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Light Pollution from Tall Office Buildings

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

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 By Palak Patel

Main Claim: Our design meets the client's need

The presentation includes:

1. Introduction to the client’s problem  By Palak Patel
2. Sub-claim A:  By Michael Tan
   - Thoroughly explored design space to select top 3 ideas
3. Sub-claim B:  By Farin Khoshsorour
   - Considered the advantages and disadvantages of the top three designs
4. Sub-claim C:  By Sam Chowdhury &  David Li &  Steph Wong
   - Presenting evidence that shows recommended design performs well in all Measures of Success.
5. Final remarks  By Steph Wong


By Palak Patel

Introduction to the Problem

- Light pollution disrupt migratory birds' daily activities
  - Birds assume better hunting advantage in light polluted area (as shown on the left [2])
  - Result in window collisions at night
- In Canada, 25 million birds die every year due to window collisions.
- FLAP working on project called "BirdSafe Design" to reduce issue.


By Palak Patel

BirdSafe Design

Figure 1: Ryerson Student Centre [3]

Figure 2: Bergeron Centre for Engineering [3]

"These structures are an excellent example of a customized approach to reducing bird strikes."
-Conversation with Michael Measure, Executive Director FLAP Canada

By Palak Patel

Existing Designs

- Three types of designs:
    1. Changing user behaviour
    2. Specialized windows (as shown in the image [1])
    3. Less-prevalent retrofittable designs
- Need widely implemented, retrofittable designs.
    - Our team has arrived at a proposed design.

By Michael Tan

Idea Generation & Selection

By Michael Tan

Examples of Idea Generation Methods used

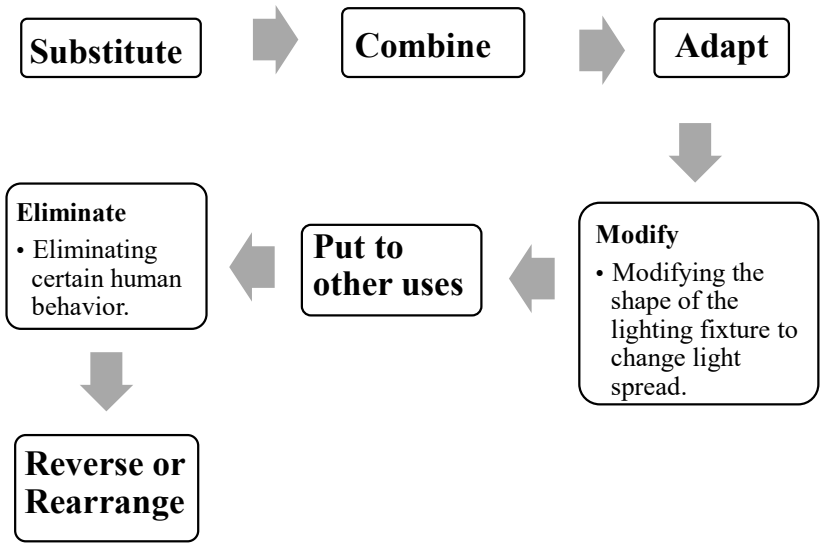


Figure 3: Examples of SCAMPER used [4]

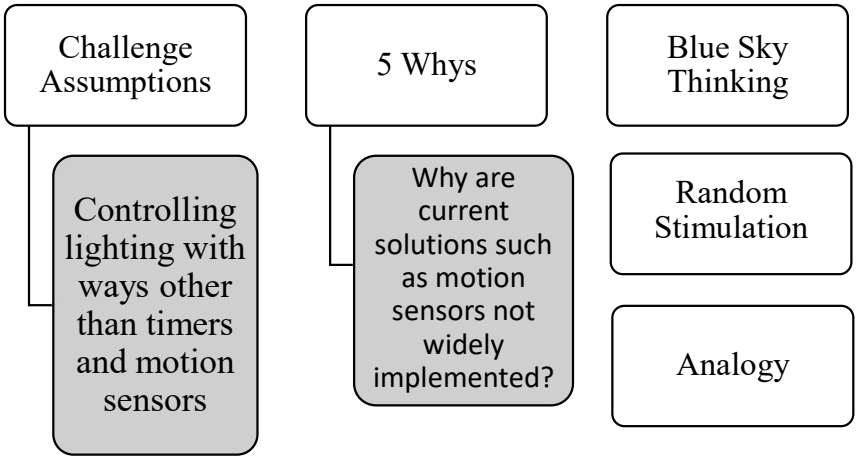


Figure 4: Examples of other brainstorming methods used [4]

By Michael Tan

Different Approaches In the Design Space

Table 1. Categorization of Approaches for Ideas

General approaches	Sub-categories	# of Ideas
Changing human behaviour	/	5
Modifications to the controls of lighting systems	Timer-based	3
	Motion-sensor-based	7
	Other ways to detect human activities	10
Modifications to lighting fixtures	/	11
Stopping light trespass through windows	Window covering	18
	Window modifications	8
Other	/	13

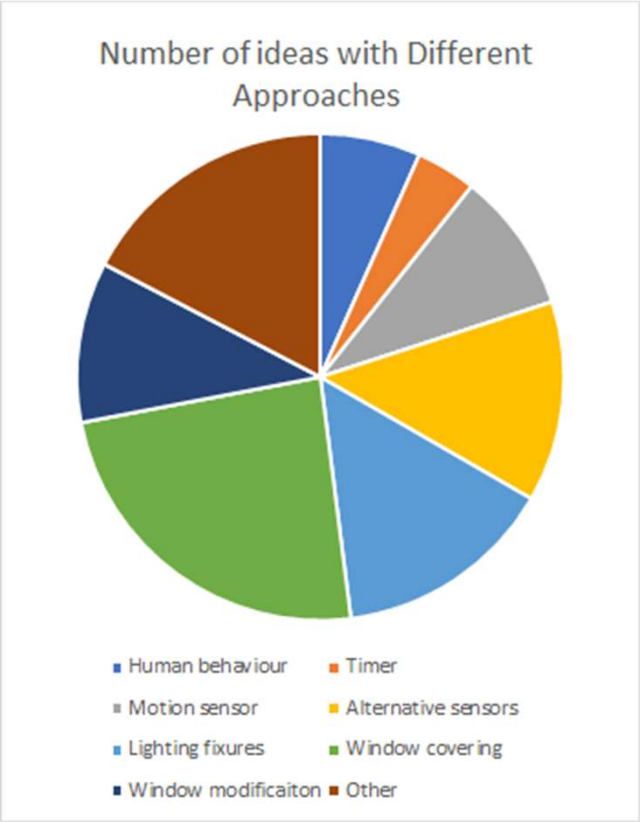


Figure 5: Pie graph of different approaches used [4]

Start of Idea Selection: Feasibility check &Multi-Voting

	Edit from Michael: is it possible to use some sort of photoelastic material to control how much lights pass through? (this basically function same as a dimmer)		
2	Change all lightbulbs in the office rooms from the bright ones to the ones that emit light of a softer colour.	Farin	F: doesn't reduce light trespass
3	Light Bulb with built-in motion sensor and photoresistive dimming. This makes replacement easy as it is all built into the bulb, and does not require physical renovations to the building. The motion sensor will turn on the light when someone is close by. The photoresistor will detect the light level in the area, to dim or brighten the lightbulb to meet the minimum light level required in the office building. (Two ideas in one; motion sensor + photoresistor dimming in a lightbulb)	Sam	
4	Use desk lamps only. The use of desk lamps instead of main	Sam	

Failed to meet primary function

Figure 6: Example of feasibility check

By Michael Tan

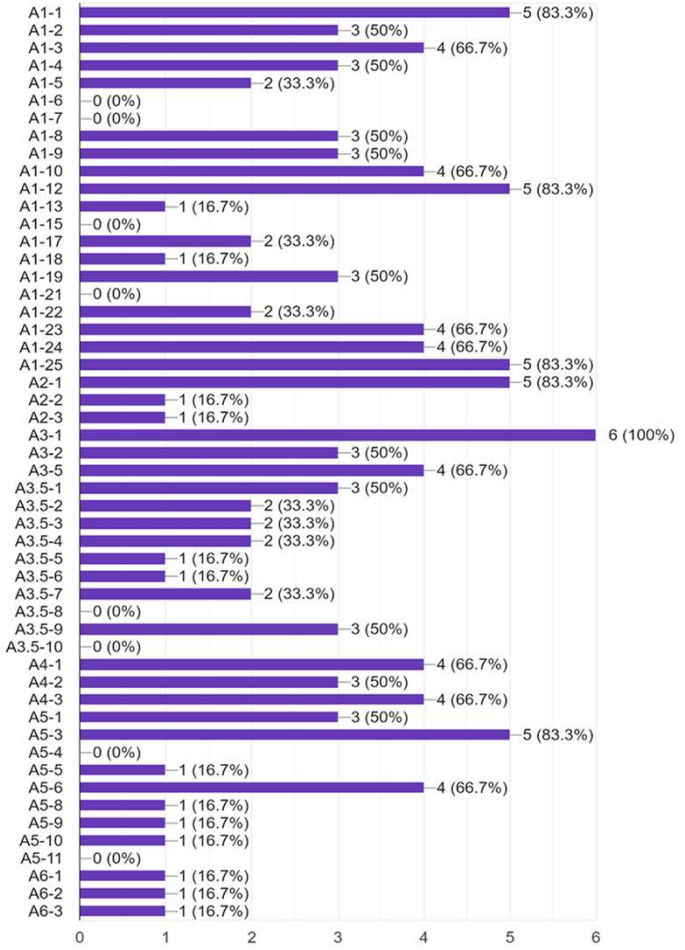


Figure 7: The results of multi-voting

By Michael Tan

Pair-wise Comparison

Table 2. Pairwise Comparison of Objectives

	Cost	Effective	Easy to use	Effect on lighting	Life expectancy	Compatibility	Score
Cost	/	1	1	1	1	1	5
Effectiveness	0	/	1	1	1	1	4
Easy to use	0	0	/	1	1	1	3
Unintrusive (effect on lighting)	0	0	0	/	1	1	2
Durable (life expectancy)	0	0	0	0	/	0	0
Compatible	0	0	0	0	1	/	1

Top objectives for Graphical decision Matrix
Cost
Effectiveness

Weighted Decision Matrix Weighting

Table 3. Objective Weighting

Objective	Weight
Cost	25%
Effectiveness	25%
Ease of Use	20%
Unintrusive	15%
Compatible	10%
Durable	5%

By Michael Tan

Graphical Decision Matrix

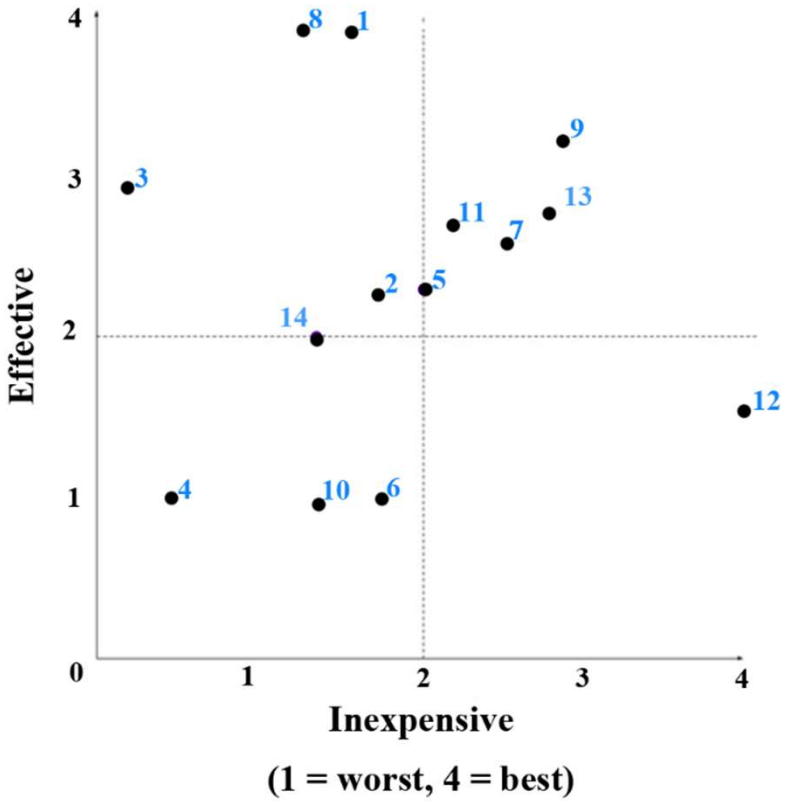


Figure 8: Graphical decision matrix [4]

