Indoor Lighting Needs Optimization Using Simple Additive Weighting Method

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Abstract: Lack or excess of lighting in the room, causing disrupted activities where the cause is the wrong choice of lamp type, lamp brand, number of lamps, and required wattage. The development of computers has caused changes in various areas of life, one of which is in the decision-making process. Sometimes decisions made by a person or group manually are less accurate in their judgment, such as deciding to buy a suitable lamp for the desired room. The Simple Additive Weighting (SAW) method can be used to help determine the type and the brand of lamp that will be used. Some parameters used as calculations are the base shape of the room with that size, the type of room, and the ranking of attributes that have been provided. The result of this research is the creation of a Decision Support System with the SAW method for optimizing room lighting needs. Based on the experiments, it proves that if the parameter value is greater, the lumen requirement will also be greater and the method used also works correctly. The final score will decide on the best alternative from the available alternatives. So it can be concluded that the SAW method is a decision support system in solving various multi-criteria decision-making problems. It can also be used as a decision support system for optimizing lighting needs in the room.

1 INTRODUCTION

The development of an increasingly advanced era like today increases the community's needs, especially with the lighting factor of the room. Lighting is one of the essential factors in designing a space to support user comfort. A room with a good lighting system can support the activities carried out in it (Ponamon et al., 2017). The use of sunlight as the primary light source can reduce the use of electricity. However, the availability of natural light sources that are not constant due to weather changes and problems related to the depth of space cause the distribution of light entering the room to be uneven because not all parts of the room are exposed to sunlight. The lighting conditions in these two conditions can be said not to meet the lighting standards, so the role of artificial light is needed in synergy with natural light (N. Azizah, 2017)(P. Satwiko, 2008).

A good lighting system must meet three main criteria: quality, quantity, and lighting rules. The lack of lighting support in-room results in disrupted activities in the room. For example, when lighting is too excessive, it will interfere with vision. Thus, the light intensity needs to be regulated to produce the appropriate vision needs in the room based on the type of activity (Ponamon et al., 2017). A decision support system is a computer-based system that can solve problems by producing the best alternative to support decisions taken by decision-makers (Kusrini, 2007).

Therefore, this final project will discuss a decision support system that is expected to assist in selecting the type of lamp desired. The Simple Additive Weighting method because this method can make a more precise assessment based on the predetermined criteria and preference weights. In addition, the SAW method can select the best alternative from several existing choices.

At a time when the times are more advanced, the lighting factor of the room is still an important thing. The problems faced by the community in choosing the best lamps are common in choosing these lamps. They must pay attention to the brand, quality, and lighting (Siburian, B., Octiviani, M., and Milawati, 2018). In addition, we must know how much lux is needed from each type of room and the lumen requirement of the space we choose. Another challenge is choosing the type of lamp based on our needs, starting from the aspect of price, lamp

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resistance, lumens per watt for each kind of lamp, wattage requirements, etc.

This final project aims to design a Web/Mobile-based decision support system with the Simple Additive Weighting method to decide on optimizing lighting needs in the room. By implementing the physics method and SAW into the system and evaluating the performance of the SAW method as a decision support system for optimizing the needs for lighting in the room.

The benefits of the final project and the writing of this final project are expected to be an alternative solution for the community in helping make decisions in choosing the lighting needs in the desired room.

2 RELATED WORKS

In this study, the author was inspired by various related references. In this study, the author was inspired by Ponamon, et al. study (Ponamon et al., 2017). From the results of this study, a decision support system for selecting lamp types for room lighting has been produced using the Analytical Hierarchy Process (AHP) method to decide the type or brand of lamps to be used in the room. Based on the AHP calculation example results by weighting the criteria and alternatives for choosing the type or brand of lamp used, the best lamp brand was selected, namely Philips. This decision support system can help people buy the kind of lamp that will be used more quickly and easily in making choices.

In (Hadikurniawati & Ami, 2016), Hadikurniawati et al. proposed multi-attribute decision-making for selecting lamp types that can provide the best-ranking order of the criteria used to determine the type of lamp. The results of the calculation of the AHP method are based on technical and economic calculations, as well as an assessment of the technical specifications of the lamp. In addition, it also uses the assistance of the super decision program to generate alternative priorities, namely alternative lamps of the Osram HQI 400W/D type, which occupy the highest priority and can be used as a consideration for decision-makers to be used in sports arena lighting systems, especially badminton courts. Furthermore, Seema et al. built a decision support system for selecting the best lamps using the Vikor method (Seema & Kumar, 2015). Table 1 shows the comparison of our proposed method with other previous related works.

