Recognizing the Situations and Supporting the Decision-Making in the Residential Luminosity Control Subsystem of «Smart House» Cyber-Physical System

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Abstract

Currently, the urgent problem is to ensure the ability of recognizing the situations and supporting the decision-making in the «Smart House» cyber-physical system. The purpose of this study is recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system. The developed in this paper method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room allows to enter the necessary parameters for further automatic operation of the residential luminosity control subsystem of «Smart House» cyber-physical system. The developed method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system provides the user of the subsystem with the ability to quickly and conveniently configure the necessary lighting mode. In addition, the developed method provides for the recognition of various situations in the lighting scenario (sufficient light flow, insufficient light flow, excess light flow – according to the current lighting standards) and support for decision-making regarding the lighting of the home according to the lighting mode set by the user (reflecting/closing shading devices, turning on/off the lamps – depending on the recognized situation).

Keywords

Recognizing the situations, supporting the decision-making, cyber-physical system "Smart House", the residential luminosity control subsystem, luminosity, luminous flux.

1. Introduction

The "Smart House" cyber-physical system is a modern home, organized using high-tech devices that integrate with each other with minimal expenditure of money and time and form an intelligent management system of all engineering networks of the house in order to ensure comfortable living conditions for residents in the premises and to significantly reduce costs energy carriers [1-3].

Such a cyber-physical system demonstrates a progressive concept of human interaction with housing, as it performs automated management of the parameters of all engineering systems in accordance with current external and internal conditions, performs numerous operations under many scenarios [4, 5].

The "Smart House" cyber-physical system consists of five main subsystems [4]:

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1. housing microclimate management subsystem
2. residential luminosity control subsystem
3. housing security management subsystem
4. multimedia control subsystem
5. home appliances and power grid control subsystem

The "Smart House" cyber-physical system should be equipped with an intuitive control and management interface so as not to require deep knowledge of computer engineering and programming from home owners, and should also be able to recognize situations (planned or emergency) and to correctly respond to them (to make correct decisions in one or another situation) [6]. Decision-making is, first of all, the ability to choose the correct solution from among alternative options for solving a situation or problem that arose during the operation of the system. Any choice is always associated with certain difficulties (for example, with insufficient information when forming alternative decision options) [7-12].

So, currently, *the urgent problem* is to ensure the ability of recognizing the situations and supporting the decision-making in the «Smart House» cyber-physical system.

2. Survey of Research

Let's conduct a survey of research of known solutions for recognizing the situations and supporting the decision-making in the "Smart House" cyber-physical system.

From the point of view of the purpose and functions of the "Smart House" cyber-physical system, we are interested in whether known solutions provide situation recognition and decision-making support in the process of managing the microclimate of the home – *criterion 1*; whether known solutions provide recognition of situations and decision-making support in the process of residential luminosity control – *criterion 2*; whether known solutions provide recognition of situations and decision-making support in the process of managing the housing security – *criterion 3*; whether known solutions provide recognition of situations and decision-making support in the multimedia control process – *criterion 4*; whether known solutions provide recognition of situations and support for decision-making in the process of control of the home appliances and the power grid – *criterion 5*.

Let's summarize the results of the survey of known solutions for recognizing the situations and supporting the decision-making in the "Smart House" cyber-physical system in terms of their satisfaction of the above criteria – Table 1.

Table 1

Survey of research of known solutions for recognizing the situations and supporting the decision-making in the "Smart House" cyber-physical system

Known decision	1	2	3	4	5
Use of fuzzy logic algorithms for determination of the comfort in the "Smart House" from the point of view of the temperature regime [13]	+				
Neural network-driven rolling-horizon optimization model, dedicated to efficiently utilizing the solar power and optimizing the battery energy storage operations in "Smart House" [14]	+				+
House energy management strategy dedicated to optimization and lower the cost of electricity, and customer satisfaction [15]		+			+
Smart Apartment Building model dedicated to reducing the carbon emissions and operation costs [16]					+
Using the fuzzy logic for the effective selection of the rules for decision-making about the control in humidity and temperature [17]	+				
OTP-based door opening system using Arduino and GSM with generation of the one-time password on mobile phone [18]			+		
Internet-of-Things-based indoor, environmental, comfortable and real-time monitoring system for the Smart House intended to the humidity and temperature measurement and the to the luminosity measurement [19]	+	+			