1. Light-detector-based automatic blinds
2. Adhesive window screen
3. Transition-lens-like windows
4. Bird balcony habitats
5. Stripped glass
6. UV-coated glass
7. **Film-Mirror complement design**
8. Timer-based automatic blinds
9. Motion-sensor-based centralized lighting control
10. Motion sensing electrochromic windows
11. **Security-camera-based centralized lighting control by room**
12. Localized dimmer switches
13. **Localized automatic lighting**
14. Variable light fixture

By Michael Tan

Pros & Cons of Top 3 Alternative Ideas

Weighted Decision Matrix

By Farin Khoshsorour

Eliminated | 3rd Alternative Design | Eliminated | Top Design | 2nd Alternative Design

Objective	Weight	Stripped glass	Film-mirror complement design	Motion-sensor-based lighting control per room	Localized automatic lighting	Security-camera-based centralized lighting control
Inexpensive	25%	20%	60%	70%	75%	75%
Effectiveness	25%	50%	65%	80%	85%	75%
Ease of Use	20%	100%	100%	100%	100%	80%
Unintrusive	15%	100%	100%	80%	80%	80%
Compatible	10%	100%	100%	90%	100%	90%
Durable	5%	90%	60%	80%	80%	80%
Totals	100%	**67%**	**79%**	**83%**	**86%**	**79%**

Table 5. Weighted Decision Matrix

By Farin Khoshsorour

Pros VS Cons

1. Film-Mirror Compliment Design

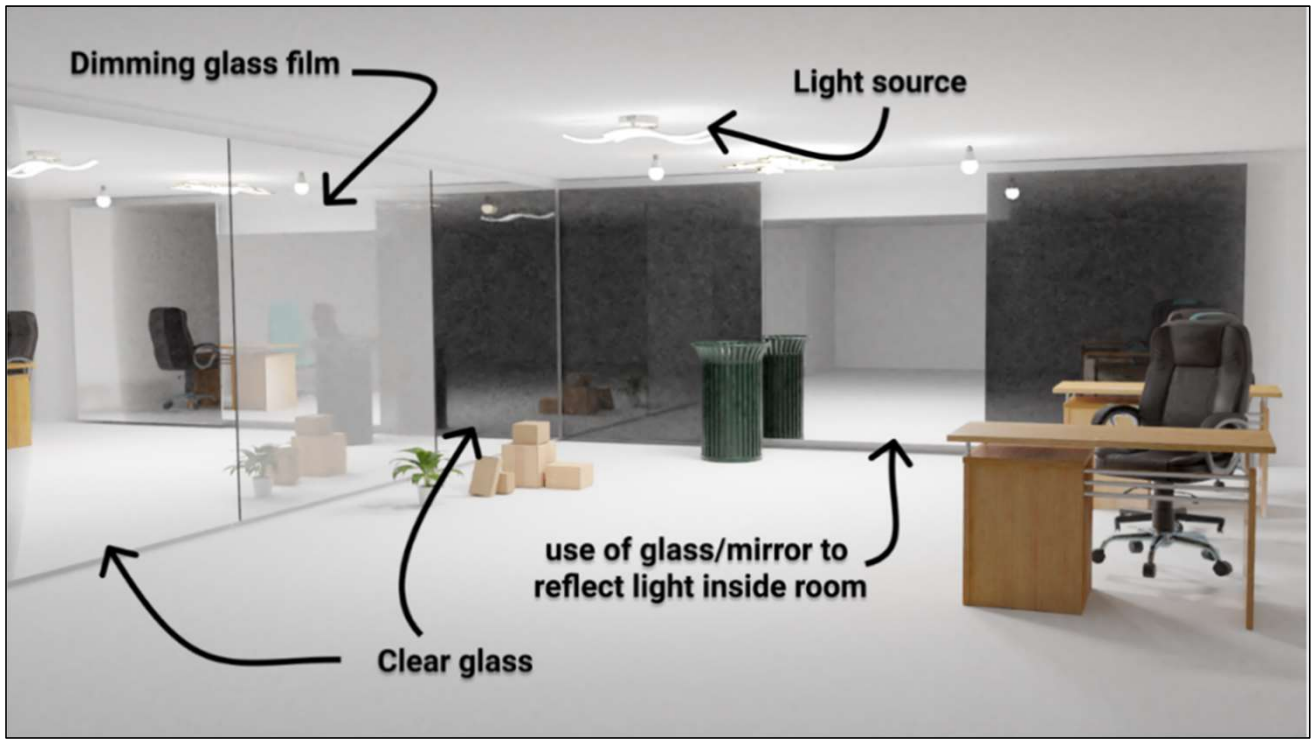


Figure 9: Diagram of Film-Mirror Complement Design [5]

By Farin Khoshsorour

Pros VS Cons

2. Centralized Lighting Control

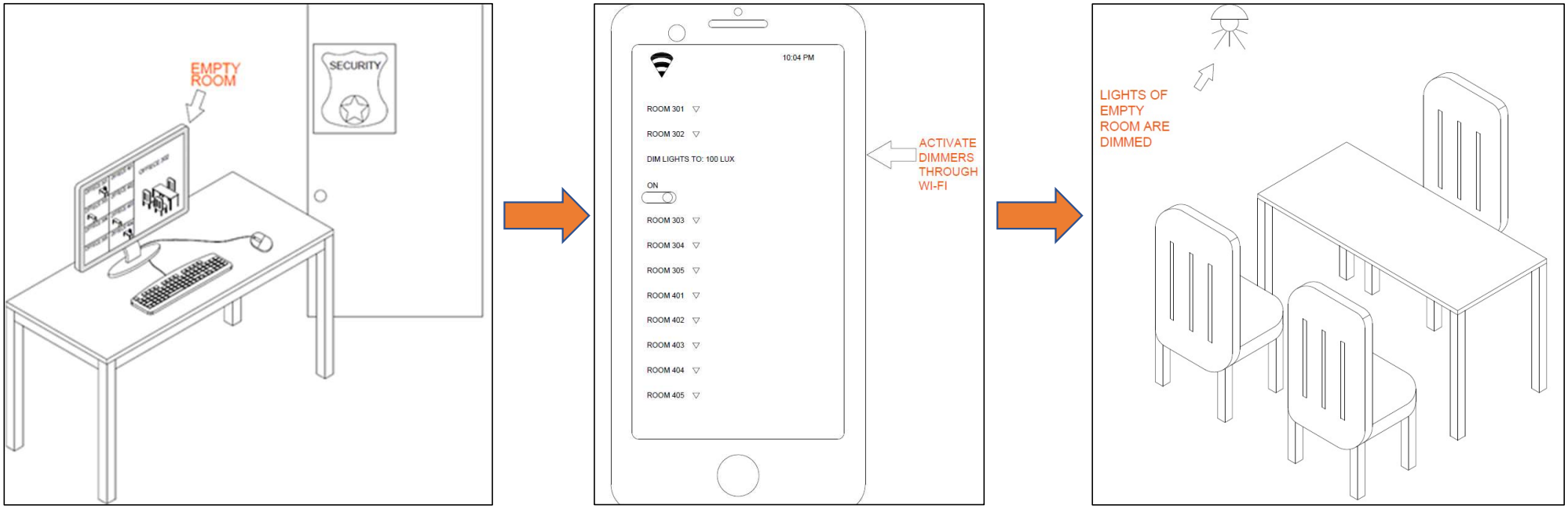


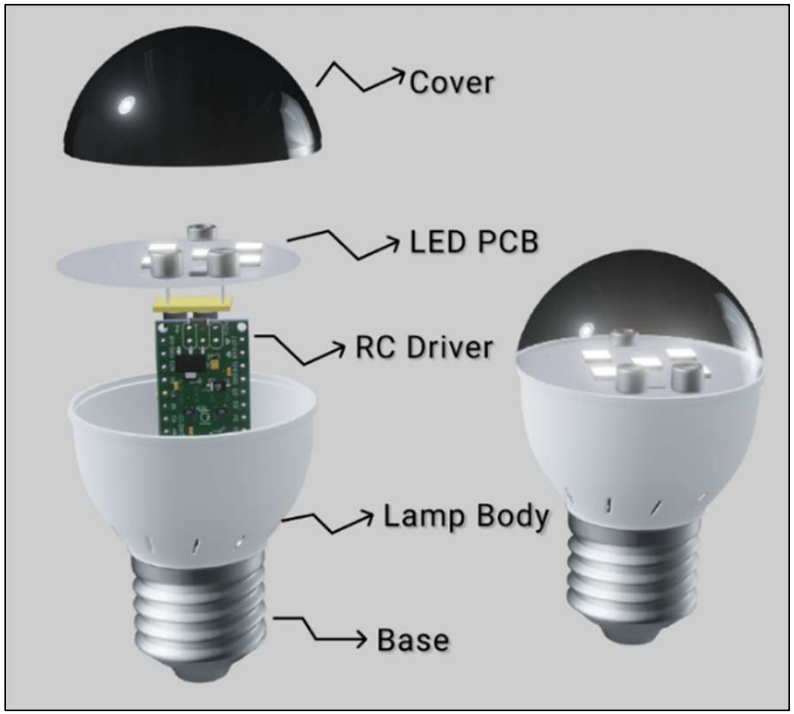
Figure 10: Diagram of Centralized Lighting Control [5]

By Farin Khoshsorour

Pros VS Cons

3. Localized Automatic Lighting (LAL)

- After 3 minutes of inactivity, the light bulb will turn off



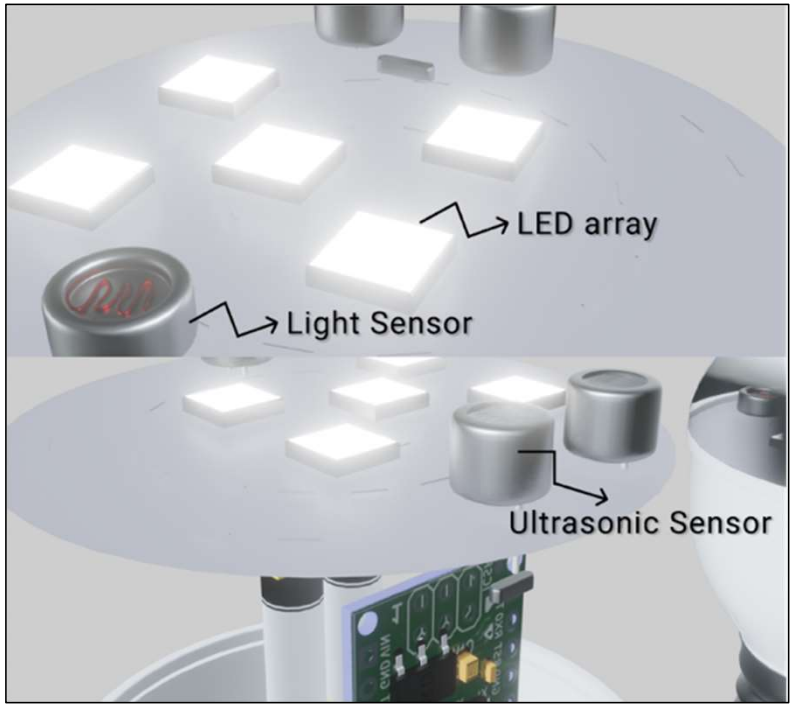


Figure 11: Diagrams of Localized Automatic Lighting [5]


By Farin Khoshsorour


By Sam Chowdhury

Measures of Success – Cost

Type of Evidence: Modelling

Reducing Design Cost

By Sam Chowdhury

Table 6. Comparison of single component costs and bulk costs

Component	First Prototype	Price	Revised Prototype (Bought in bulk)	Price
LED Light Bulb	NOMA A19 60W LED Bulb [6]	$4	NOMA A19 60W LED Bulb [6]	$4
Arduino Nano	Arduino Nano Every [13]	$14	Nano Board CH340/ATmega328P [7]	$5
Ultrasonic Sensor	HC-SR04 Ultrasonic Sensor [14]	$5	HC-SR04 Ultrasonic Sensor 4pin [8]	$0.6593
Light Sensor	GL5528 Light Sensor [15]	$7	Grove Light Sensor v1.2 - RobotShop [9]	$3.87
AC Dimming Relay	RobotDyn 1 Channel Arduino Light Dimmer [10]	$9.24	RobotDyn 1 Channel Arduino Light Dimmer [10]	$9.24
Bulb Holder	HEMMA Cord set [16]	$10	STRÅLA Cord set [11]	$6
Male-Female Jumper Wires	6" Jumper Wire (10 Pack) [17]	$6	Jumper Connection Wire [12]	$1.27
Total		**$55**		**$30**