Table 1: Comparison study with other previous methods.

Title	Method	A	B	C
Decision support system for selection of lighting types for room lighting using AHP method	Analytic Hierarchy Process (AHP)	No	No	Application Implementation
A decision support system for IMS selection based on fuzzy VIKOR method	VIKOR	No	No	Concept Theory
Multi attribute decision in light selection in badminton field lighting system	Analytical Hierarchy Process (AHP)	No	No	Application Implementation
Our proposed method	Simple Additive Weighting (SAW)	Yes	Yes	Application Implementation

A: Choosing a Room Type
B: Generating Wattage Requirements for The Selected Room
C: Application Implementation / Concept Theory

3 METHODOLOGY

3.1 System Design

The system design can bee seen in Figure 1. The first step is when the user inputs data, it includes things like Room Type (Bedroom, Bathroom, etc.), then Room Size (in centimeters), and will rank the attributes that will be provided. For the physics formula itself, we will use the formula of Lux to Lumen formula, which can be calculated as

$$\Phi V_{(lm)} = Ev_{(lx)} \times A_{(m^2)} \times \frac{T_{(m)}}{3_{(m)}} \quad (1)$$

($\Phi V_{(lm)}$) is the total lumen requirement of a room. To get it, it must be known beforehand ($Ev_{(lx)}$) which is the lux requirement of the room. Based on Equation 1, ($A_{(m^2)}$) is the area of the room and ($\frac{T_{(m)}}{3_{(m)}}$) is the height of the room.

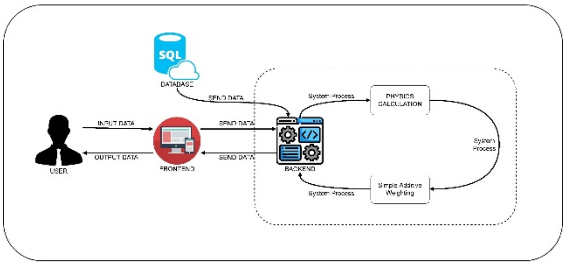

Figure 1: System Design.

and Lumen to Watts Formula, which can be calculated as

$$P_{(W)} = \frac{\Phi V_{(lm)}}{\eta_{(lm/W)}} \quad (2)$$

($P_{(W)}$) is the total wattage for the lamp that will be used. To get it, it must be known beforehand ($\Phi V_{(lm)}$) which is the total lumen requirement of a room and ($\eta_{(lm/W)}$) is the coefficient of lumens per watt of the lamp.

Table 2: The need for lux for each room type (SNI 03-6575-2021, 2001).

Room Function	Illumination Level (lux)
Residential Home :	
Terrace	60
Living room	120 ~ 250
Dining room	120 ~ 250
Workspace	120 ~ 250
Bedroom	120 ~ 250
Bathroom	250
Kitchen	250
Garage	60
Office :	
Director's Room	350
Workspace	350
Computer room	350
Meeting room	300
Drawing Room	750
Archives	150
Active Archive Space	300
Educational institutions :	
Classroom	250
Library	300
Laboratory	500
Drawing Room	750
Canteen	200
Hotels and Restaurants	
Lobby, Corridor	100
Ballroom/courtroom	200
Dining room	250
Cafeteria	250
Bedroom	150
Kitchen	300
Hospital / treatment centre:	
Inpatient Room	250
Operating Room, Delivery Room	300
Laboratory	500
Recreation and Rehabilitation Room	250
Shops/showrooms :	
Showrooms with large objects (e.g., cars)	500
Cake and food shop	250
Book and stationery/drawing shop	300
Jewellery shop, watch	500
Leather goods and shoe shop	500
Clothing store	500
Supermarkets	500
Electrical appliance shop (TV, Radio/tape, washing machine, etc.)	250
General :	
Parking Space	50
Warehouse	100
Rough work	100 ~ 200
Medium job	200 ~ 500
Smooth work	500 ~ 1000
Very smooth work	1000 ~ 2000
Color check	750
Praying room :	
Mosque	200
Church	200
Monastery	200

Table 2 will be used in the Physics Calculation method. Churchman and Ackoff first used the SAW method to solve the selection problem. The basic concept of the SAW method is to find the sum of the weights of the performance rating for each candidate on all attributes. The SAW method requires the process of normalizing the decision matrix (X) to a scale that can be compared with all existing candidate ratings (Eka P et al., 2016).