Using the machine learning algorithms for tracking the electrical use for detecting the presence/absence of people in the Smart House [20]			+		
Full state feedback and feed forward control method for determining the best control of the smart window systems for improving the luminosity and air circulation [21]	+	+			
Internet-of-Things-based smart kitchen system on the Arduino board with automatic detection of the humidity level, temperature, with built-in gas detection sensors for remotely control of household appliances [22]	+			+	+
Emergy-based methodological approach for reducing the energy consumption and environmental impacts of Smart House systems [23]					+
ESP-Mesh-based smart house system with 3 different nodes – humidity and temperature sensors, mechanical (door lock), electrical (generic power switch, fan, power plug) [24]	+		+		+
Data driven method for increasing the accurate of the indirect heat accounting in apartment smart buildings [25]	+				
Embedded components-based method and TOPPERS Embedded-Component System for improving the efficiency and scalability of smart houses' electrical equipment [26]					+
Voice-activated house automation system on the basis of Natural Language Processing, Artificial Intelligence, Blockchain, Internet of Things designed to cost-effective interaction of the household appliances [27]					+
Method of optimal energy consumption in the smart houses taking into account the electrical grids' techno-economic indices [28]	+				+
Internet-of-Things-based system for control cooling and\or heating in the smart residential housing [29]	+				
Smartphone controlled smart house with advanced system for monitoring the humidity control and temperature control [30]	+				

The conducted survey of research showed that: known solutions provide for situation recognition and decision-making support only, as a rule, for one or two subsystems of the "Smart House" cyber-physical system, and also do not provide for the possibility of assessing the sufficiency of information for decision-making in the "Smart House" cyber-physical system house". Therefore, *the goal of our overall research* is recognizing the situations and supporting the decision-making for all 5 subsystems of the «Smart House» cyber-physical system, with an assessment of the sufficiency of information for all decisions by developing a comprehensive situation recognition and decision support system in the «Smart House» cyber-physical system, and *the purpose of this study* is recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system.

3. Recognizing the Situations and Supporting the Decision-Making in the Residential Luminosity Control Subsystem of «Smart House» Cyber-Physical System

The residential luminosity control subsystem of «Smart House» cyber-physical system (Figure 1) controls the following types of lighting: natural (adjustment of the position of blinds and rollers shutters, mechanical opening/closing of curtains), artificial (adjustment of brightness and number of lighting devices depending on weather conditions, time of day, the type of activity of the residents at this moment), creating light scenarios that provide optimal lighting for a particular situation.

Figure 1: Example of functioning the residential luminosity control subsystem of «Smart House» cyber-physical system

Correct lighting is extremely important, because the amount of light can affect the atmosphere in the room: create a mood for work and active brain activity or, on the contrary, adjust for relaxation and sleep. Even well-being depends on the level of illumination. A cozy atmosphere at home or a well-lit work area in the office are created by determining the coefficient of use of the light flux and the correct calculation of the luminosity of the room. It is worth concentrating your attention for the goal – to create high-quality working conditions or to provide comfort for relaxation – before moving on to the organization of room lighting.

Method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room:

1. selection by the subsystem's user of the room type (kitchen; living room; children's room/bedroom; office/working cabinet; bathroom/corridor)
2. if the subsystem's user has chosen the "kitchen" room type, then *tr=1*
3. if the subsystem's user has chosen the room type "living room", then *tr=2*
4. if the subsystem's user has chosen the room type "children's room/bedroom", then *tr=3*
5. if the subsystem's user has chosen the type of room "working cabinet", then *tr=4*
6. if the subsystem's user has chosen the room type "bathroom/corridor", then *tr=5*
7. selection by the subsystem's user of the ceiling height interval of the room (2.5-2.7 m; 2.7-3 m; 3-3.5 m; 3.5-4.5 m)
8. if the subsystem's user has chosen the ceiling height interval of the room "2.5-2.7 m", then *chi=1*
9. if the subsystem's user has chosen the ceiling height interval of the room "2.7-3 m", then *chi=2*
10. if the subsystem's user has chosen the ceiling height interval of the room "3-3.5 m", then *chi=3*
11. if the subsystem's user has chosen the ceiling height interval of the room "3.5-4.5 m", then *chi=4*
12. input by the subsystem's user of the value of the area of the room (in m^2) – the entered value is assigned to the variable *S*
13. selection by the subsystem's user of the type of lamps used in the room (LED, energy-saving, halogen, incandescent lamps)
14. if the subsystem's user has chosen the "LED" type of used in the room lamps, then *trl=1*
15. if the subsystem's user has chosen the "energy-saving" type of used in the room lamps, then *trl=2*
16. if the subsystem's user has chosen the "halogen" type of used in the room lamps, then *trl=3*