By Sam Chowdhury

Prototype Energy Consumption

Figure 12: Localized Automatic Lighting in action [5]

Theoretical Usage

- Regular Light Bulb
  - On all day (24 hours)
- Localized Automatic Lighting
  - Off when user absent (16 hours)
  - On when user present (8 hours)

Table 7. Design Comparison through Theoretical Usage

	Regular Light Bulb	LAL
Energy per day (kWh)	0.24	0.1052
Energy per year (kWh)	87.6	38.398
Initial cost	$3.99	$30.01
Initial cost difference	0%	+86.7%
Energy cost per year*	$10.20	$4.53
Energy cost difference	0%	-55.6%

*Tier 2 Toronto Hydro costs [18]

By Sam Chowdhury

Prototype Energy Consumption

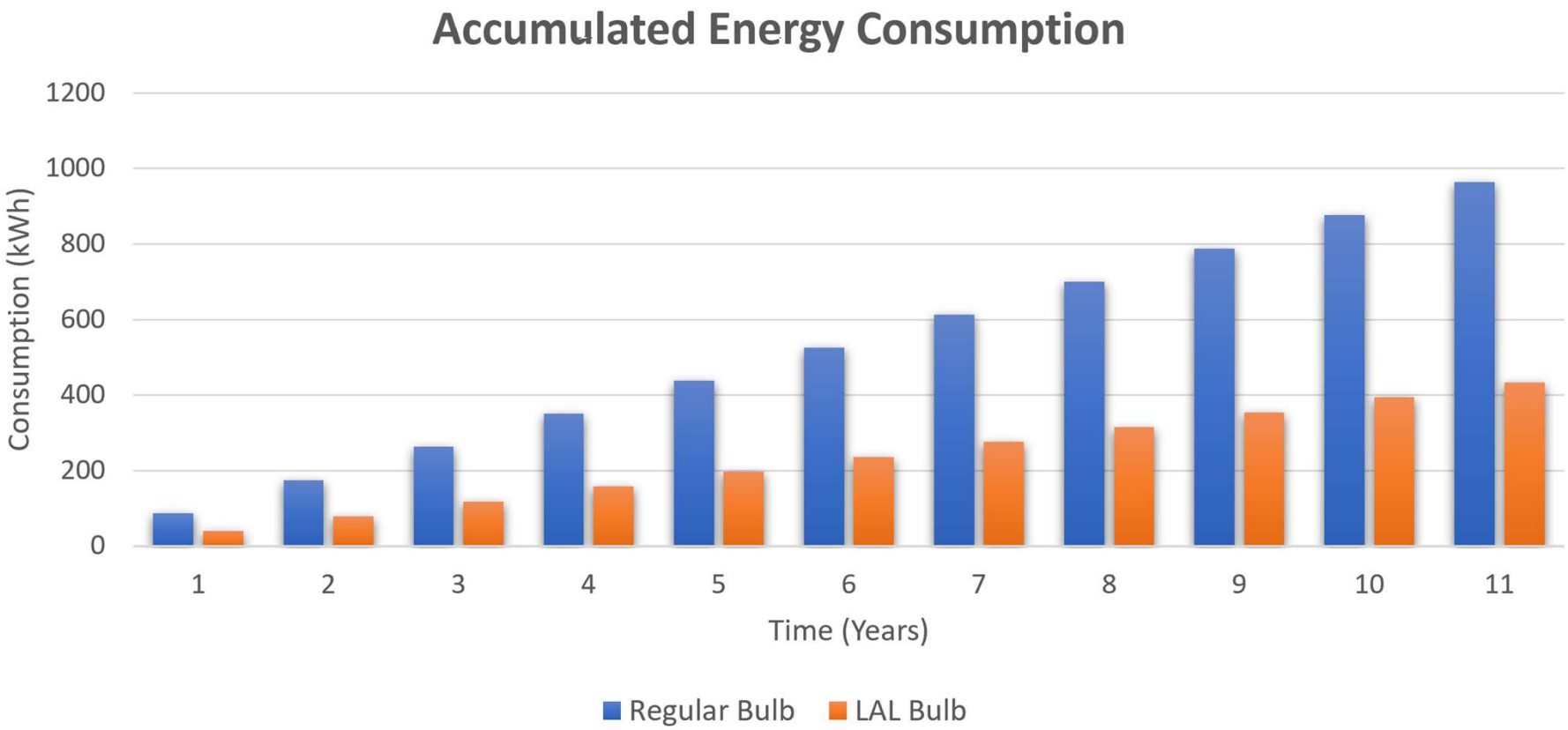


Figure 13: Accumulated energy consumption over time [19]

Prototype Cost and Energy Consumption

By Sam Chowdhury

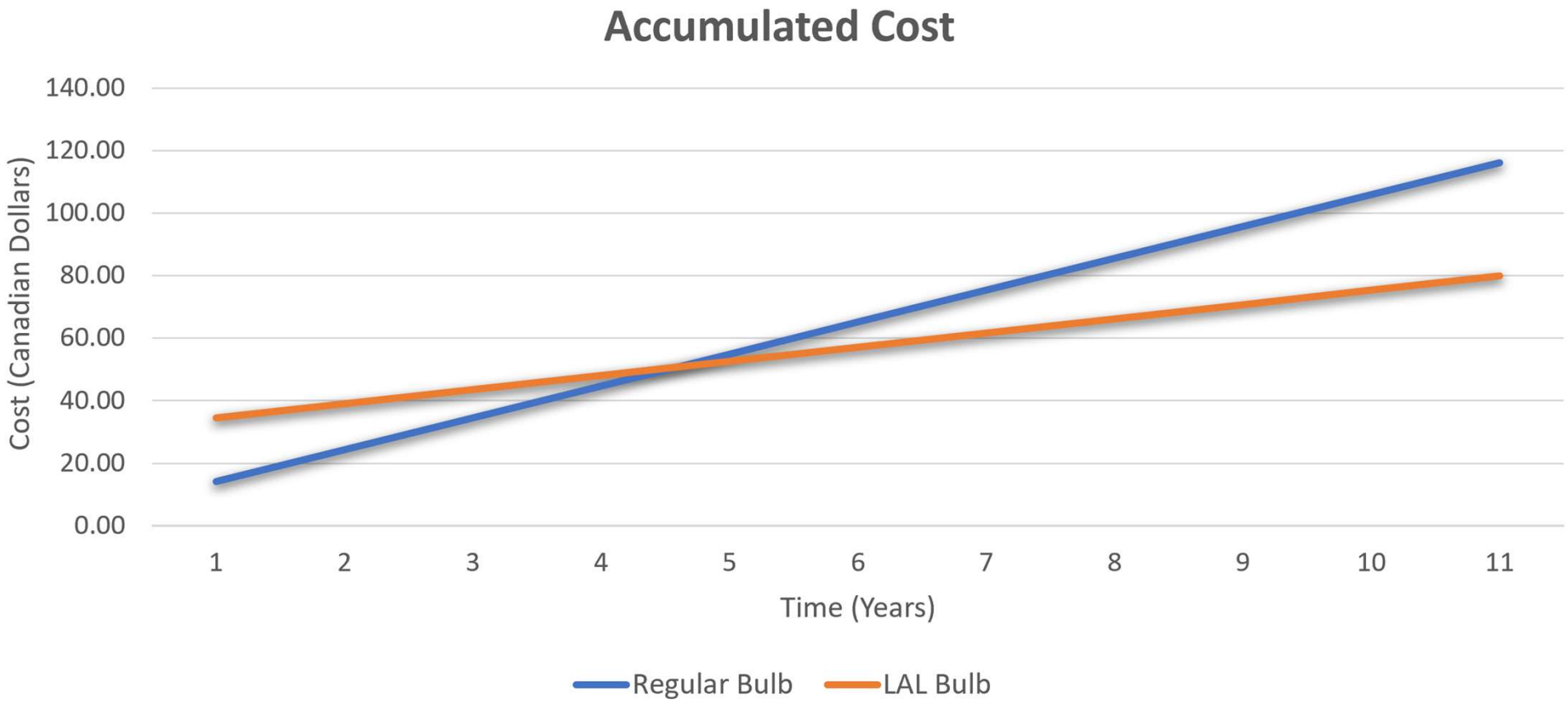


Figure 14: Cost of convention light bulb vs. Prototype [19]

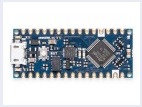
By David Li

Measures of Success – Durable

Type of Evidence: Estimation

By David Li

Table 8. Prototype Component Lifespans [5]

Component	Life (yr)	
LED Light Bulb	14[22]	
Arduino Nano	20-30[23]	
Ultrasonic Sensor	22[24]	
Light Sensor	~20[25]	
AC Dimming Relay	<20[26]	
Bulb Holder	----------	
Male-Female jumper Wires	----------	

The design successfully meets the objective goal of 10.5 years.

By David Li

Measures of Success – Effective

Type of Evidence: Simulation


By David Li

Localized Automatic Lighting (LAL) Simulation

The purpose of the simulation is to test out the effectiveness objective of the design. In order to cover more possible scenarios, the sample office building is planned to contain both corridor and working spaces and varied level of activity in each floor.

Note: In order to collect most accurate data from outside view and remove any visual obstacles, the sample building doesn't contain any Blinds in front of the windows.

By David Li

Items Used :

Softwares:
-Autodesk 3D studio Max,
-Chaos-Group V-ray Lighting Analysis System

Table 9. GL5528 Light Sensor Specifications

Type	Max. Voltage	Max. power	Environmental temp.	Response Time	Material	Size
5528	150v DC	100mv	-30 ~+70 degrees	Up: 20/ Down: 30 (ms)	Carbon	5 x 3mm/0.2 x 0.12"

Figure 15: GL5528 light sensor

Table 10. HC-SR04 Ultrasonic Sensor Specifications

Working Voltage	Working Current	Working Frequency	Max Range	Min Range	Measuring angle	Trigger Input Signal
DC 5 V	15mA	40Hz	400 cm	2 cm	15°	10uS TTL pulse

