of the main focus of the business case, serving also as the main expenses. There is no exact price for the software, however there is a range of pricing which is around €66,000/year. Hence, for an operational duration of 15 years, the total cost is €990,000.

a. Acquisition & Implementation Costs

i. Application development for minimum viable product with the use of low code enterprise licenses for a platform like Mendix, Outsystems costs around €5,500 per month which is among the top 10 low code applications (Software Testing Help, 2020).

b. Operational Costs

i. The licenses would cover the security and other cloud operations for the application on a cloud platform for the required duration of 15 years.

3. **Personnel Costs**: This would mostly consist of deployment services. Those services provided by a vendor or third party to assist with the planning and deployment of hardware and/or software.

a. Acquisition & Implementation Costs

i. Personnel hiring for system set up - Considering the work of a developer 8 hour per day, 5 days per week, with a salary rate of € 70 per hour (Chekalin & Nechvolod, 2021). By calculating their salary per month as € 12,320, and a 50% overhead (€ 6,160 in total). The total spent per month per developer would be € 18,480 per month. Considering only 1 developer will spend his full hours on this project, and that the project set up usually takes around 4 months, the full cost on setup is € 73,920.

ii. Personnel hiring for hardware installation - Considering a team of 4 people fully dedicated to the installation of hardware in the set up phase of this project (4 months) and considering a salary of € 20 euros per hour, the total estimated cost for hardware installation would be constituted by the following formula: (4 employees X 20 euros per hour salary X 176 hours per month X 4 months) + 50% overhead = € 84,480 in total or € 21,120 per month.

b. Operational Costs

i. Training the training systems for system usage - The cost of training consists of training and done every two year assuming the training needs 25 hours per year or around 2 hours per month. The average wage in the Netherlands is €15-€25 [1], therefore we estimate that it would cost 18 euros per trainer. Usually the training is included with the software system. However, an extra training might be necessary, the training would then consist of software failure, system downtime, etc. Considering 2 trainers, the total amount in training per month would be calculated by (2 trainers X 18 euros per hour salary X 2 hours X 1 month) + 50% overhead costs = 103 euros per month. Or €412 in total.

c. Ongoing Changing & Growth Costs

i. Personnel hiring for hardware maintenance - The university already has a team dedicated to maintenance in the Campus, therefore we assume that they would have to allocate 4 hours per week for the project. Since there are 2 people dedicated to maintenance and we estimate that they get paid 28 euros per hour, the total could be calculated by (2 employees X 28 euros per hour salary X 18 hours per month X 1 month) + 50% overhead = 1512 euros per month, therefore €18,144 per year. For the 15 year project, the total cost would be €272,160.

ii. Personnel hiring for software maintenance - The university also has a team dedicated to the ICT responsibilities on campus, therefore, the project would become another responsibility for them. We assume that 4 people would work 3 hours per week in the smart lighting project, and the average salary of an employee in the ICT team is 65 euros per hour. The cost would be calculated by (4 employees X 65 euros per hour salary X 13,5 hours per month X 1 month) + 50% overhead = 5,265 euros per month or €63,180 per year. Which would be €947,700 for the total project period of 15 years.

4. **Computing Costs**:

   a. Acquisition & Implementation Costs

      i. Cloud set up - This is already included in the personnel hiring system set up costs. Since no hardware would need to be purchased for the computing costs.

   b. Operational Costs

      i. Monthly usage fees - The monthly usage fees change according to the cloud vendor as well as the services hired. For this specific case we are choosing to hire Software as a Service, so the university can solely focus on the Smart Lighting project without having to worry about infrastructure or platform development and maintenance. The today estimated cost to have the infrastructure in Microsoft Cloud today would be € 2,454 monthly or €505,163 for the 15 years project period. The products included would be Azure Analysis Services, Azure Cosmos DB, Azure Data Factory, Azure Databricks, HDInsight, Power BI Embedded and Storage accounts (for more details about total values used to make the estimation check the link, also in the sources at Cloud Costs Estimation, 2021).

   c. Ongoing Changing & Growth Costs

i. Migration costs - The migration costs should be calculated in case it is decided to migrate the project to, for example, another cloud provider. In that case, the costs would also be more related to the developers working hours, which is already being included in the costs planning regarding personnel.

5. **Other related costs**:

   a. Operational Costs

      i. Electricity Energy costs - The price of electricity is €0.095 for businesses which includes all components of the electricity bill such as the cost of power, distribution and taxes. Although, these costs will not be included in the business case, as the costs are already in place and the smart LEDs will in fact reduce it.

      ii. Maintenance costs - Those costs can vary a lot. In order to have an estimation, we took into consideration the papers from Olanrewaju, Idrus and Khamidi (2011) and Krstić, Hrvoje and Marenjak (2017), where they try to come up with models to estimate the maintenance costs in a university. Though, we were not able to find the information that would serve as input for the models. Therefore, the best way to do it would be to have an estimation based on the past costs that the university has had with maintenance. In this case we will consider the work from Agron (2009), where he gives means to make a maintenance estimation based on the number of students of a university. Since the University of Twente campus has around 11,000 enrolled students, it would mean that the maintenance cost is around $1,162,260 American dollars or €979,623 euros per year, considering the Utilities and Total Equipment & Supplies parts. Considering the project is around 5% of that total cost, we get to the final figure of €48,980 per year. Which would total around €734,720 as a maintenance cost for the 15 years period of the project.