17. if the subsystem's user has chosen the "incandescent lamps" type of used in the room lamps, then, then *trl=4*
18. input by the subsystem's user of the power value of one used lamp (in W) – the entered value is assigned to the variable *Pl*
19. input by the subsystem's user of the number of lamps used in the room – the entered value is assigned to the variable *ak*
20. selection by the subsystem's user of shading devices available in the room (blinds, roller shutters, curtains; let's assume that one of the shading devices is used or none of these devices are used)
21. if the subsystem's user has chosen “no shading devices are used”, then *asd=0*
22. if the subsystem's user has chosen the available in the room shading device "blinds", then *asd=1*
23. if the subsystem's user has chosen the available in the room shading device "roller shutters", then *asd=2*
24. if the subsystem's user has chosen the available in the room shading device "curtains", the *asd=3*
25. delection of the subsystem's user the start room lighting mode (activity, relaxation, sleep) – the user can change the room lighting mode at any time
26. if the subsystem's user has chosen the room lighting mode "activity", the *rlm=1*
27. if the subsystem's user has chosen the room lighting mode "relax", then *rlm=2*
28. if the subsystem's user has chosen the room lighting mode "sleep", then *rlm=3*

The developed method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room allows to enter the necessary parameters for further automatic operation of the residential luminosity control subsystem of «Smart House» cyber-physical system.

Luminosity is a physical-optical quantity that characterizes the ratio of the light flux to the surface area over which it spreads. The standard values of the luminosity for different types of rooms: standard of luminosity of the kitchen – 150 lux, living room – 450 lux, children's room/bedroom – 200 lux, working cabinet/office – 300 lux, bathroom/corridor – 50-75 lux.

The room luminosity can be calculated using the formula:

$$E = \Phi/S, \quad (1)$$

where Φ – luminous flux, S – illuminated area.

Then the luminous flux will be determined by the formula:

$$\Phi = E * S. \quad (2)$$

For calculation of the luminous flux, it is important to take into account the height of the ceiling in the room, then the luminous flux will be determined by the formula:

$$\Phi = E * S * K_c, \quad (3)$$

where K_c – the ceiling height factor (K_c=1 for ceiling heights from 2.5 to 2.7 m; K_c=1.2 for ceiling heights from 2.7 to 3 m; K_c=1.5 for ceiling heights from 3 to 3.5 m; K_c=2 for ceiling heights from 3.5 to 4.5 m).

Let, we need to calculate the necessary light flux for a kitchen with an area of 12 m2 with a ceiling height of 2.5 m:

$$\Phi_k = 150 * S * 1 = 150 * S = 150 * 12 = 1800\ (lumens).$$

Similarly, let's calculate the value of the required (according to standards) luminous flux for rooms of different types with different ceiling heights – Table 2.

Since different lamps emit light of different strengths, their power depends on the type of the used lamp – LED (75 lumens per 1 W), energy-saving (47 lumens per 1 W), halogen (15 lumens per 1 W) or incandescent lamps (12 lumens per 1 W). The required total power provided by different types of lamps for different types of rooms in order to create a normal light flux is presented in Tables 3-6.