Figure 16: Ultrasonic Sensor HC-SR04

Ultrasonic Sensor HC-SR04

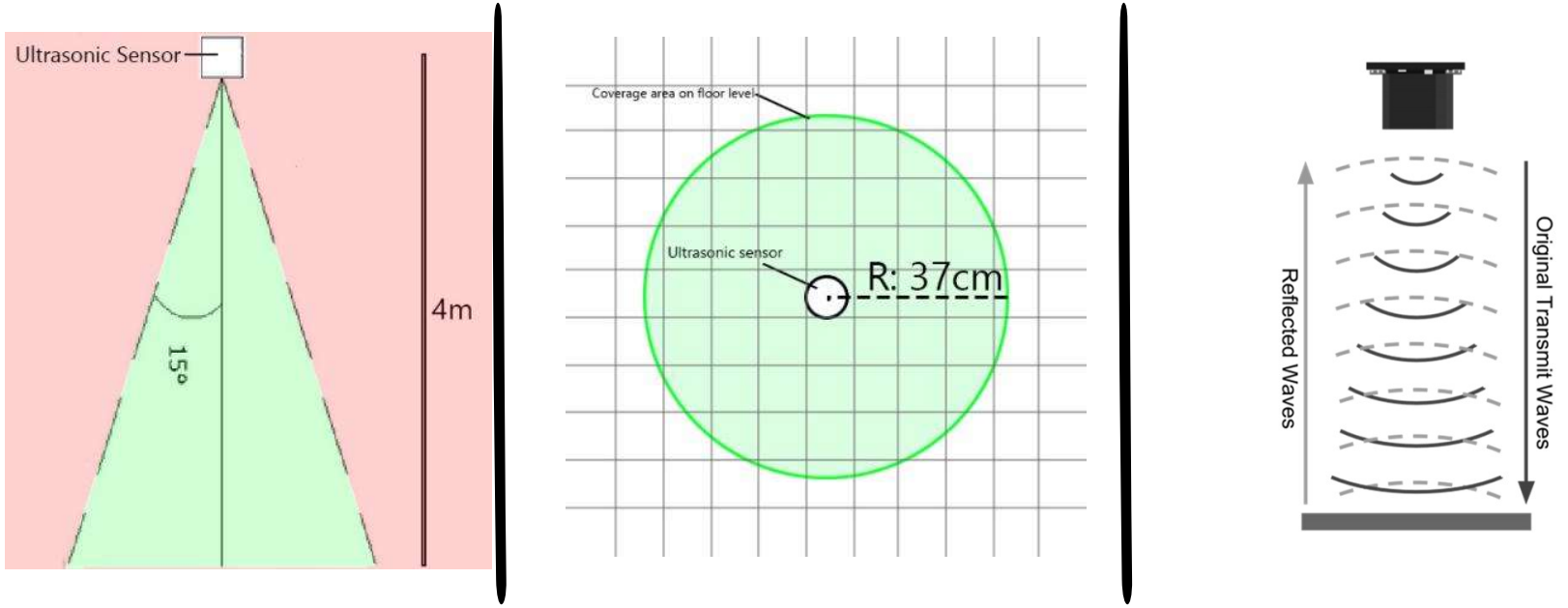
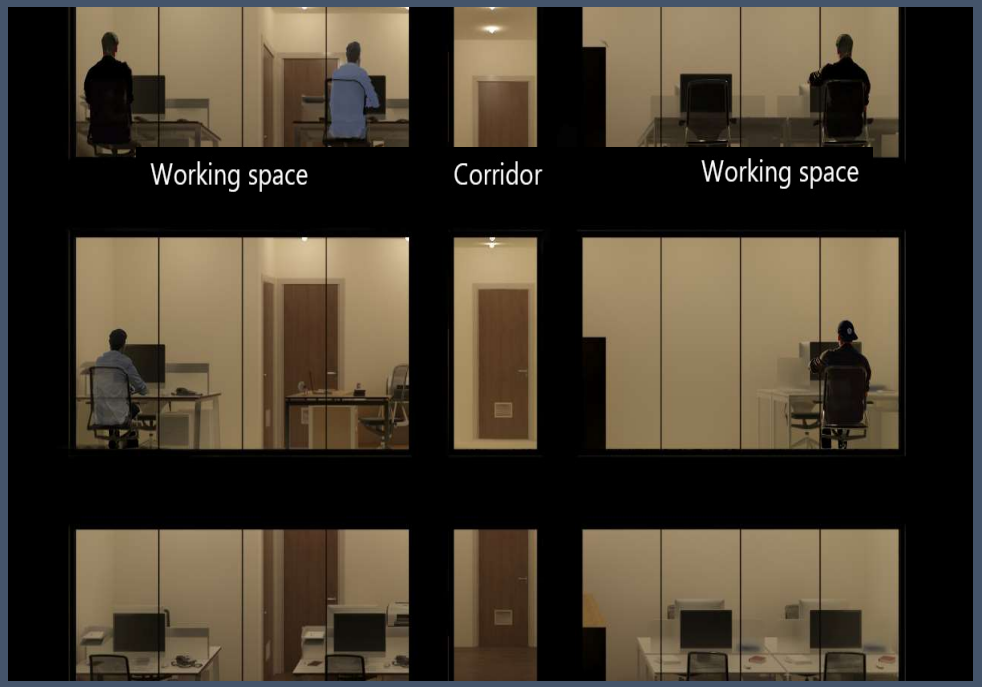


Figure 17: Range of ultrasonic sensor HC-SR04 [5]

By David Li

First scenario Part-1: Full-Active hours without the LALs



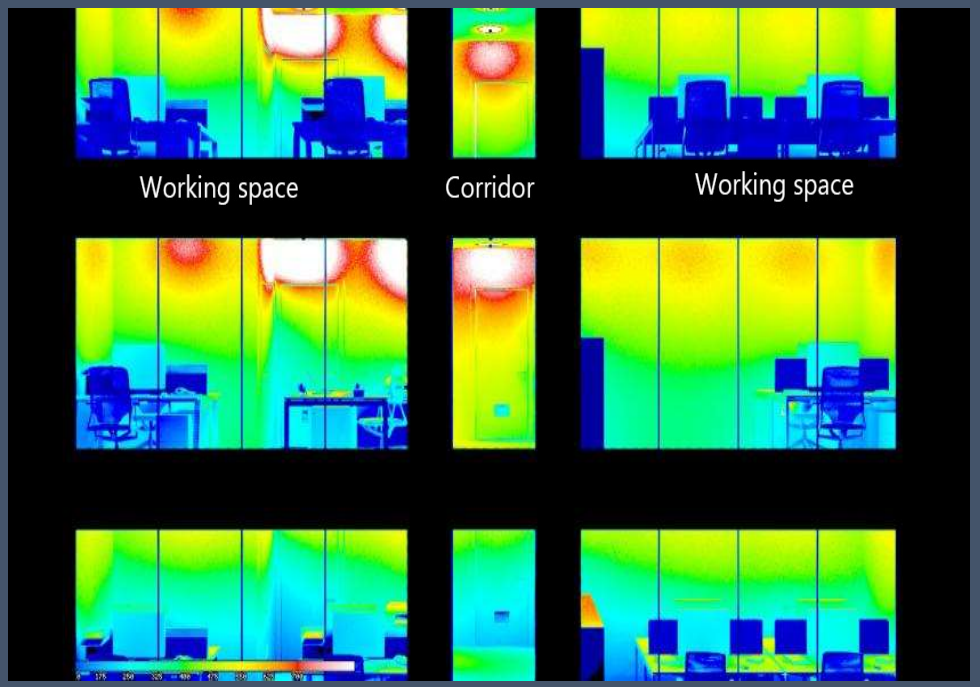


Figure 18: Simulation of full-Active hours without the LALs

By David Li

First scenario Part-2: Full-Active hours after installing the LALs

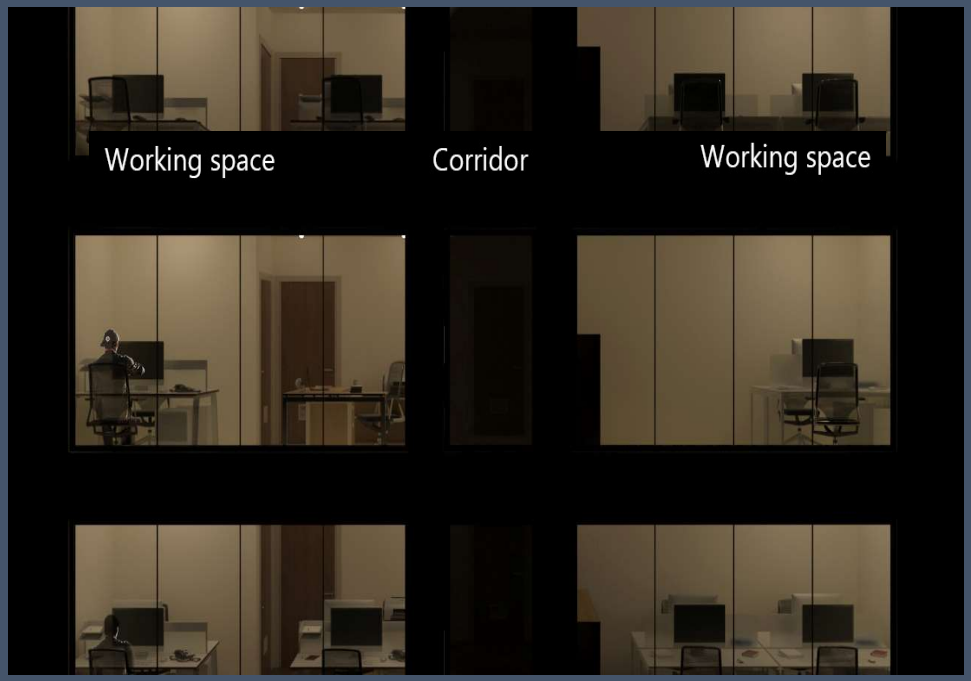
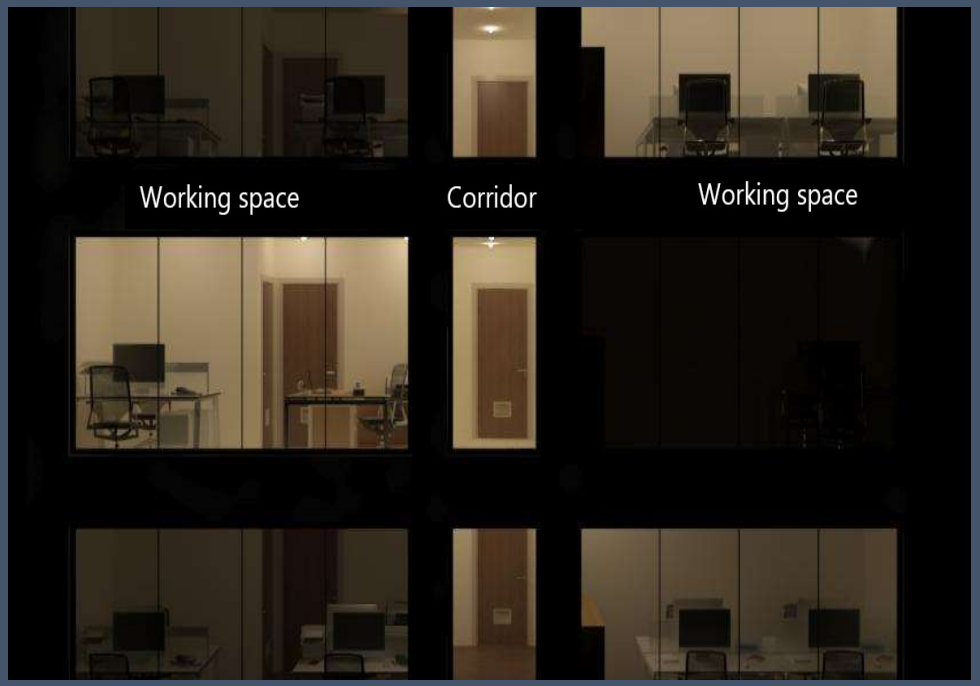


Figure 19: Simulation of full-Active hours with the LALs

By David Li

Second scenario Part-1: Reduced-Activity hours without the LALs



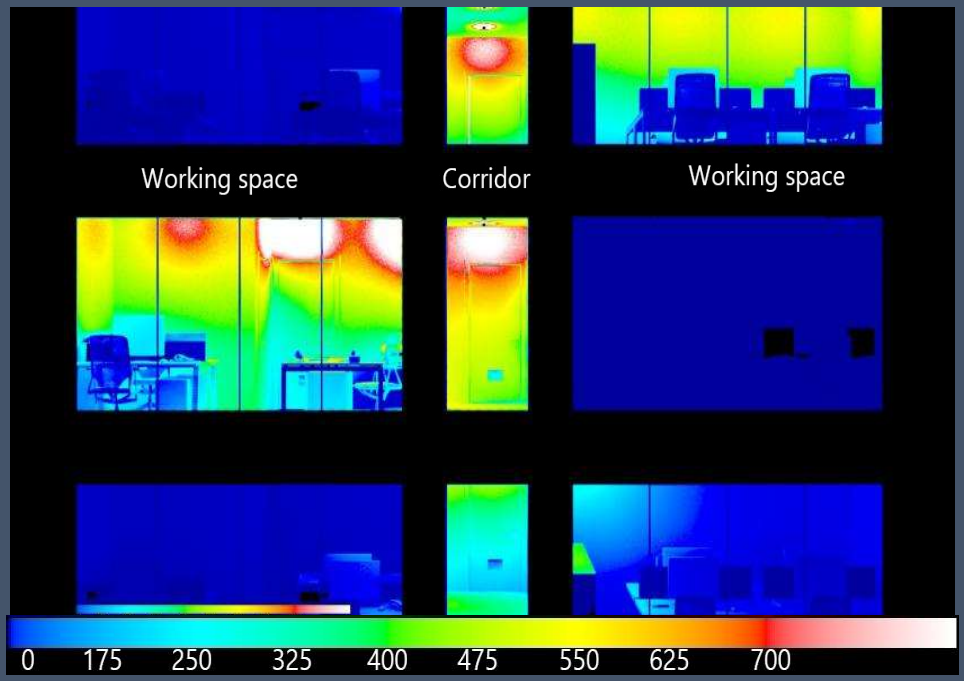
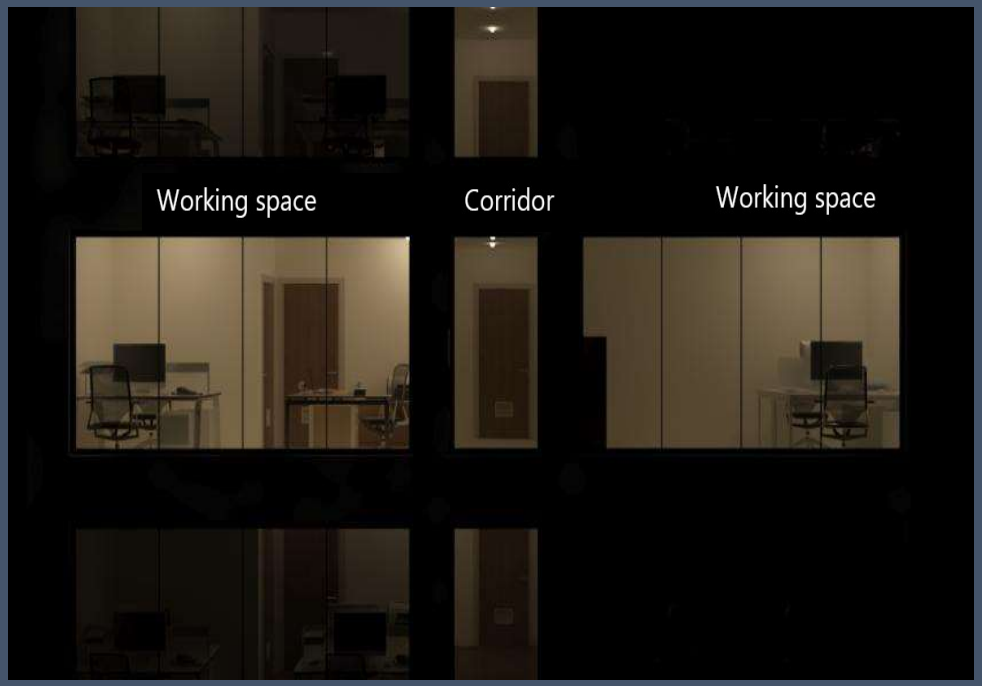