Therefore, we get to the final table with all the costs that the project would have.

Total Costs	**Estimated Costs in euros (for the 15 years period and implementation)**
Hardware	€ 345,000
Software	€ 990,000
Personnel	€ 1,378,672
Cloud Computing	€ 505,163
Other Related Costs	€ 734,720
Total	**€ 3,953,555**

Table 3: *Total Costs in euros*

The final cost that the project would have is € 3,953,555 for the 15 years period that has been established before, that is a feasible budget for such a project. Although it would still be interesting to first have a pilot project to have more tangible data regarding the benefits, that way the university would be able to check whether the smart LED lamps indeed offer a real gain for the university and its students and professors. In the following chapters (decision tree part) the pilot project will be added as an option.

Risk Assessment

The risk management plan is a good approach to avoid interferences and undesirable situations during the project. Also, by using some tools and techniques, it is possible to completely avoid or be prepared in case one of those risks happen, which would diminish the impact it would have in the overall project (Peixoto et. al., 2014).

Below we present the project's risk matrix and the risk decision tree for the risks that would cause most impact in the project.

Risk Matrix

Likelihood	Almost certain			A		J
	Likely		B			I
	Possible				C, H	E, F
	Unlikely	L		G, K		D
	Rare					
		Insignificant	Minor	Moderate	Major	Severe
		Impact				

Table 4: *Risk Matrix*

A. Delay in the project implementation

> Although it is very important to have a plan and stick to it until the end of each project, most times it is very difficult to predict and follow every step according to the plan. In that case, it is possible that the plan might be delayed, which can result in a rise in the financial costs. For that reason it is important to have a project manager that will make sure people are following the initial plan and will make the changes if necessary, but trying to keep the same final deadline.

B. Light bulbs with defects

The main hardware material used in this project will be the smart light bulbs. It is important that they are able to provide what is required and that they meet expectations regarding technical requirements. It is essential that the bulbs have warranty, to make sure that any manufacturer defects will not add a financial impact to the project. Also, it is crucial that the bulbs are ensured of a high quality, and that their life-cycle is assessed before the product is bought in large amounts for the installations.

C. Minor accidents during the project

Minor accidents might happen when installing the hardware or during the rest of the project. In that case, safety protocols should be created and project members must ensure to follow them, which will avoid that this risk evolves to the following risk.

D. Accidents that are life threatening during implementation of smart bulbs

A more serious accident that might happen during the implementation of smart bulbs are life threatening accidents. For that reason, it is important that well qualified and experienced professionals are hired for the setup of the hardware. Moreover, it is crucial that they wear all the safety equipment necessary and ensure that they are focused while installing the lights. In order to have a more detailed assessment of this risk a decision tree was created in the following chapter.

E. Cyberattacks

There might also be some security issues associated with smart Lighting systems. For example, a hacker could hack into your management system and might get access to important information about the university and also of the users. Moreover, hackers may also steal your data.

Thus, even though smart systems are quite convenient, there are significant security issues related to them and one should be aware of those issues if you plan to invest in smart systems.

F. Power outages due to Wifi failure

Another downside of smart lighting systems and the management system is that they need a reliable internet connection to work properly. So if there is a power failure it would result in the shutdown of the systems.

G. Compatibility problems between users devices (Lack of interoperability)

The idea behind smart lighting systems is to have one single program that will allow users to connect to the applications with smart devices but there can be compatibility problems between the hardware used in the project.

H. Implementation of limiting laws of IoT in public places

There is a constant increase in the number of controllable IoT devices and potential threats on its security. This could call for demand in the creation of new laws that limit its overuse at public spaces. Such measures could be counterproductive in the motivation to implement smart lights.

I. Climate risks that could cause direct damage to assets and indirect damage from supply chain disruption, impacting its financial condition and operating results

The unpredictability of the weather and climate conditions could potentially hinder the process of the industries responsible for production and installation of these smart devices.

J. Changes to energy consumption tax ration

Energy consumption taxes vary from time to time on the basis of standardization of electricity consumed. Governmental norms tend to control the environmental standards based on experimental research on the global warming reports. Due to continuous global warming every year, we can expect high taxation on the energy standards of smart lights as well.

K. Technological innovation to bring new lighting standards

Our technological progress is astounding and things that seemed to be impossible may become possible in just a few years due to artificial intelligence and machine learning. And therefore in future there can be new technology which will make the current system outdated.

L. Car accident or assault not detected because of light fail

Improbable but it could cause an accident when the lighting in the campus. It could cause damage for the vehicle travelling by the route or on the being that is suddenly on the way.

Although, it is not probable that the accident would be linked to the light fail as it is mandatory that bicycles and cars have their own lighting and pedestrians usually keep attention to their way.