Table 2

Calculation of normal luminous flux (*Ф*) for rooms of different types with different ceiling heights (lumens, Lm)

Type of room	The ceiling height from 2.5 to 2.7 m (*chi=1*)	The ceiling height from 2.7 to 3 m (*chi=2*)	The ceiling height from 3 to 3.5 м (*chi=3*)	The ceiling height from 3.5 to 4.5 м (*chi=4*)
Kitchen (*tr=1*)	$150 * S$ (Lm)	$180 * S$	$225 * S$	$300 * S$
Living room (*tr=2*)	$450 * S$	$540 * S$	$675 * S$	$900 * S$
Children's room/bedroom (*tr=3*)	$200 * S$	$240 * S$	$300 * S$	$400 * S$
Working cabinet/office (*tr=4*)	$300 * S$	$360 * S$	$450 * S$	$600 * S$
Bathroom/corridor (*tr=5*)	$75 * S$	$90 * S$	$112.5 * S$	$150 * S$

Table 3

Calculation of the total power (*P*) of LED lamps (*trl=1*) for creation of the normal luminous flux for rooms of different types with different ceiling heights (Вт)

Type of room	The ceiling height from 2.5 to 2.7 m (*chi=1*)	The ceiling height from 2.7 to 3 m (*chi=2*)	The ceiling height from 3 to 3.5 м (*chi=3*)	The ceiling height from 3.5 to 4.5 м (*chi=4*)
Kitchen (*tr=1*)	$\frac{(150 * S)}{75} = 2 * S$ (W)	$2.4 * S$	$3 * S$	$4 * S$
Living room (*tr=2*)	$6 * S$	$7.2 * S$	$9 * S$	$12 * S$
Children's room/bedroom (*tr=3*)	$2.67 * S$	$3.2 * S$	$4 * S$	$5.33 * S$
Working cabinet/office (*tr=4*)	$4 * S$	$4.8 * S$	$6 * S$	$8 * S$
Bathroom/corridor (*tr=5*)	S	$1.2 * S$	$1.5 * S$	$2 * S$

Table 4

Calculation of the total power (*P*) of the energy-saving lamps (*trl=2*) for creation of the normal luminous flux for rooms of different types with different ceiling heights

Type of room	The ceiling height from 2.5 to 2.7 m (*chi=1*)	The ceiling height from 2.7 to 3 m (*chi=2*)	The ceiling height from 3 to 3.5 м (*chi=3*)	The ceiling height from 3.5 to 4.5 м (*chi=4*)
Kitchen (*tr=1*)	$\frac{(150 * S)}{47} = 3.2 * S$ (W)	$3.83 * S$	$4.79 * S$	$6.39 * S$
Living room (*tr=2*)	$9.58 * S$	$11.49 * S$	$14.37 * S$	$19.15 * S$
Children's room/bedroom (*tr=3*)	$4.26 * S$	$5.11 * S$	$6.39 * S$	$8.52 * S$
Working cabinet/office (*tr=4*)	$6.39 * S$	$7.66 * S$	$9.58 * S$	$12.77 * S$
Bathroom/corridor (*tr=5*)	$1.6 * S$	$1.92 * S$	$2.4 * S$	$3.2 * S$

Table 5

Calculation of the total power (*P*) of the halogen lamps (*trl=3*) for creation of the normal luminous flux for rooms of different types with different ceiling heights

Type of room	The ceiling height from 2.5 to 2.7 m (*chi=1*)	The ceiling height from 2.7 to 3 m (*chi=2*)	The ceiling height from 3 to 3.5 м (*chi=3*)	The ceiling height from 3.5 to 4.5 м (*chi=4*)
Kitchen (*tr=1*)	$\frac{(150 * S)}{15} = 10 * S$ (W)	$12 * S$	$15 * S$	$20 * S$
Living room (*tr=2*)	$30 * S$	$36 * S$	$45 * S$	$60 * S$
Children's room/bedroom (*tr=3*)	$13.34 * S$	$16 * S$	$20 * S$	$26.67 * S$
Working cabinet/office (*tr=4*)	$20 * S$	$24 * S$	$30 * S$	$40 * S$
Bathroom/corridor (*tr=5*)	$5 * S$	$6 * S$	$7.5 * S$	$10 * S$

Table 6

Calculation of the total power (*P*) of the incandescent lamps (*trl=4*) for creation of the normal luminous flux for rooms of different types with different ceiling heights