Figure 20: Simulation of reduced-activity hours without the LALs

By David Li

Second scenario Part-2: Reduced-Activity hours after installing the LALs



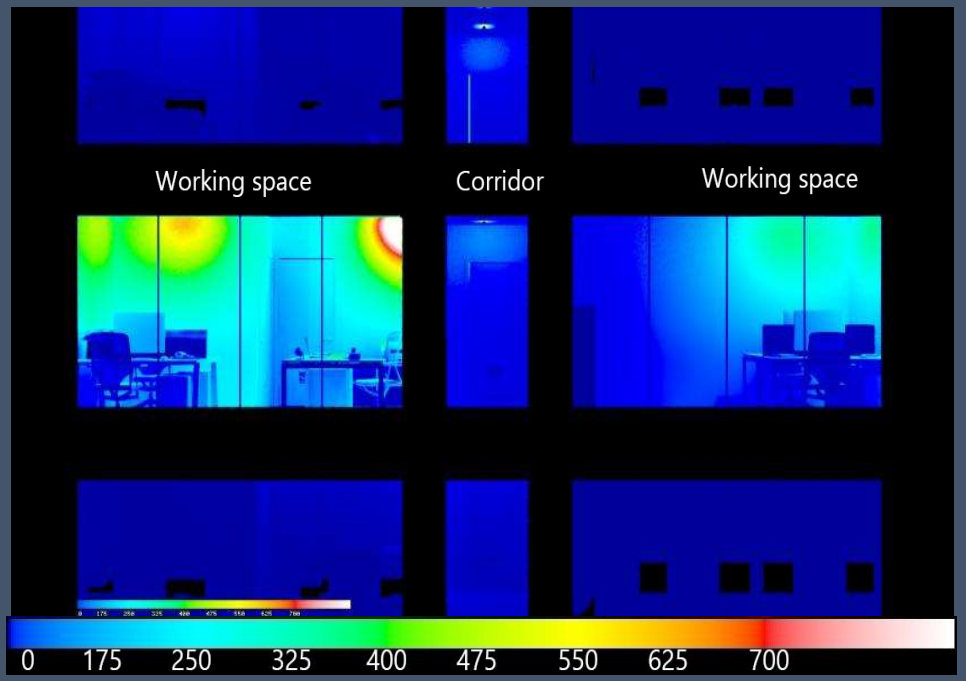


Figure 21: Simulation of reduced-activity hours with the LALs

By Steph Wong

Measures of Success – Unintrusive

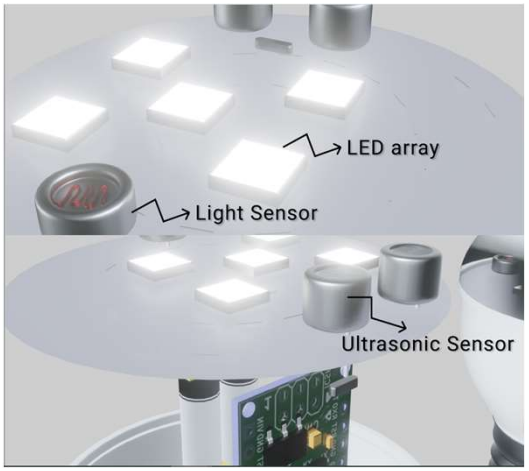
Type of Evidence: Estimation + eventually prototype

By Steph Wong

Conclusions

By Steph Wong

- Determined 3 alternative designs
- Final recommended design is the Localized Automatic Lighting
- Recommended design meets all measures of success
- Recommended design meets client need and requirements
- The client may use our plan to build a prototype



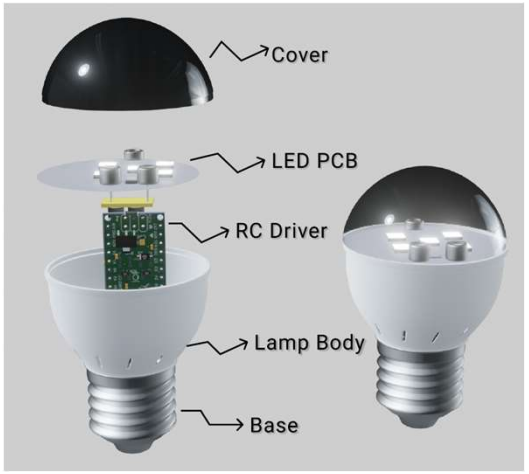


Figure 22: Diagrams of LAL [5]


Palak Patel


Michael Tan


Farin Khoshsorour


Sam Chowdhury


David Li


Steph Wong

Thank you

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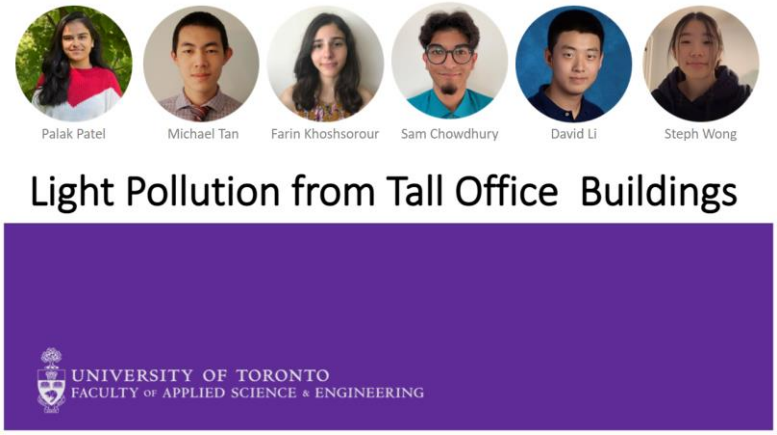
APS112 Final Presentation Transcript

Project: APS112 "Light Pollution from Tall Office Buildings" Final Presentation

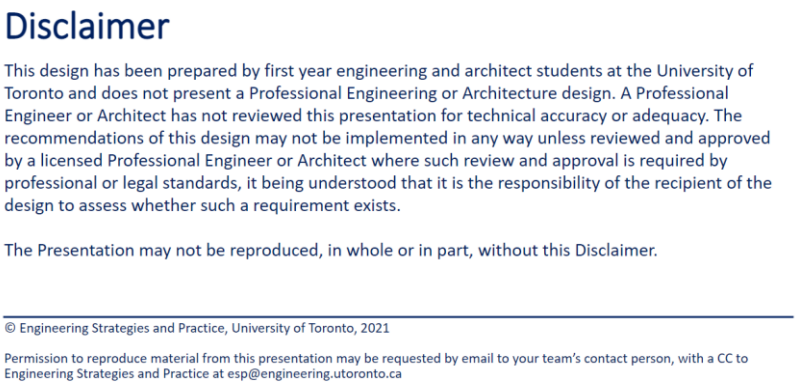
All Presenters: Palak Patel, Michael Tan, Farin Khoshsorour, Sam Chowdhury, David Li, Steph Wong

Slide Number: 1



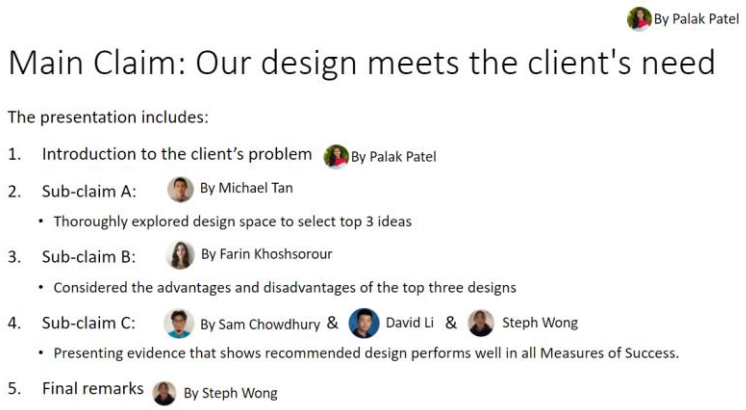
[Palak Patel] "Welcome to our presentation on light pollution from tall office buildings for the engineering strategies and practices design project."

Slide Number: 2



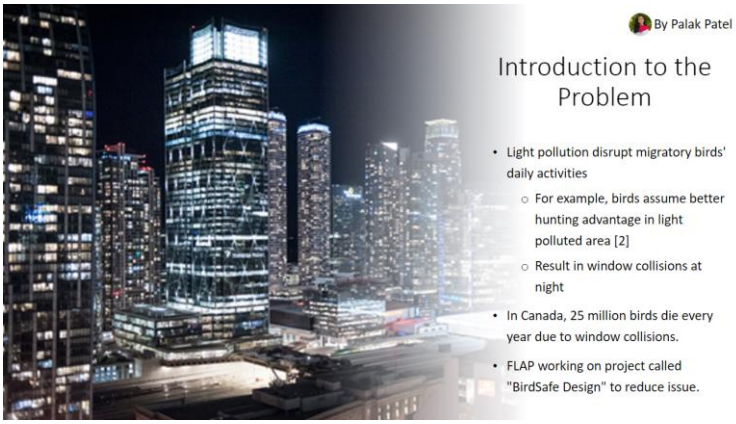
[Palak Patel] "Disclaimer: This project has not been reviewed by a professional architect or engineer. The designs in this project may not be implemented in any way unless they have been reviewed by licensed engineers or architects."

Slide Number: 3



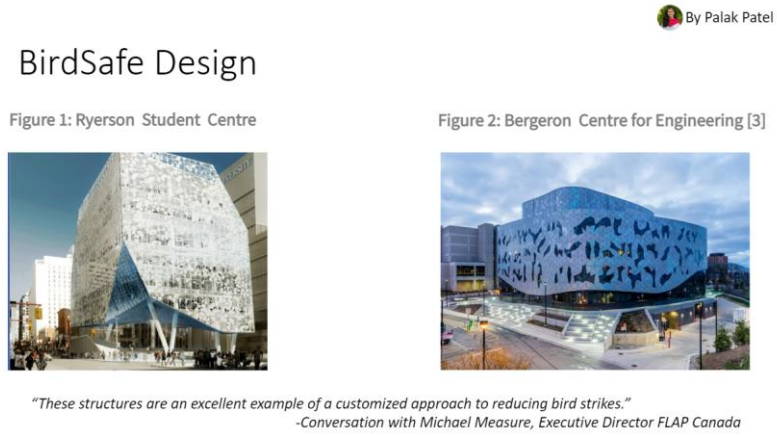
[Palak Patel] "We believe that our recommended design meets all of the client's needs, and so we will begin this presentation by introducing the problem. Next, we will explain how our team generated the ideas for a potential solution, and the selection methods we used to reduce the long list of ideas brainstormed. Then, we will describe the top three designs our team selected, including the proposed design, followed by describing the tests, simulations, and prototype plans that prove the recommended design's efficacy. And finally, we will conclude the presentation by sharing some final key points with you. So let us get started!"