Risks detailing

The risk detailing part can help the project stakeholders further understand the risk and manage them in order to avoid further consequences. Below it is stated each risk and more details about them including owner, mitigating actions, contingent actions, progress on actions and status.

Risk	Severity	Owner	Mitigating actions	Contingent actions	Progress on actions	Status
A	High	Project Manager	Weekly meeting to assure everyone's commitment	Schedule meetings	-	Open
B	Medium	Purchasing Manager	Only buy products with warranty	Contact manufacturer	-	Open
C	High	Maintenance Supervisor	Ensure that every worker is wearing safety equipment and following the right safety measures	Call ambulance	-	Open
D	High	Maintenance Supervisor	Ensure that every worker is wearing safety equipment and following the right safety measures		-	Open
E	High	Technology Management officer	- Inform Authorities, staff employees, students about the cyberattack - Data protection regulations, safety responses and policies should be developed that are linked to the impact these technologies can have on traffic and people.	Call IT Security Professionals	-	Open

F	High	Electricity and Wifi Management officer	- Have a redundant network connection - Employ a backup power connection	Call the Authorities	-	Open
G	Medium	Developers	Create a user friendly applications and available for all types of devices	Discuss with the developers	-	Open
H	High	University	Sustainable increase in the smart lighting system that doesn't permit the over dependence and surge on implementation of these devices.	Plan with manufacturers	-	Open
I	Medium	Manufacturers	Silo based production can help in continuous transfer of produced goods.	Track the production service	-	Open
J	Medium	Information technology officer	Assessment on the most efficient energy standards that is accepted by norms across the globe to avoid inconsistency on the compliance.	Check with lawmakers and external auditors	-	Open
K	Medium	Project Manager	To discuss and ready to adapt new technologies if any in near future	Schedule meetings	-	Open
L	Low	University	Automatic identification for a failed bulb in the system so that it is replaced by security personnel at untimely hours.	Alert message to available personnel in shift.	-	Open

Table 5: *Risk Detailing*

Risk Decision Tree

A risk decision tree can be useful to break down the risk in minor actions/events, which are usually easier to help prevent a major event with more severe consequences. The tree is made up of nodes and branches. The nodes represent an event, while the branches represent an alternative course of action or decision. The nodes at the end (right extremity) are the possible outcomes (Magee, 1964).