In this method, it is required for the decision-maker to determine the weight of each attribute. The total score of an alternative is obtained from the sum of all the multiplication results between the rating and

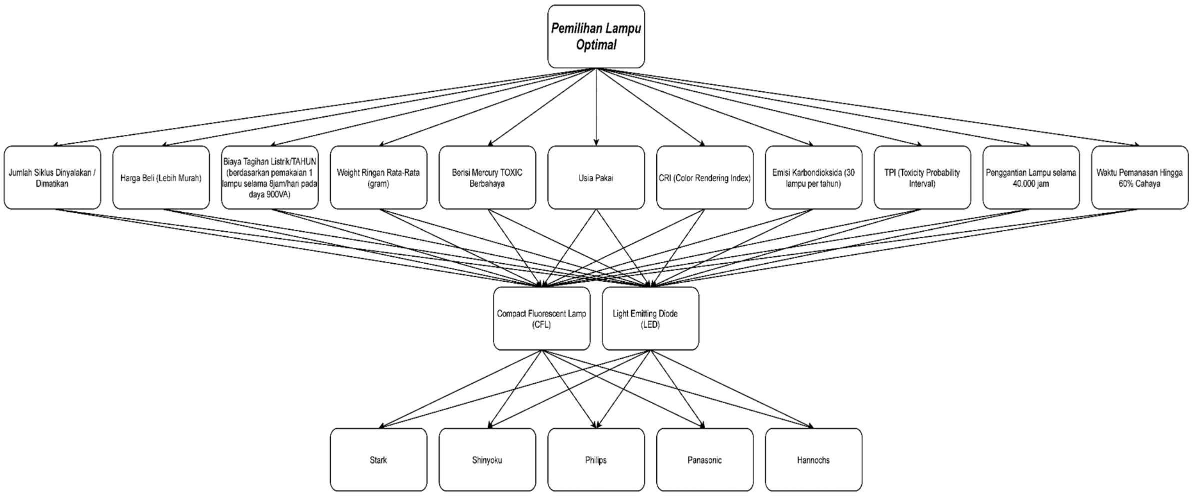

Figure 2: Our proposed decision diagram.

the weight of each attribute itself (Firnando, I. and Joni, W. 2020).

Compared to other methods, the Simple Additive Weighting method lies in the assessment more precisely because it is based on the value of the criteria and preference weights that have been determined. Besides, the SAW can select the best alternative from several alternatives because of the ranking process after determining the weight value for each attribute (Firnando, I. and Joni, W. 2020).The problem hierarchy is structured to assist the decision-making process by considering all decision elements involved in the system.

Figure 2 is a decision diagram or decision hierarchy based on this research and will be used until the next stage. Then, these attributes have attribute data for each type of lamp (Table 3). These attributes will be used as input in Simple Additive Weighting.

Table 3: Data attribute (Lim et al., 2013) (Spesifikasi Teknis, 2021).

Attribute Data	Score	
	LED	CFL
Usage Period	40000	9000
CRI (Color Rendering Index)	80	78
Contains mercury TOXIC	-4.8	-83.7
Average weight (grams)	-172	-58
Carbon Dioxide Emissions (30 lamps per year)	-451	-4500
Electricity Bill Fee/Year (based on the use of 1 lamp for 8 hours/day at 900VA power)	-14454	-36144
Purchase Price (Cheaper)	0.01	1
TPI (Toxicity Probability Interval)	-42027	-80454
Lamp Replacement for 40,000 hours	-0.000001	-4
Warm-up time up to 60% light	-1	-40
Number of cycles on/off	20000	4000

4 RESULTS

In the experiments, we try a test scenario with the following input options:
- Base shape: square
- Size: side length → 200 cm
  room height → 300 cm
- Room type: residential house
- Sub room: bedroom
- Attribute rank: see Table 4

Table 4: Attribute Ranking in scenario-1.