Slide Number: 4



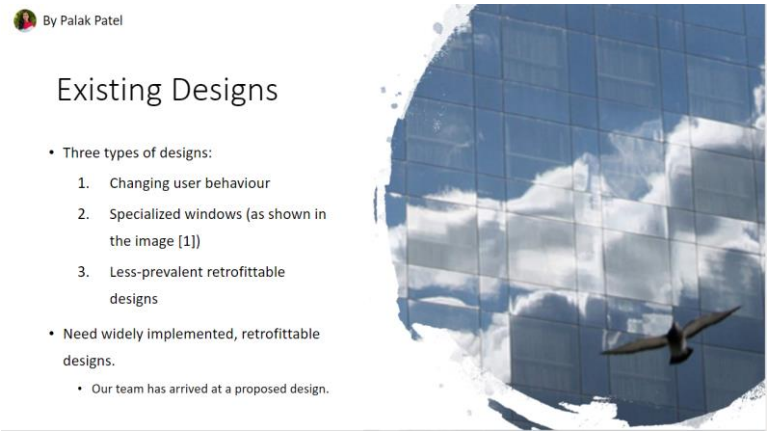
[Palak Patel] "Light pollution from tall downtown buildings is detrimental to the environment, in particular to migratory bird species. Because of light pollution, the daily activities of migratory birds, such as hunting, become disrupted. Annual statistics have also shown that more than 25 million birds die each year from window collisions alone and many organizations have made an effort towards reducing this issue."

Slide Number: 5



[Palak Patel] "In fact, our team member had a conversation with the executive director of the Fatal Light Awareness Program, and we have learned that they are working on a project called "BirdSafe Design" that also aims to tackle this problem. The images of the Ryerson Student Centre and Bergeron Centre for Engineering, shown here, are actually examples of the BirdSafe Design project application."

Slide Number: 6



[Palak Patel] "There are currently three types of existing solutions that aim to mitigate bird-window collisions. The first is asking to change user behaviour, so for example, closing the curtains in office spaces to reduce light trespass. The second type is specialized windows like the one shown in the figure here. However, these windows are often too expensive to retrofit to existing buildings. Lastly, there are retrofittable designs such as one-way window films, timer-based lighting, and motion sensors. But unfortunately, these designs are not largely implemented. And as one of the members in our team discussed with the director of the Fatal Light Awareness Program, we need widely implemented, consistent, and retrofittable designs for new buildings as well as already existing buildings.

Thus, to address this severe issue, our team has conducted thorough research and has arrived at a proposed design which aims to reduce bird mortality due to light pollution."

Slide Number: 7

[Michael Tan] "Well put, Palak, in order to meet the client need, the team thoroughly explored the design space before narrowing it down to the top 3 ideas using a multi-step selection process."

Slide Number: 8

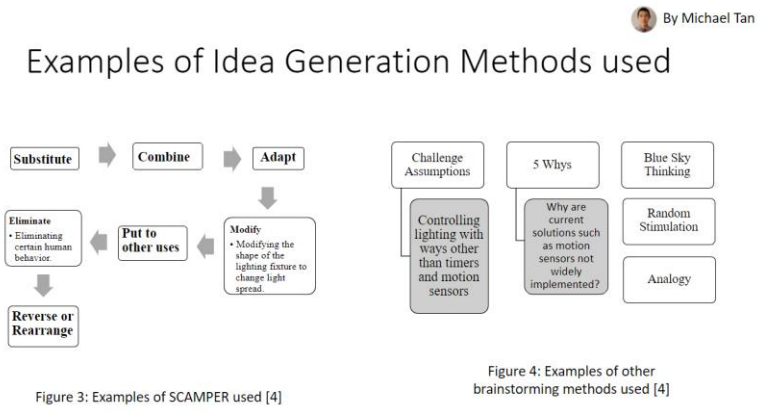


Figure 3: Examples of SCAMPER used [4]

Figure 4: Examples of other brainstorming methods used [4]

[Michael Tan] "During idea generation, the team used SCAMPER and other lateral thinking techniques such as "challenging assumptions", "5 why's", blue sky thinking, random stimulation, and analogy. Notably, the idea of modifying the shape of lighting fixtures and eliminating certain human behaviours causing overnight lighting, have led to the generation of entire design approaches. Furthermore, we also asked, "why current solutions are not wide-spread". The different answers, such as cost and intrusiveness, served as jumping off points for our brainstorming."

Slide Number: 9

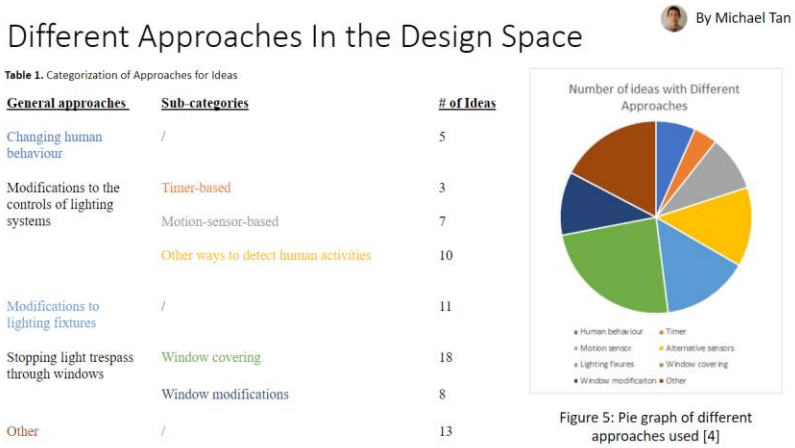


Figure 5: Pie graph of different approaches used [4]

[Michael Tan] "In the end, the team came up with 79 ideas, categorized into the 5 general approaches for stopping the flow of light. Some general approaches also have sub-categories based on specific methods proposed. The diversity of our ideas should be apparent in figure 5."

Slide Number: 10

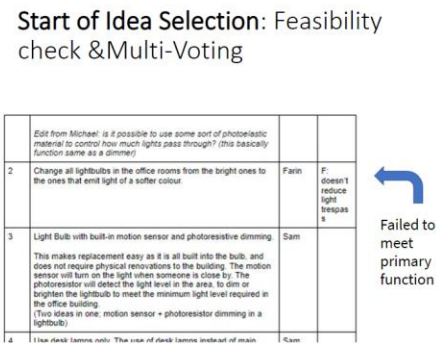


Figure 6: Example of feasibility check

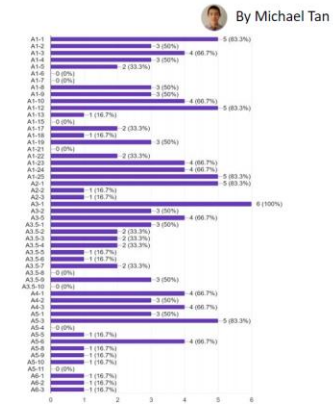
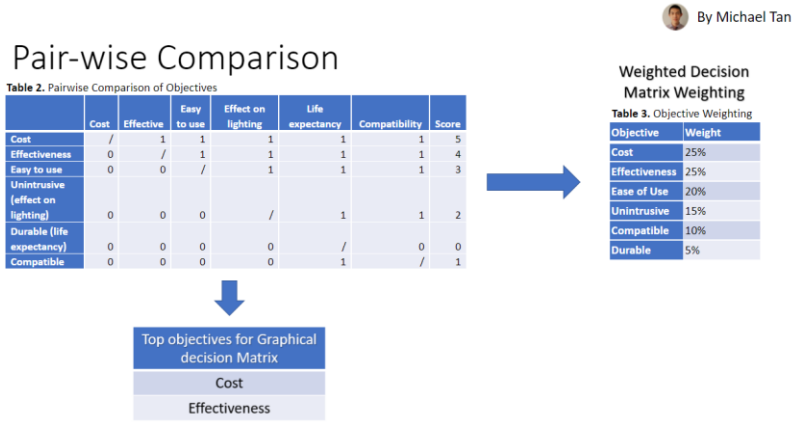


Figure 7: The results of multi-voting

[Michael Tan] "In order to select ideas that best meet the client need, the team started with a feasibility check, which eliminated the ideas that either failed to meet a function or a constraint. The team then performed multi-voting on the 61 ideas left and decided that only the 14 ideas that received over three votes will advance to the next stage of idea selection."

Slide Number: 11



[Michael Tan] "Before advancing though, the team needed to rank the 6 objectives from project requirement, as they will be needed again for both the graphical and weighted decision matrices that follows. Thus, the team used pairwise comparison to identify the top two objectives for graphical decision matrix, and the weightings for weighted decision matrix. Of note is that the team decided to give both top two objectives, "cost" and "effectiveness" equal weighting, as it is important to achieve a balance between them."

Slide Number: 12

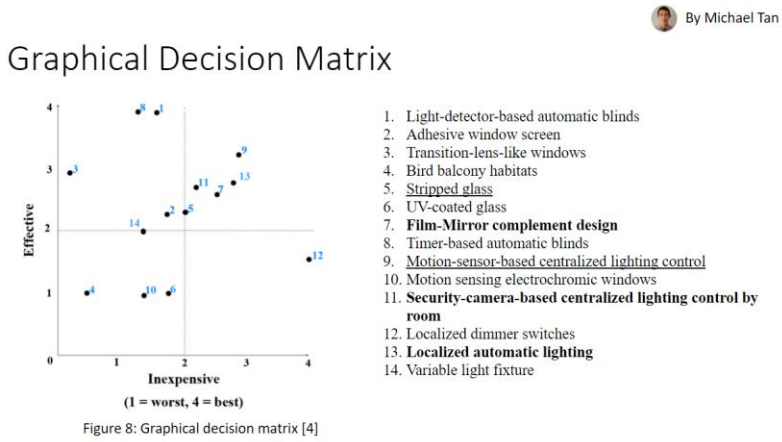


Figure 8: Graphical decision matrix [4]

[Michael Tan] "With the top two objectives decided, the team then performed a graphical decision matrix on the aforementioned 14 ideas, based on how well they perform relative to each other. Since there are five ideas in quadrant 3, a weighted decision matrix was used to eliminate idea 5 and 9, which share similar approaches but received lower scores compared to idea 7 and 11 respectively."

Slide Number: 13

By Michael Tan

Pros & Cons of Top 3 Alternative Ideas

[Michael Tan] "Farin will now go over the pros and cons of the top 3 ideas and identify the best among them."

Slide Number: 14

By Farin Khoshsorour

Weighted Decision Matrix

		Eliminated	3rd Alternative Design	Eliminated	Top Design	2nd Alternative Design
Objective	**Weight**	**Stripped glass**	**Film-mirror complement design**	**Motion-sensor-based lighting control per room**	**Localized automatic lighting**	**Security-camera-based centralized lighting control**
Inexpensive	25%	20%	60%	70%	75%	75%
Effectiveness	25%	50%	65%	80%	85%	75%
Ease of Use	20%	100%	100%	100%	100%	80%
Unintrusive	15%	100%	100%	80%	80%	80%
Compatible	10%	100%	100%	90%	100%	90%
Durable	5%	90%	60%	80%	80%	80%
Totals	100%	**67%**	**79%**	**83%**	**86%**	**79%**

Table 5. Weighted Decision Matrix

[Farin Khoshsorour] "Using the weighted decision matrix, we decided on our three alternative designs and came to the conclusion that the "Localized Automatic Lighting" was our best idea. This matrix also highlighted the strengths and weaknesses of each idea."

Slide Number: 15

By Farin Khoshsorour

Pros VS Cons

1. Film-Mirror Compliment Design

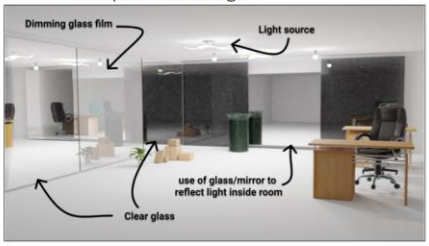


Figure 9: Diagram of Film-Mirror Complement Design [5]

[Farin Khoshsorour] "Our third alternative design was the "Film-Mirror Compliment Design," which involves attaching a smart tint window film to the building's windows. A switch will shift

the window between being opaque and transparent. One downside of this idea is that it can be quite expensive. Each window in the building will have to be covered with the smart tint film, each of which costs anywhere between $60 to $80. On the other hand, however, this design is very easy to use. The windows will switch between the two forms with the mere press of a button. As well, the design is unintrusive. The film is attached to the windows and will not disturb the lighting inside the building."

Slide Number: 16

Figure 10: Diagram of Centralized Lighting Control [5]

[Farin Khoshsorour] "Our second alternative design was the "Centralized Lighting Control." This design requires that dimmers are added to each office in the building. Then, security guards, looking through the already existing cameras, will identify vacant rooms and use the designated app to activate the dimmers. One con of this idea is that it may turn out to not be as effective as we hope. Since the design will be controlled by security guards, a human factor has come into play, and this could negatively affect the performance. However, one major pro of this design is that it is easy to use. The dimmers are controlled by an app so the security guards can quickly, easily, and remotely, activate or deactivate them. Another pro of this idea is its compatibility. The dimmers can be added to the building's current lighting system with ease."