Accidents that are life threatening during implementation of lighting

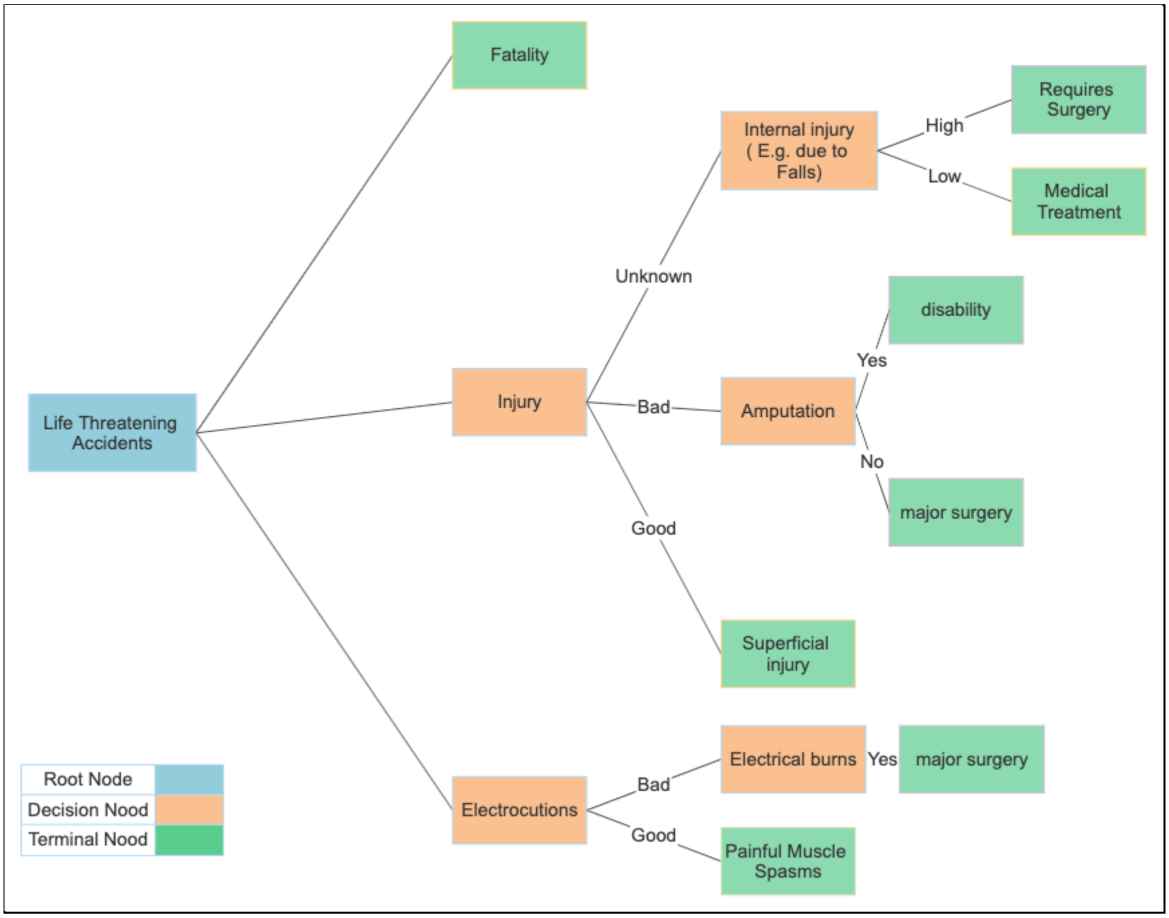

Figure 5: *Risk Life Threatening Accidents Decision Tree*

Most fatal injuries from direct exposure to electricity occurred while workers were engaged in constructing, repairing, or cleaning activities or while workers were engaged in physical activities or material handling operations.

One of the problems that is highlighted for the workplace is injuries due to slipping, and falling.

An electric shock is the passage of an external electrical current between parts of the body or through the body which can cause injury or death. Faulty wiring can occur for many reasons, including poor quality electricals, badly installed wiring or an overused cable that has split, causing the wires to become visible. Faulty wiring can lead to electric shocks, burns or severe injuries.

Risk: Delay in the project implementation

Delay risk is one of the major risks in implementation. In a project finance setting, the consequences of the delay can be particularly costly. Therefore, effective project management during the implementation is essential for success in infrastructure project financing. Delay means higher costs because of a longer work period, additional material cost, and extra labor cost.

Risk reduction measures

- **Contractors' Pre-qualification:** The contractors will be pre-qualified for their experience in lighting projects, technical capabilities of their personnel, installation equipment, financial capabilities to make sure the good quality of the contractors are selected for the project.

- **Contract conditions:** The implementation conditions, performance bond, warranty period and retention money are some measures in the contract to assure contractors performance and on time completion.

- **Project implementation schedule:** Overall project implementation schedule takes into account the pessimistic and maximum time for the critical activities to derive the optimistic schedule with the help of "Microsoft Project" software by experienced personnel. The contracts will incorporate adequate penalties for the implementation delays while contractors should be responsible for the effective implementation of the project under the direct supervision of the University of Twente.

- **Contract packaging:** The project is divided into several contracts to avoid the dependency risk on a single contractor.

- **Adequate and timely fund allocation:** Delay in funds availability will hamper the implementation period and delay the project completion and its impact.

Real options

Real options are considered to be choices that are made in order to change and expand a project based on different economical, technological or market changes. Taking into account real options can lead to a correct valuation of potential investments in certain areas of the developed product or service. A correct analysis of the real options makes the difference between a further development of a product, or abandoning the product.

To decide whether the investment is economic and acceptable, Net Present Value is used to calculate the discounted value of the costs and benefits. It determines the value of an investment project based on future cash flows and the amount of uncertainty within the investment project.

In order to review the costs for the 15 years period discussed before, the following table might be useful:

	Acquisition & Implementation Costs	Operational Costs	Ongoing Change & Growth Costs	Total
Hardware Costs	300,000.00	45,000.00	-	**345,000.00**
Software Costs	-	990,000.00	-	**990,000.00**
Personnel Costs	158,400.00	412.00	1,219,860.00	**1,378,672.00**
Computing Costs	-	505,163.00	-	**505,163.00**
Other Costs	-	734,720.00	-	**734,720.00**
Total	**458,400.00**	**2,275,295.00**	**1,219,860.00**	**3,953,555.00**

Table 6: *Estimated costs for the 15 year period*

The Formula is ,

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where:

Rt =Net cash inflow-outflows during a single period

i = Discount rate or return that could be earned in alternative investments

t = Number of timer periods

In our case let's consider the number of periods is 3 years, which means there will be 36 cash flows and 36 periods included in the calculation. Let's assume a discount rate of 3% per year.

As seen in the cost analysis, let's start with an initial investment(Acquisition & Implementation Costs) of €458,400 that is incorporated as an outflow in year 0. Since the university already has (normal) LED lights installed, the project will not add monetary benefits, as the smart LED lights have a similar saving in energy. Although the recurring costs (Operational costs) will be €151686.3. Both cash flow types are expected to increase by 2% each year. The detailed forecast covers how 3 years will be:

Period	Investment and Cost (outflows)	Benefits and Earnings (inflows)	Net Cash flow	Formula for discounting cash flows	Discounted Net Cash Flow & RV
0	- 458,400	-	- 458,400	-458,400/(1+3%)^0	- 458,400
1	- 151686.3	0	151686.3	151686.3/(1+3%)^1	147268.2
2	- 154720.02	0	154720.02	154720.02/(1+3%)^2	145838.45
3	- 157814.42	0	157814.42	157814.42/(1+3%)^3	144426.11

Table 7: *NPV analysis*

The net present value of the investment is the sum of all discounted cash flows :

NPV = -458,400 + 437532.76 = € 20867.24

The positive NPV indicates a profitable investment.