Type of room	The ceiling height from 2.5 to 2.7 m (*chi=1*)	The ceiling height from 2.7 to 3 m (*chi=2*)	The ceiling height from 3 to 3.5 м (*chi=3*)	The ceiling height from 3.5 to 4.5 м (*chi=4*)
Kitchen (*tr=1*)	$\frac{(150 * S)}{12} = 12.5 * S$ (W)	$15 * S$	$18.75 * S$	$25 * S$
Living room (*tr=2*)	$37.5 * S$	$45 * S$	$56.25 * S$	$75 * S$
Children's room/bedroom (*tr=3*)	$16.67 * S$	$20 * S$	$25 * S$	$33.34 * S$
Working cabinet/office (*tr=4*)	$25 * S$	$30 * S$	$37.5 * S$	$50 * S$
Bathroom/corridor (*tr=5*)	$6.25 * S$	$7.5 * S$	$9.38 * S$	$12.5 * S$

In general, recognizing the situations and decision-making consists of the following steps:

1. determination of the aim (goal) and means of its achievement
2. formation of options for achieving the goal (set of alternatives)
3. evaluation of alternatives in order to choose the best alternative(s)

For the residential luminosity control subsystem of «Smart House» cyber-physical system, the aim (goal) of recognizing the situations and making the decisions is ensuring the comfortable conditions depending on the type of user's activity at the current moment (for example, to create high-quality work/activity conditions or to provide comfort for relaxation or sleep). Means of achieving the goal in this case can be blinds, rollers shutters, curtains, lighting lamps.

When the user has chosen the goal (the required lighting mode are: "activity" (*rlm=1*; when the user chooses this mode, the residential luminosity control subsystem of «Smart House» cyber-physical system must ensure the normal value of the luminous flux in the room specified in Table 2), "relax" (*rlm=2*; when the user selects this mode, the residential luminosity control subsystem of «Smart House» cyber-physical system must provide half of the normal value of the luminous flux in the room specified in Table 2), "sleep" (*rlm=3*; when the user chooses this mode, the residential luminosity control subsystem of «Smart House» cyber-physical system should ensure the absence of light flow in the room)), then the residential luminosity control subsystem of «Smart House» cyber-physical system should form a set of alternatives (scenarios) using natural and artificial lighting, which provide optimal luminosity for a particular situation.

The set of possible alternatives (scenarios) is formed according to Table 2 and has the following form:

$$SCP = \{scp_1, \dots, scp_{121}\}, \quad (4)$$

where scp_1 – if *rlm=1* and *tr=1* and *chi=1* and $\Phi=150*S$, then the available luminosity is sufficient; scp_2 – if *rlm=1* and *tr=1* and *chi=1* and $\Phi>150*S$, then there is excess luminosity; scp_3 – if *rlm=1* and *tr=1* and *chi=1* and $\Phi<150*S$, then the available luminosity is insufficient; scp_4 – if *rlm=1* and *tr=1* and *chi=2* and $\Phi=180*S$, then the available luminosity is sufficient; scp_5 – if *rlm=1* and *tr=1* and *chi=2* and $\Phi>180*S$, then there is excess luminosity; scp_6 – if *rlm=1* and *tr=1* and *chi=2* and $\Phi<180*S$, then the available luminosity is insufficient; scp_7 – if *rlm=1* and *tr=1* and *chi=3* and $\Phi=225*S$, then the available luminosity is sufficient; scp_8 – if *rlm=1* and *tr=1* and *chi=3* and $\Phi>225*S$, then there is excess luminosity; scp_9 – if *rlm=1* and *tr=1* and *chi=3* and $\Phi<225*S$, then the available luminosity is insufficient; scp_{10} – if *rlm=1* and *tr=1* and *chi=4* and $\Phi=300*S$, then the available luminosity is sufficient; scp_{11} – if *rlm=1* and *tr=1* and *chi=4* and $\Phi>300*S$, then there is excess luminosity; scp_{12} – if *rlm=1* and *tr=1* and *chi=4* and $\Phi<300*S$, then the available luminosity is insufficient; scp_{13} – if *rlm=1* and *tr=2* and *chi=1* and $\Phi=450*S$, then the available luminosity is sufficient; scp_{14} – if *rlm=1* and *tr=2* and *chi=1* and $\Phi>450*S$, then there is excess luminosity; scp_{15} – if *rlm=1* and *tr=2* and *chi=1* and $\Phi<450*S$, then the available luminosity is insufficient; scp_{16} – if *rlm=1* and *tr=2* and *chi=2* and $\Phi=540*S$, then the available luminosity is sufficient; scp_{17} – if *rlm=1* and *tr=2* and *chi=2* and $\Phi>540*S$, then there is excess luminosity; scp_{18} – if *rlm=1* and *tr=2* and *chi=2* and $\Phi<540*S$, then the available luminosity is insufficient; scp_{19} – if *rlm=1* and *tr=2* and *chi=3* and $\Phi=675*S$, then the available luminosity is sufficient; scp_{20} – if *rlm=1* and *tr=2* and *chi=3* and $\Phi>675*S$, then there is excess luminosity; scp_{21} – if *rlm=1* and *tr=2* and *chi=3* and $\Phi<675*S$, then the available luminosity is insufficient; scp_{22} – if *rlm=1* and *tr=2* and *chi=4* and $\Phi=900*S$, then the available luminosity is sufficient; scp_{23} – if *rlm=1* and *tr=2* and *chi=4* and $\Phi>900*S$, then there is excess luminosity; scp_{24} – if *rlm=1* and *tr=2* and *chi=4* and $\Phi<900*S$, then the available luminosity is insufficient; scp_{25} – if *rlm=1* and *tr=3* and *chi=1* and $\Phi=200*S$, then the available luminosity is sufficient; scp_{26} – if *rlm=1* and *tr=3* and *chi=1* and $\Phi>200*S$, then there is excess luminosity; scp_{27} – if *rlm=1* and *tr=3* and *chi=1* and $\Phi<200*S$, then the available luminosity is insufficient; scp_{28} – if *rlm=1* and *tr=3* and *chi=2* and $\Phi=240*S$, then the available luminosity is sufficient; scp_{29} – if *rlm=1* and *tr=3* and *chi=2* and $\Phi>240*S$ then there is excess luminosity; scp_{30} – if *rlm=1* and *tr=3* and *chi=2* and $\Phi<240*S$, then the available luminosity is insufficient; scp_{31} – if *rlm=1* and *tr=3* and *chi=3* and $\Phi=300*S$, then the available luminosity is sufficient; scp_{32} – if *rlm=1* and *tr=3* and *chi=3* and $\Phi>300*S$, then there is excess luminosity; scp_{33} – if *rlm=1* and *tr=3* and *chi=3* and $\Phi<300*S$, then the available luminosity is insufficient; scp_{34} – if *rlm=1* and *tr=3* and *chi=4* and $\Phi=400*S$, then the available luminosity is sufficient; scp_{35} – if *rlm=1* and *tr=3* and *chi=4* and $\Phi>400*S$, then there is excess luminosity; scp_{36} – if *rlm=1* and *tr=3* and *chi=4* and $\Phi<400*S$, then the available luminosity is insufficient; scp_{37} – if *rlm=1* and *tr=4* and *chi=1* and $\Phi=300*S$, then the available luminosity is sufficient; scp_{38} – if *rlm=1* and *tr=4* and *chi=1* and $\Phi>300*S$, then there is excess luminosity; scp_{39} – if *rlm=1* and *tr=4* and *chi=1* and $\Phi<300*S$, then the available luminosity is insufficient; scp_{40} – if *rlm=1* and *tr=4* and *chi=2* and $\Phi=360*S$, then the available luminosity is sufficient; scp_{41} – if *rlm=1* and *tr=4* and *chi=2* and $\Phi>360*S$, then there is excess luminosity; scp_{42} – if *rlm=1* and *tr=4* and *chi=2* and $\Phi<360*S$, then the available luminosity is insufficient; scp_{43} – if *rlm=1* and *tr=4* and *chi=3* and $\Phi=450*S$, then the available luminosity is sufficient; scp_{44} – if *rlm=1* and *tr=4* and *chi=3* and $\Phi>450*S$, then there is excess luminosity; scp_{45} – if *rlm=1* and *tr=4* and *chi=3* and $\Phi<450*S$, then the available luminosity is insufficient; scp_{46} – if *rlm=1* and *tr=4* and *chi=4* and $\Phi=600*S$, then the available luminosity is sufficient; scp_{47} – if *rlm=1* and *tr=4* and *chi=4* and $\Phi>600*S$, then there is excess luminosity; scp_{48} – if *rlm=1* and *tr=4* and *chi=4* and $\Phi<600*S$, then the available luminosity is insufficient; scp_{49} – if *rlm=1* and *tr=5* and *chi=1* and $\Phi=75*S$, then the available luminosity is sufficient; scp_{50} – if *rlm=1* and *tr=5* and *chi=1* and $\Phi>75*S$, then there is excess luminosity; scp_{51} – if *rlm=1* and *tr=5* and *chi=1* and $\Phi<75*S$, then the available luminosity is insufficient; scp_{52} – if *rlm=1* and *tr=5* and *chi=2* and $\Phi=90*S$, then the available luminosity is sufficient; scp_{53} – if *rlm=1* and *tr=5* and *chi=2* and $\Phi>90*S$, then there is excess luminosity; scp_{54} – if *rlm=1* and *tr=5* and *chi=2* and $\Phi<90*S$, then the available luminosity is insufficient; scp_{55} – if *rlm=1* and *tr=5* and *chi=3* and $\Phi=112.5*S$, then the available luminosity is sufficient; scp_{56} – if *rlm=1* and *tr=5* and *chi=3* and $\Phi>112.5*S$, then there is excess luminosity; scp_{57} – if *rlm=1* and *tr=5* and *chi=3* and $\Phi<112.5*S$, then the available luminosity is insufficient; scp_{58} – if *rlm=1* and *tr=5* and *chi=4* and $\Phi=150*S$, then the available luminosity is sufficient; scp_{59} – if *rlm=1* and *tr=5* and *chi=4* and $\Phi>150*S$, then there is excess luminosity; scp_{60} – if *rlm=1* and *tr=5* and *chi=4* and $\Phi<150*S$, then the available luminosity is insufficient; scp_{61} – if *rlm=2* and *tr=1* and *chi=1* and $\Phi=75*S$, then the available luminosity is sufficient; scp_{62} – if *rlm=2* and *tr=1* and *chi=1* and $\Phi>75*S$,