Slide Number: 17

Figure 11: Diagrams of Localized Automatic Lighting [5]

[Farin Khoshsorour] "Our top design was the "Localized Automatic Lighting." This design involves adding an ultrasonic sensor and a dimmer inside a lightbulb. When the sensor detects presence, it will turn the individual bulbs on, and when there is none, the bulbs will be dimmed. One shortcoming of this idea is that it can be expensive. The cost to make each bulb will be high,

however, buying in bulk for the building will ease this issue. A positive factor of this design is that it is effective. If no motion is sensed under a bulb, it will be dimmed, meaning only a select few bulbs will be on at a time, thus, greatly reducing the light pollution and saving lighting costs over time. Another major benefit of this idea is that it is easy to use. The bulbs work automatically, so other than screwing the bulbs in, no work needs to be done."

Slide Number: 18

[Farin Khoshsorour] "Using the weighted decision matrix, and comparing these pros and cons, it was clear that the automatic light bulb was the design that we should move forward with and conduct tests on."

[Sam Chowdhury] "The first step in measuring the success of our design was to determine the theoretical cost and energy consumption. This would be done using the prototype parts that we would use."

Slide Number: 19

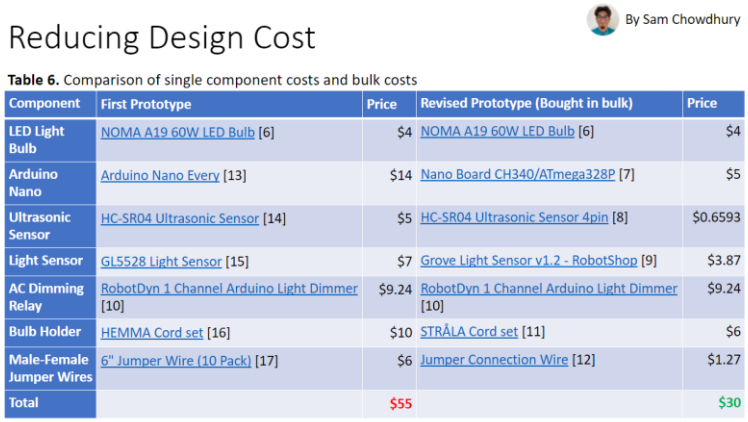


Table 6. Comparison of single component costs and bulk costs

Component	First Prototype	Price	Revised Prototype (Bought in bulk)	Price
LED Light Bulb	NOMA A19 60W LED Bulb [6]	$4	NOMA A19 60W LED Bulb [6]	$4
Arduino Nano	Arduino Nano Every [13]	$14	Nano Board CH340/ATmega328P [7]	$5
Ultrasonic Sensor	HC-SR04 Ultrasonic Sensor [14]	$5	HC-SR04 Ultrasonic Sensor 4pin [8]	$0.6593
Light Sensor	GL5528 Light Sensor [15]	$7	Grove Light Sensor v1.2 - RobotShop [9]	$3.87
AC Dimming Relay	RobotDyn 1 Channel Arduino Light Dimmer [10]	$9.24	RobotDyn 1 Channel Arduino Light Dimmer [10]	$9.24
Bulb Holder	HEMMA Cord set [16]	$10	STRÅLA Cord set [11]	$6
Male-Female Jumper Wires	6" Jumper Wire (10 Pack) [17]	$6	Jumper Connection Wire [12]	$1.27
Total		$55		$30

[Sam Chowdhury] "This theoretical calculation began with finding the cost to create a prototype. The goal was to determine the functionality of individual parts of the design. This would ideally be integrated into a design that fits within the size of a lightbulb. Thus, the prototype at this stage would be attached to a relay, controlling a regular light bulb, before moving onto the compact design. Table 6 shows a prototype cost comparison. On the left, we have our initial cost, where we purchase only the necessary number of components. And on the right, we have a revised cost,

where some parts are bought in packs or bulk. As shown in the totals row, the cost of bulk purchases, nearly halves the price of the prototype."

Slide Number: 20

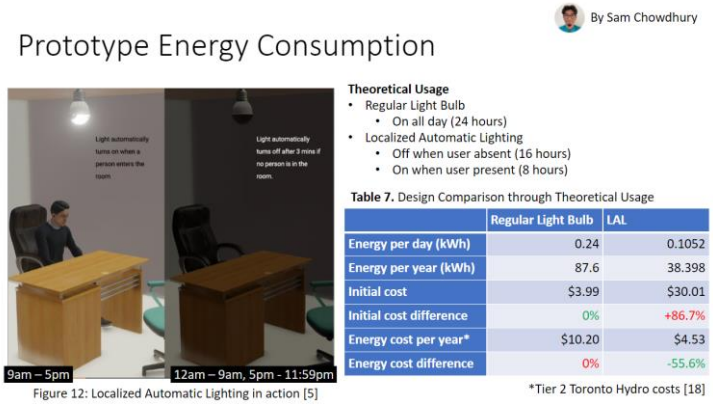


Figure 12: Localized Automatic Lighting in action [5]

[Sam Chowdhury] "The next step was to compute the energy consumption of the design and compare it to a regular lightbulb. To do so, we used a theoretical usage model of the design, where the user is present under a single lightbulb, and only during office hours. While a regular bulb would stay on for the full day in this model, our design would turn off for the remaining 16 hours of the day. This saves electricity, as only the microcontroller within our design would be running. And that uses a tenth of the energy compared to a lightbulb. Extending this model to the span of a year shows us the yearly energy consumption. Converting this to energy costs, allows us to see the cost to operate our design. As shown in Table 7, the initial cost of our prototype is much higher than the regular light bulb. However, our design saves on over half the electricity cost every year, which would lead to savings in the long run."

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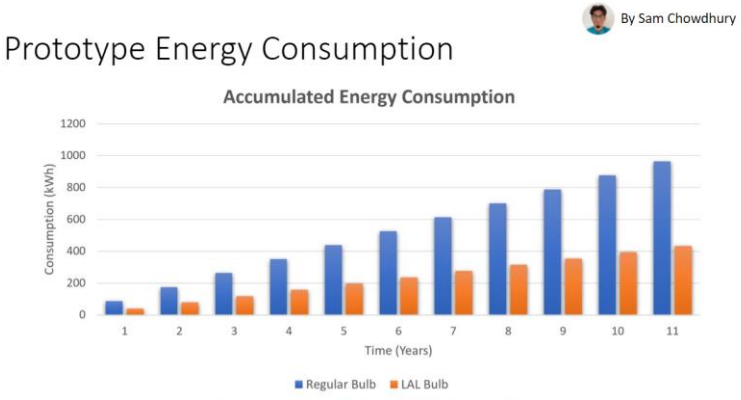


Figure 13: Accumulated energy consumption over time [19]

[Sam Chowdhury] "Representing the accumulated energy consumption over time shows that overall, energy saving increases. We see that in roughly four to five years, a regular light bulb consumes the same amount of energy as our design would in eleven years."

Slide Number: 22

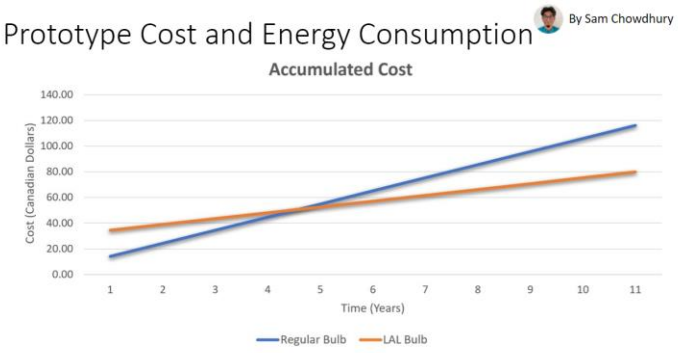
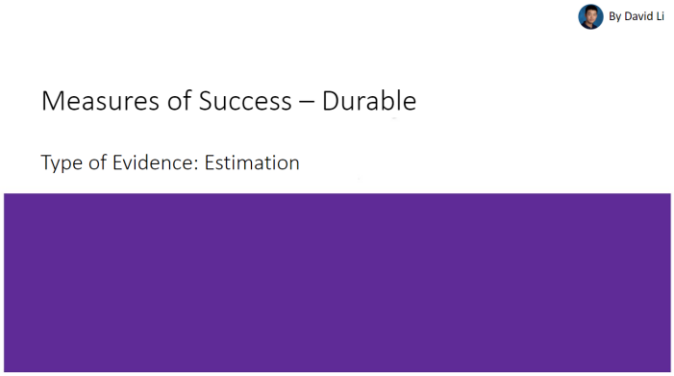


Figure 14: Cost of convention light bulb vs. Prototype [19]

[Sam Chowdhury] "and graphing the accumulative costs shows us that it does indeed take four to five years for our design to start saving money. To allow for more savings, the initial cost of the design could be reduced by purchasing components in mass. Alternatively, the design could be durable enough to last longer than five years, to allow for savings."

Slide Number: 23



[David Li] "In terms of durability,"

Slide Number: 24

By David Li

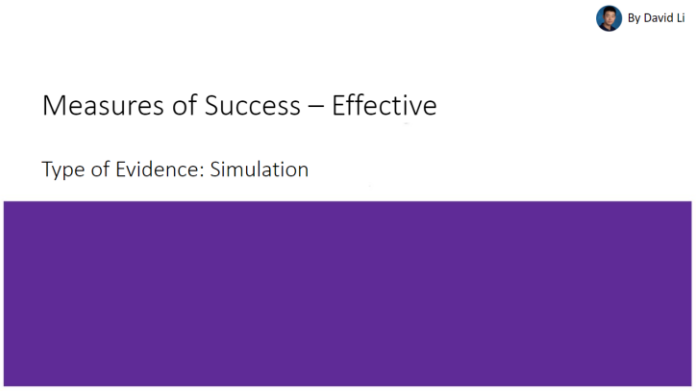
Table 8. Prototype Component Lifespans [5]

Component	Life (yr)	
LED Light Bulb	14[22]	
Arduino Nano	20-30[23]	
Ultrasonic Sensor	22[24]	
Light Sensor	~20[25]	
AC Dimming Relay	<20[26]	
Bulb Holder	----------	
Male-Female jumper Wires	----------	

The design successfully meets the objective goal of 10.5 years.

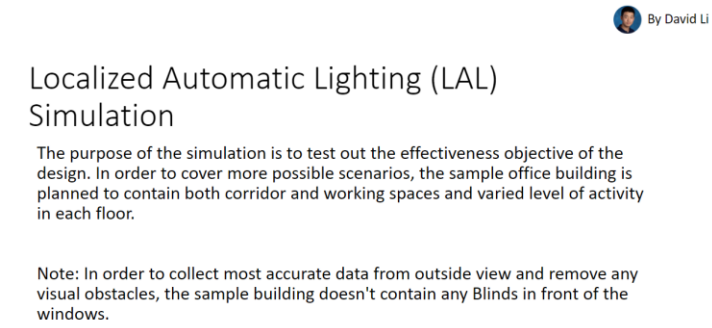
[David Li] "Based on the theoretical usage mentioned by Sam and research, the lightbulb lives shorter than all the other components, so we can consider the lifespan of the lightbulb as the lifespan of the design, and it successfully meets the objective goal."

Slide Number: 25



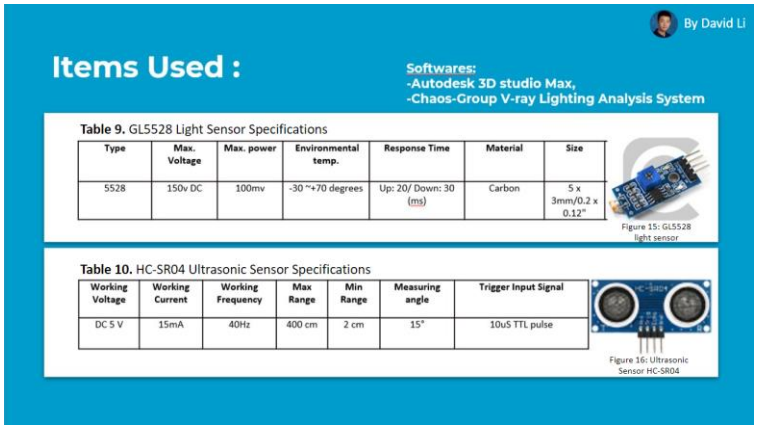
[David Li] “As for the effectiveness of the design,”

Slide Number: 26



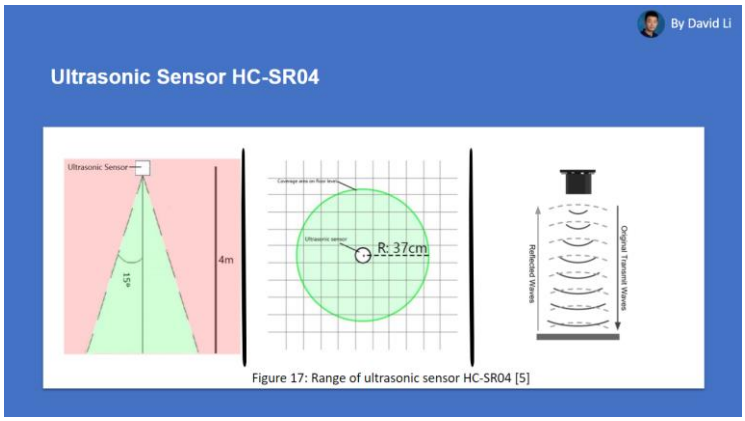
[David Li] “The localized automatic lighting simulation has been made to calculate the light pollution created by office buildings at night. The pollution output has been calculated in Lux before and after using the design in two different space usage intensity.”