Sensitivity Analysis

In addition to the previous multiple scenarios analysis , we look further into the variation of the minimum acceptable rate of return (MARR), also known as the discount rate. An MARR that is too low can cause an uneconomic investment to be accepted, but if it is too high an economic investment can be rejected. Therefore, selecting a suitable MARR is important.

In this analysis, we tried lowering the rate to 2% as well as raising it to 5% as a project with higher risk usually has a higher MARR. Table 7 shows the calculated NPV of the realistic case for each rate.

MARR	NPV
2%	NPV = €12,037.2
3%	NPV = € 20,867.24
5%	NPV = € 37,272.4

Table 8: *Sensitivity analysis*

As the NPV at 3% is already very positive, it can be seen that a slight variation in the discount rate will not change the recommendation for the investment.

Decision tree

Based on the Acquisition & Implementation Costs calculated before, a decision tree was created in order to help in the decision making process for the investors in the project.

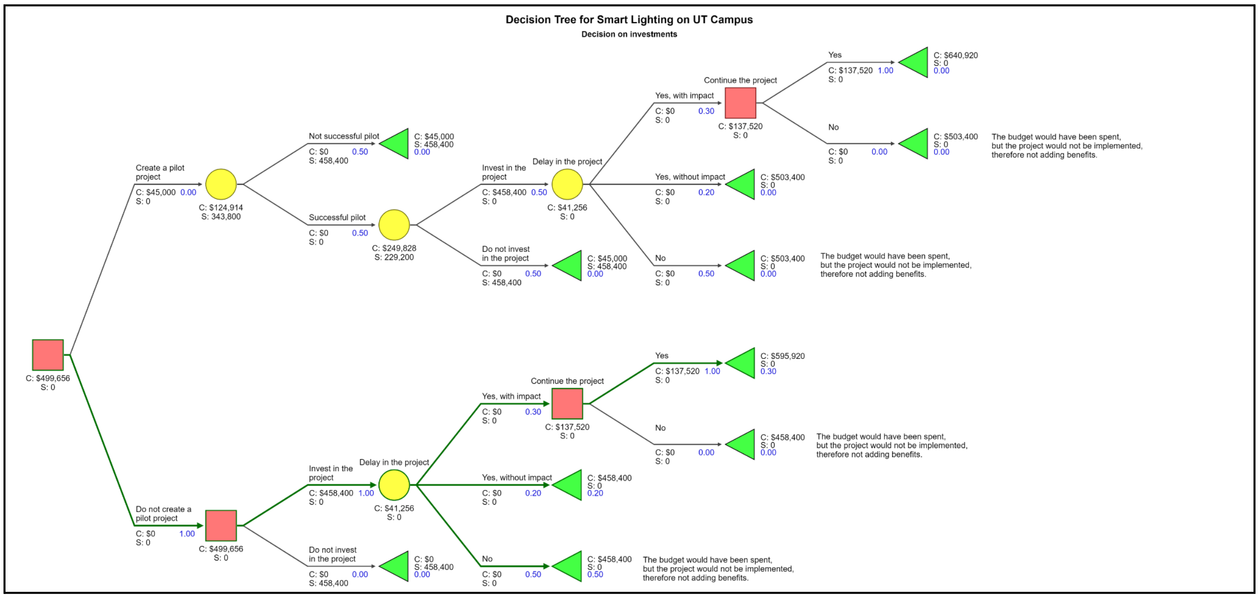

Figure 6: *Decision tree*

A version with more quality of the decision tree will be added as an appendix.

The decision tree takes into consideration possible events that could occur in the project. First, it is necessary to decide whether to create a pilot project or not. Then, based on the result of the pilot, the decision makers would have more information in order to decide whether they want to invest in the project.

"C" is the label for the cost of the decisions, while "S" labels the savings of the project at each event. The delay in the project probabilities were based on the statistics from a Project Management Institute (PMI) from 2017 (Grenee, 2020).

In the case of the cost estimation for the pilot project, we considered that it will not be more than 10% of the total cost for Acquisition & Implementation costs. Therefore, it would have a total maximum of €45,000 for its costs. In case the pilot is not successful, it would have a saving of €458,400, which is the total cost of implementation for the project.

We decided to consider a 30% (totalling €137,520) financial impact in the implementation costs, in case the project suffers a delay. That was chosen to make sure that the project still has the budget to continue, in case that risk happens.

After analysing the decision tree it is clear that once started, it does not make sense to stop the project in case of a delay, otherwise the investment made in the project will not have any return. Moreover, delays with impact are really probable and most probably will incur in extra costs, therefore it is important that stakeholders are aware of it before starting the project.

Solution Architecture

The architecture model below will help in understanding the complete processes involved with the smart lighting. It includes a bottom up approach starting from the technology layer to application to business layers which in turn realizes the motivation layer.