Attribute Data	Ranking
Usage Period	Ranking 1
CRI (Color Rendering Index)	Ranking 2
Contains mercury TOXIC	Ranking 3
Average weight (grams)	Ranking 4
Carbon Dioxide Emissions (30 lamps per year)	Ranking 5
Electricity Bill Fee/Year (based on the use of 1 lamp for 8 hours/day at 900VA power)	Ranking 6
Purchase Price (Cheaper)	Ranking 7
TPI (Toxicity Probability Interval)	Ranking 8
Lamp Replacement for 40,000 hours	Ranking 9
Warm-up time up to 60% light	Ranking 10
Number of cycles on/off	Ranking 11

The ranking above is used in the Simple Additive Weighting method, where rank 1 has the highest weight. Then, we will describe the calculations performed by the application system. Figure 3 is a Data Entry Page Display, the earliest display to enter data that will be processed by the system later. The Data is following input options from the test scenario. Then Figure 4 is a display of the Attribute Rank Page which can still be scrolled down again. Rank with number 1 has the highest value until number 11 has the lowest value.

Figure 3: Data Entry Page Display.

Figure 4: Rank Attribute-1 Page Display.

1) Physics Calculation Method

Using the Equation (1) and Equation (2). We calculate data from user input in the application according to scenario-1. In Table II. The bedroom has about 120 to 250, and we take the amount of 250 lux. The room is a square with a side length of 200 cm. Then the area of the room is

Area of Room = Length of Side x Length of Side

= 200 cm x 200 cm

= 40000 cm^2

= 4 m^2

Then the lumen requirement in the room is

Room Lumen = Room Lux Requirement x Room Area x (Room Height / 3 m)

= 250lx x 4m^2 x (3m / 3m)

= 1000 lm

Therefore, the requirement of scenario-1 is 1000 lumens. Next will go to the second method.

2) Simple Additive Weighting Method

This method calculates the best type of lamp for the user after the user has ranked the attributes provided by the system. The attribute ranks for scenario-1 are based on Table 4.

2.1) The First Phase

The first stage is to get the weight normalization value from the ranking input. To find the weight value, subtract the largest rank value of all attributes with the rank value. The normalized value of the weights is by dividing weight by total weight.

Table 5: Table for First Phase.

No	Attribute Data	Rank	Weight	Weight Normalization Value
1.	Usage Period	1	11.0	0.167
2.	CRI (Color Rendering Index)	2	10.0	0.152
3.	Contains mercury TOXIC	3	9.0	0.136
4.	Average weight (grams)	4	8.0	0.121
5.	Carbon Dioxide Emissions (30 lamps per year)	5	7.0	0.106
6.	Electricity Bill Fee/Year (based on the use of 1 lamp for 8 hours/day at 900VA power)	6	6.0	0.091

Table 5: Table for First Phase. (cont.)

7.	Purchase Price (Cheaper)	7	5.0	0.076
8.	TPI (Toxicity Probability Interval)	8	4.0	0.061
9.	Lamp Replacement for 40,000 hours	9	3.0	0.046
10.	Warm-up time up to 60% light	10	2.0	0.031
11.	Number of cycles on/off	11	1.0	0.015
Total			66	1

2.2) The Second Phase

Next is the second stage, calculating the normalization score from Table 3. The normalization value divides the attribute value by the largest among the available attribute values. The normalization score can be seen in Table 6.

Table 6: Attributes for Second Phase Normalization Results.

Attribute Data	Normalization Score	
	LED	CFL
Usage Period	1.000	0.225
CRI (Color Rendering Index)	1.000	0.975
Contains mercury TOXIC	1.000	0.057
Average weight (grams)	0.337	1.000
Carbon Dioxide Emissions (30 lamps per year)	1.000	0.101
Electricity Bill Fee/Year (based on the use of 1 lamp for 8 hours/day at 900VA power)	1.000	0.399
Purchase Price (Cheaper)	0.010	1.000
TPI (Toxicity Probability Interval)	1.000	0.522
Lamp Replacement for 40,000 hours	1.000	0.001
Warm-up time up to 60% light	1.000	0.025
Number of cycles on/off	1.000	0.200

2.3) The Final Stage

After normalizing, the next step is calculating the final score of the normalized attribute values by multiplying the weight normalization value and attribute normalization value. The final score stage attributes can be seen in Table 7.