Slide Number: 27



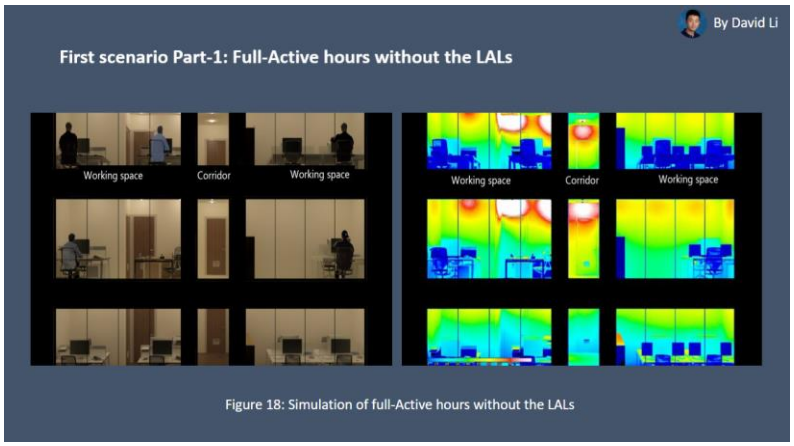
[David Li] “The software used are the Autodesk 3D studio max, which have been used to create the virtual office environment, and the V-ray light analysis system used to show illuminance diagrams with pseudo colours. The items used are the light sensor and the ultrasonic sensor.”

Slide Number: 28



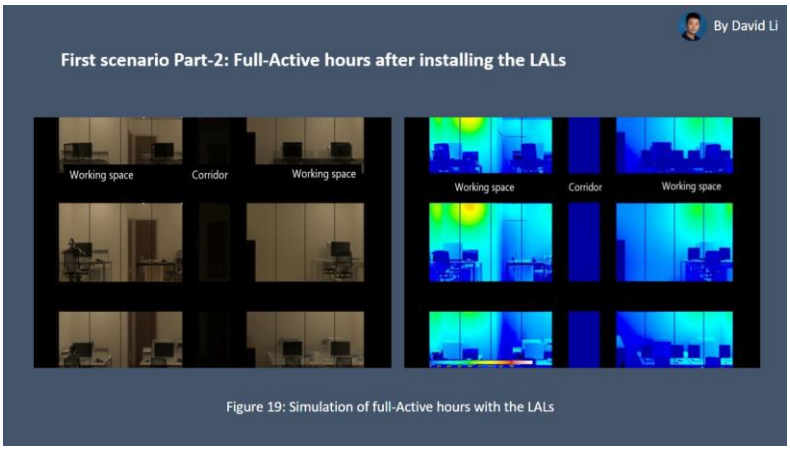
[David Li] “The Ultrasonic sensor used in this simulation can detect movement up to four meters of range and 15 degrees circular angle from it’s center as shown here.”

Slide Number: 29



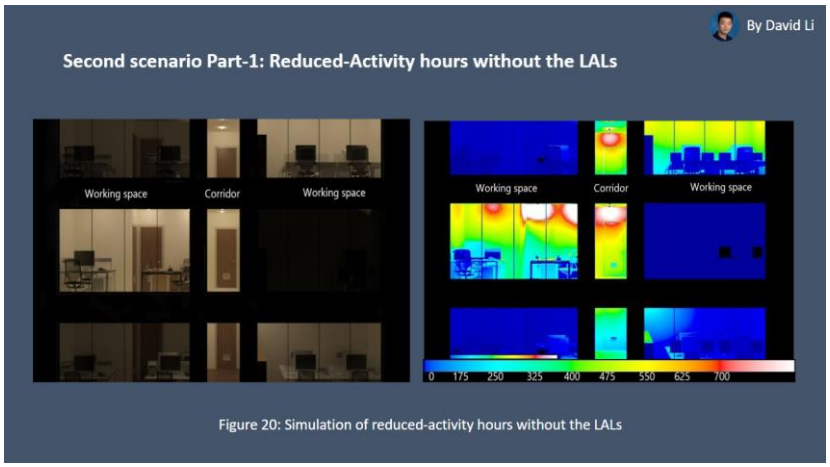
[David Li] “Now you can see the first scenario of the simulation. Part 1. As we can see in the figure on the left, all light sources are active on all three floors. According to the lighting analysis on the right, the average brightness measure is 500 Lux. Also, the corridors which aren’t being used as much as working spaces are also lit with the same amount of brightness.”

Slide Number: 30



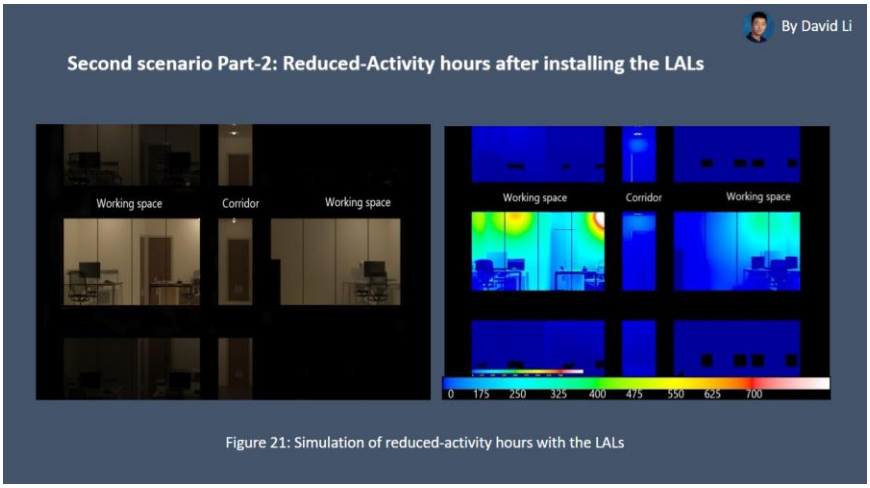
[David Li] "In part 2, the lighting method has been changed from ordinary light bulbs to LAL's. The figure indicates some dark spaces has been created compared to part 1. For example, In the corridors, the sensor system deactivated the light source after NOT sensing any activity after 3-minutes. If we look at the lighting analysis on the right, many spots of the room are darker due to reduced sensing of activity by LAL's, and the light sources are being dimmed to 100 lux."

Slide Number: 31



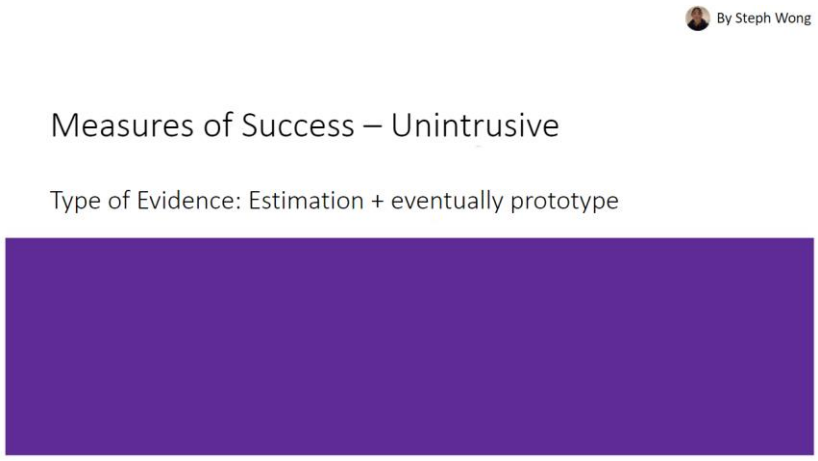
[David Li] "In the first part of the second scenario, the space is being used by no users and normal light bulbs are being used. Considering the lighting analysis, the upper parts of the active spaces produce excess light. Additionally, the corridors are also fully active even without any users."

Slide Number: 32



[David Li] "In the second part of the second scenario as we can see in the figure while using the LALs, the middle floor has controlled amount of brightness, and inactive rooms are fully deactivated by sensors. The lighting analysis indicates that even the active areas of the building produces lesser amounts of light pollution. And that the corridors are dimmed to a minimum level and doesn't create any excess light. In summary, the data derived from simulations proves that using this design, besides decreasing the amount of excess light, also reduces the power consumption amount."

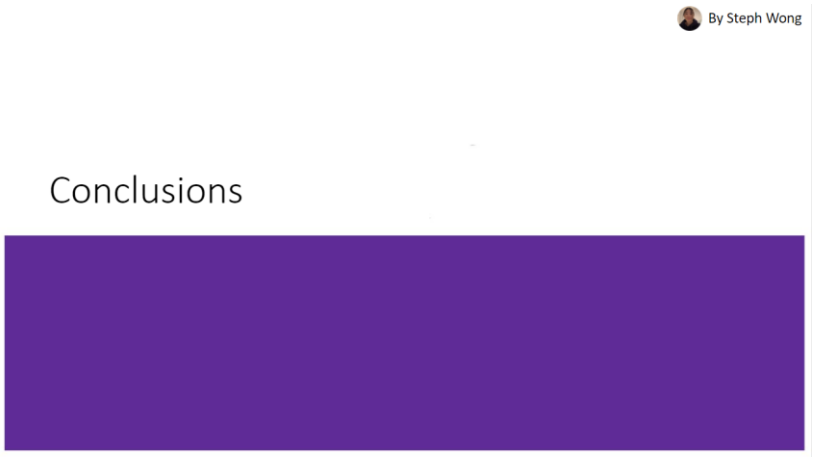
Slide Number: 33



[Steph Wong] "As for the unintrusive measure of success, we originally planned to test it using the prototype plan in the CDS appendices. Unfortunately, we were unable to build the prototype due to conflicting shipping dates for parts required. For now, we have estimated the plan for the prototype and theoretically, it should meet the unintrusive objective goal. When there is inactivity, the design will dim to a hundred lux for the first three minutes, and only completely turn off if no activity is detected within that time period. This dimming will ensure minimum floor level

illumination in the three-minute time period in the case that there is human activity nearby that the sensors are unable to detect. This meets the constraints outlined in the project requirements. Thus, the design should not completely turn off in human presence or hinder the office workers."

Slide Number: 34



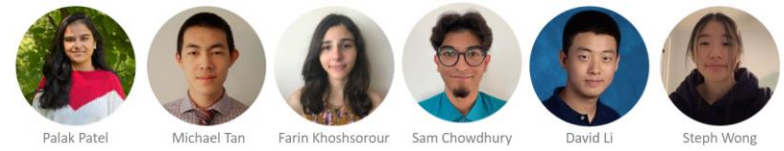
[Steph Wong] "To summarize our presentation, there is a lack of affordable solutions that can be widely implemented to prevent light trespass, which has resulted in an increase in migratory bird mortality. We generated and sorted 79 ideas narrowing down our design space to 3 alternative designs. In order to determine the best design, we used the weighted decision matrix and determined that the Localized Automatic Lightbulb was the best design of the three. Therefore, our team has thoroughly explored the design space, and used many different methods to determine the best possible solution for the presented problem."

Slide Number: 35

Figure 22: Diagrams of LAL [5]

[Steph Wong] “The final recommended design is the Localized Automatic Lightbulb as it meets all the project requirements and the prototype simulations along with calculations meet all the measures of success. On the screen are diagrams of this final design in which the client is free to use in order to build a prototype as she wishes.”

Slide Number: 36



Thank you

[Steph Wong] “Our team has enjoyed working on this project to target this prevalent issue and we hope that this design will be of help to mitigate light trespass. Thank you for listening!”

Slide Number: 37

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[1] B. L. International, “How can we REALLY prevent birds from flying into our windows?,” *BirdLife*. [Online]. Available: https://www.birdlife.org/worldwide/news/how-can-we-really-prevent-birds-flying-our-windows. [Accessed: 21-Apr-2021].
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