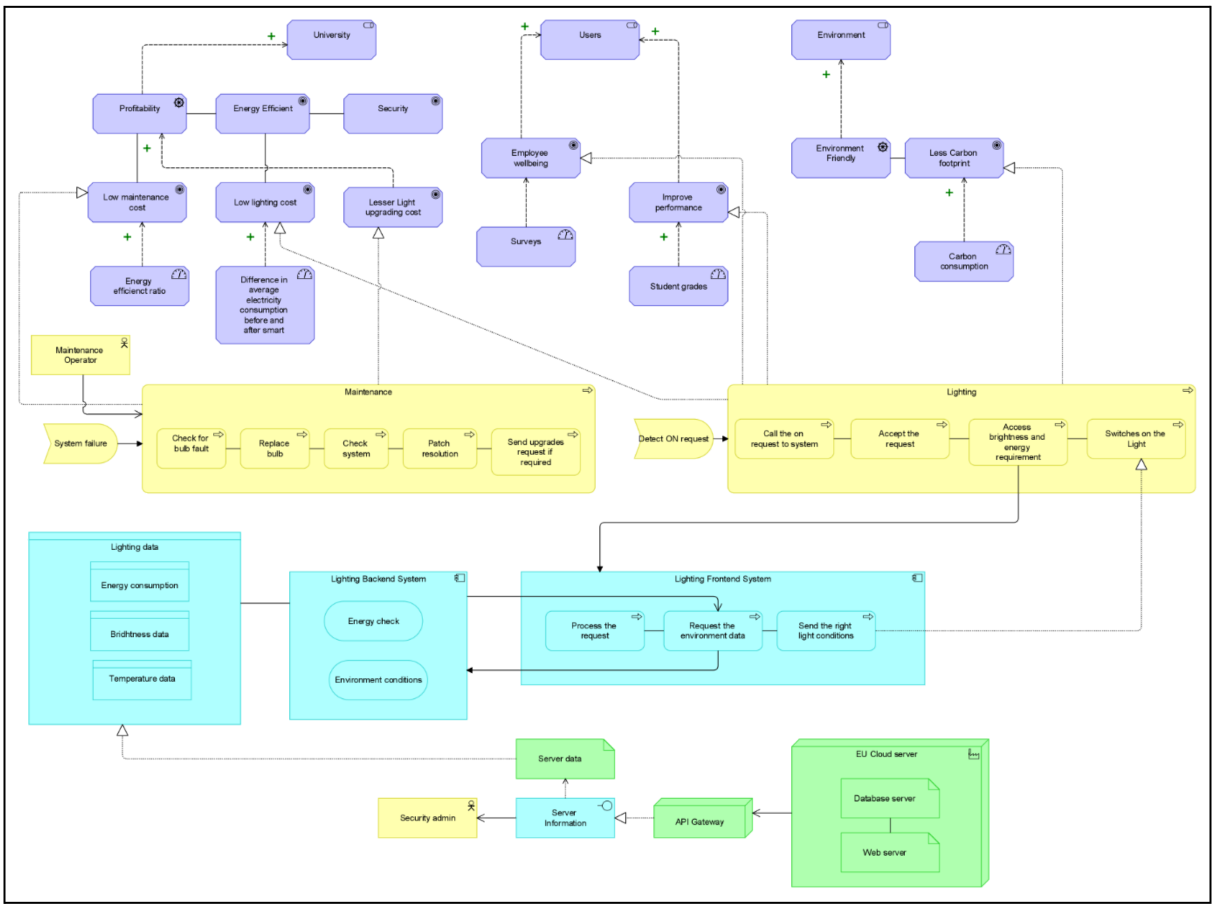

Figure 7: *Solution Architecture*

Here, the cloud service in the EU region that handles both web and database servers serves for the API gateway through internal technology communication. This serves as the fundamental for smart devices to interoperate between different systems. There are two application components both on the frontend and backend which receives its input from the data sources transferred on the application layer.

These components communicate with each other based on the process requirement on the lighting. The smart lighting where it needs to access if there is a requirement for a certain lighting intensity is achieved through the application components. This would thereby help in the motivational goals to be realized where the major drivers are “profitability” and “Environment friendly” usage. Clearer images are located in the appendix section of the report.

Sustainability - Green IT

University of Twente by using LED lighting on campus has a positive sustainable impact on the environment. The university will be able to reduce carbon emissions by reducing electricity consumption. Regarding the materials of LED smart lighting; the LED tubes are recyclable. The aluminum and plastic of LEDs can be recycled and also the LED driver and chips can be taken to an e-cycling center. They are made of non-toxic materials meaning they are 100% recyclable.

Furthermore, long lifespan is the another most environmentally beneficial characteristic of smart bulbs. They will generally last about 25,000 hours. Using one LED, we can produce one third of traditional bulbs. It means less landfill use, less production costs, and less transportation consumption can create this opportunity to keep air cleaner.

For all buildings on campus, replacing the old halogen lights with LED lighting can impact not only on energy efficiency, but also requires far fewer lights to create all the color schemes. It is currently done in the following buildings, but by expanding LED smart lighting to other buildings, this positive effect can be multiplied.