Table 7 shows the highest final score is the Type of LED Lamp. Then the system results, the best type of lamp for the user is an LED (Light Emitting Diode). We try to do a manual calculation to validate the result, and the results are the same output as our system. Therefore, the system is declared to have no errors. There is a display of the system calculation results to produce the best choice for the user. There are how many lux needed from the selected room to the best type of lamp. The number of watts the user needs is shown in Figure 5.

2.4) The Final Experiment Results

From experiments conducted based on test scenarios using input options, among others, Base Shape (Square) with Size (Side Length is 200 cm and Room Height is 300 cm), Room Type is (Residential House with Sub Room (Bedroom)), attribute ranking in Table 4 which then uses the Physics Formulas (Lux to Lumen Conversion Formula and Lumen to Watts Conversion Formula) and Simple Additive Weighting method, the results of the optimization decision are obtained, the room requires an LED type of lamp that produces a lumen size of 1000 lm or about 10 watts.

If the parameters of the Base Shape and Room Size of the room are getting bigger, the greater the Lumen requirement will be. In addition, the Lux Requirement of the Room Type also affects the amount of Lumen required for the room. For example, if we changed the shape of the base into a (circle with a diameter of 200cm) and a room height of 300cm, and the type of room is a drawing room, the lumen requirement of the room is 2357 lm. The experiment required 2357 lm, while the first experiment required 1000 lm. This proves that if the parameter value is greater, the lumen requirement will also be greater, and the method used works correctly.

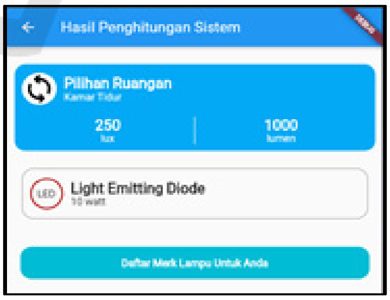

Figure 5: System Calculation Result Display.

Then, the Attribute Rank will generate the weight that is used to get the final score. Here it is found that the final total score will result in a decision on the best alternative from the available alternatives. This system is dynamic toward weights in decision-making so that the weight of each attribute can change at any time by following the rank of the attribute itself.

Table 7: Final Score Stage.

Attribute Data	Final Score	
	LED	**CFL**
Usage Period	0.166	0.037
CRI (Color Rendering Index)	0.152	0.147
Contains mercury TOXIC	0.136	0.007
Average weight (grams)	0.041	0.121
Carbon Dioxide Emissions (30 lamps per year)	0.106	0.011
Electricity Bill Fee/Year (based on the use of 1 lamp for 8 hours/day at 900VA power)	0.091	0.036
Purchase Price (Cheaper)	0.001	0.075
TPI (Toxicity Probability Interval)	0.061	0.031
Lamp Replacement for 40,000 hours	0.045	0.001
Warm-up time up to 60% light	0.031	0.001
Number of cycles on/off	0.0152	0.003
Total	0.844	0.472

5 CONCLUSIONS

Based on the experiments and analyzes that have been carried out, the following conclusions can be drawn. From experiments conducted based on test scenarios using input options, among others, Base Shape (Square) with Size (Side Length is 200 cm and Room Height is 300 cm), Room Type is (Residential House with Sub Room (Bedroom)), attribute ranking in table 4 which then uses the Physics Formulas (Lux to Lumen Conversion Formula and Lumen to Watts Conversion Formula) and Simple Additive Weighting method, the results of the optimization decision are obtained, the room requires an LED type of lamp that produces a lumen size of 1000 lm or about 10 watts. This proves that if the parameter value is greater, the lumen requirement will also be greater and the method used also works correctly. The final total score will result in a decision on the best alternative from the available alternatives. So it can be concluded that the SAW method is a decision support system in solving various multi-criteria decision-making problems. It can also be used as a decision support system for optimizing lighting needs in the room. With this decision support system, it is hoped that it can help the community choose the lighting needs in the desired room.

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