Location	Old situation - halogen	New situation - LED
Amphi backlighting	9x 500 watt	3x 150 watt
Agora backlighting	12x 1200 watt	4x 150 watt
Amphi front light	4x 1000 watt	4x 200 watt
Agora front light	6x 1000 watt	5x 200 watt
Amphi extra spotlights / moving heads	500 watt each	3x 120 watt
Agora extra spotlights / moving heads	1000 watt each	4x 120 watt

Table 9: *Lighting replacement details*

The Netherlands is facing a major challenge to substantially reduce the use of primary energy. For this reason, the government has drawn up targets which are set out in a climate agreement. According to a University of Twente report (n.d.), in practice the university strives to reduce our CO2 footprint by 15% in 2023 (compared to 2020) and become CO2 neutral by 2030.

Recommendations

Based on our business case analysis, there are few recommendations enlisted in this section. The smart lighting system implementation focused on the pilot first and consequently for the whole scope provided a detailed understanding on the cost factor in this project.

In the cost estimation, it was seen that the hardware acquisition and installation is feasible at 345,000.00 euros. It can be used for the pilot testing at the university for strategically significant rooms. Using the low code application development platforms, the university can also focus less on the software maintenance. It also helps in the interoperability with different systems with ease of user accessibility. The platform also facilitates cloud server security with Azure, as suggested. The total costs for the top trending low code platforms as mentioned in the costs analysis section has a net value of 990,000.00 euros. With the personnel costs, computing and the other costs tallying to 3,953,555.00 (3.9M) euros approximately, it is positive to expect that a pilot implementation is feasible.

However, during the analysis, we learnt that the costs could be decreased with new hardware advancement and availability of more economical methods of bulb productions. The risks identified have to be kept in mind at every stage of operation and the respective stakeholders be prepared with mitigation strategies to tackle them. Timely response to risks can counter other costs expected for the implementation of the business case. In the future, the advancements in computing, lighting standards and the personnel costs for maintenance, can potentially reduce the total cost.

In the opinion of Green IT and sustainability, the technology will benefit the environment and nature. It is the logical direction to move towards a greener society utilizing the green source of energy.

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Appendix A

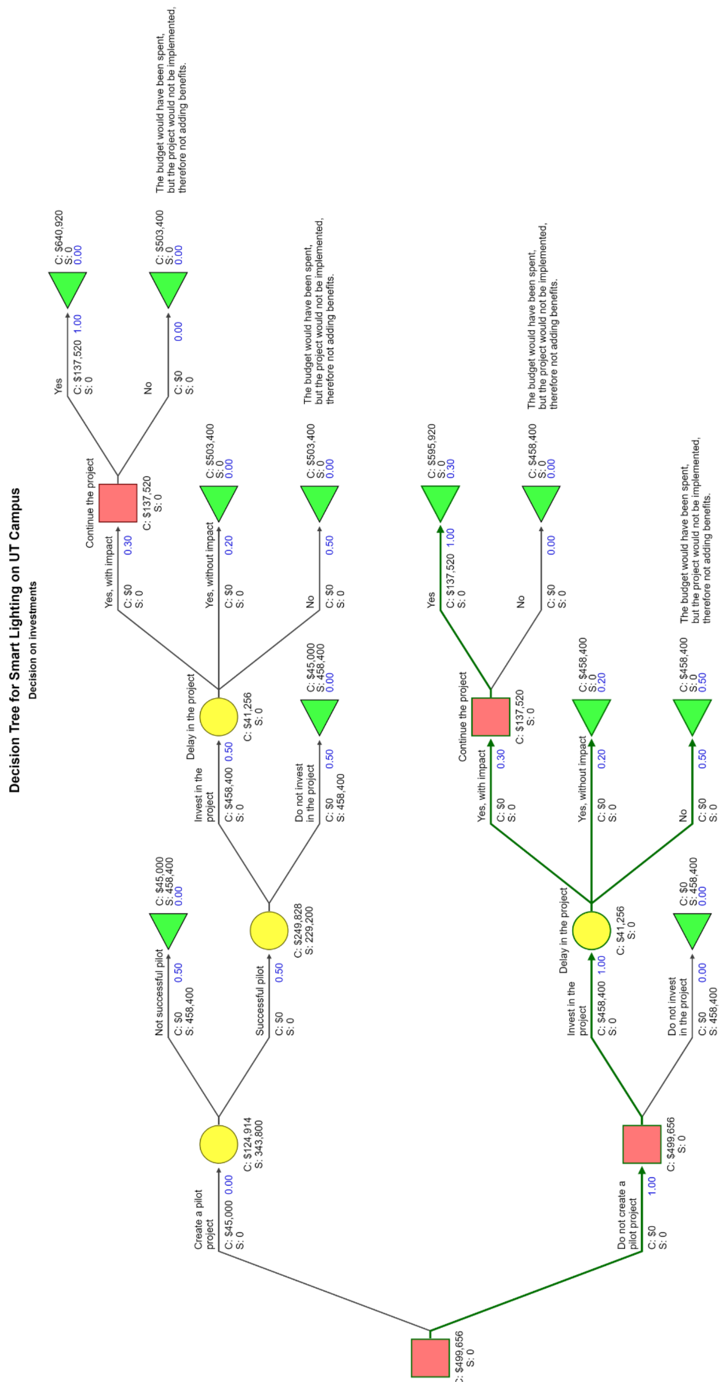

Figure 8: *Decision Tree*

Appendix B

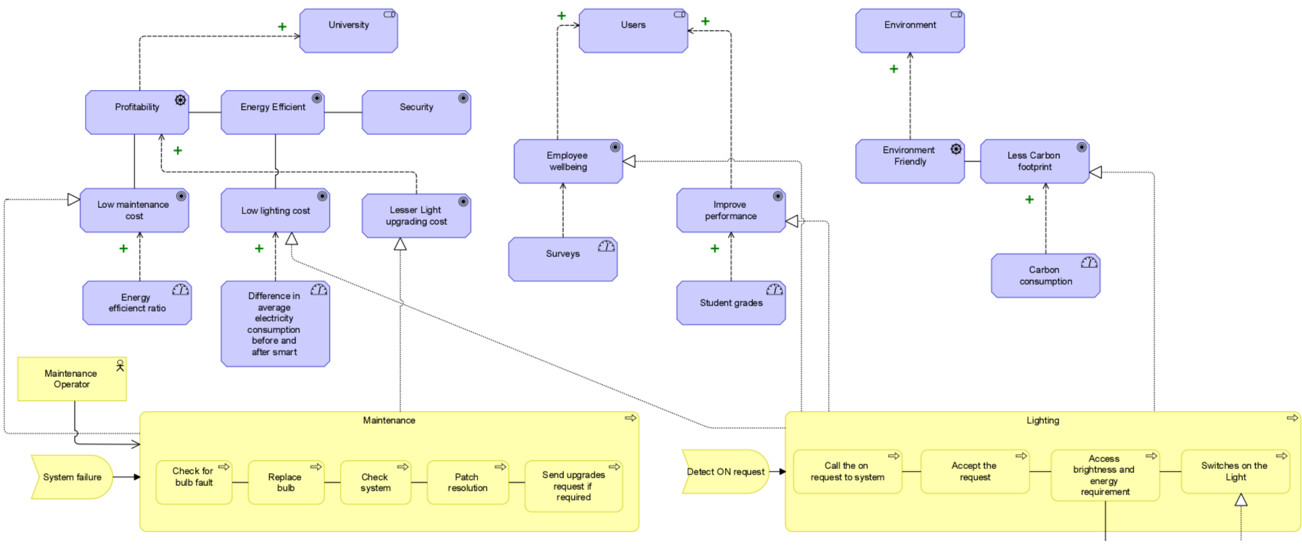

Figure 9: *Motivation and Business layer*

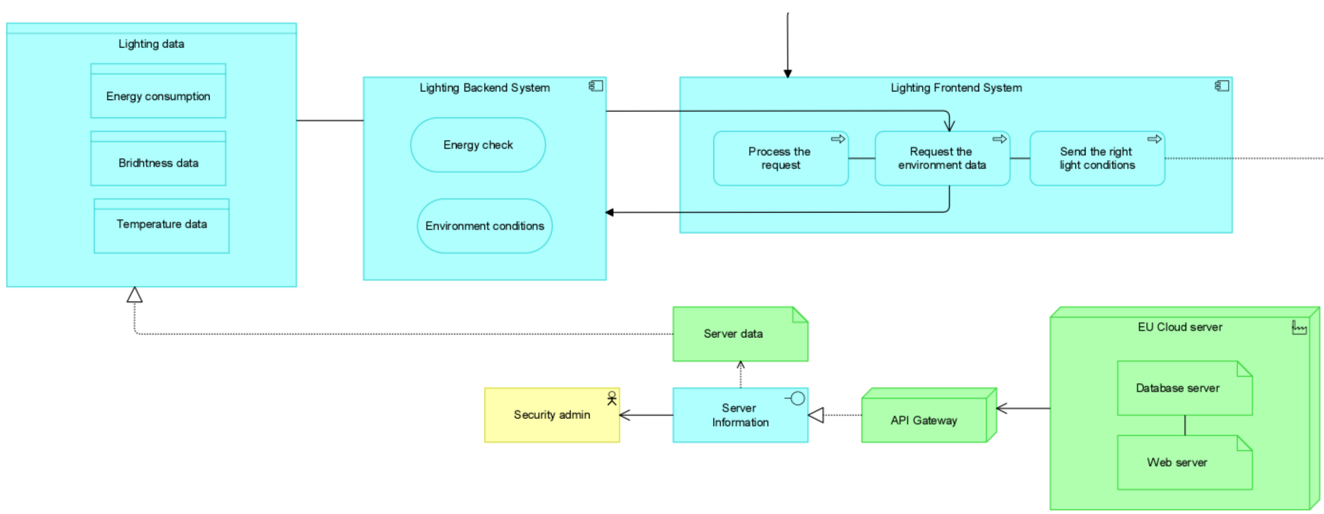

Figure 10: *Technology and Application layer*