then there is excess luminosity; scp_{63} – if *rlm=2* and *tr=1* and *chi=1* and $\Phi<75*S$, then the available luminosity is insufficient; scp_{64} – if *rlm=2* and *tr=1* and *chi=2* and $\Phi=90*S$, then the available luminosity is sufficient; scp_{65} – if *rlm=2* and *tr=1* and *chi=2* and $\Phi>90*S$, then there is excess luminosity; scp_{66} – if *rlm=2* and *tr=1* and *chi=2* and $\Phi<90*S$, then the available luminosity is insufficient; scp_{67} – if *rlm=2* and *tr=1* and *chi=3* and $\Phi=112.5*S$, then the available luminosity is sufficient; scp_{68} – if *rlm=2* and *tr=1* and *chi=3* and $\Phi>112.5*S$, then there is excess luminosity; scp_{69} – if *rlm=2* and *tr=1* and *chi=3* and $\Phi<112.5*S$, then the available luminosity is insufficient; scp_{70} – if *rlm=2* and *tr=1* and *chi=4* and $\Phi=150*S$, then the available luminosity is sufficient; scp_{71} – if *rlm=2* and *tr=1* and *chi=4* and $\Phi>150*S$, then there is excess luminosity; scp_{72} – if *rlm=2* and *tr=1* and *chi=4* and $\Phi<150*S$, then the available luminosity is insufficient; scp_{73} – if *rlm=2* and *tr=2* and *chi=1* and $\Phi=225*S$, then the available luminosity is sufficient; scp_{74} – if *rlm=2* and *tr=2* and *chi=1* and $\Phi>225*S$, then there is excess luminosity; scp_{75} – if *rlm=2* and *tr=2* and *chi=1* and $\Phi<225*S$, then the available luminosity is insufficient; scp_{76} – if *rlm=2* and *tr=2* and *chi=2* and $\Phi=270*S$, then the available luminosity is sufficient; scp_{77} – if *rlm=2* and *tr=2* and *chi=2* and $\Phi>270*S$, then there is excess luminosity; scp_{78} – if *rlm=2* and *tr=2* and *chi=2* and $\Phi<270*S$, then the available luminosity is insufficient; scp_{79} – if *rlm=2* and *tr=2* and *chi=3* and $\Phi=337.5*S$, then the available luminosity is sufficient; scp_{80} – if *rlm=2* and *tr=2* and *chi=3* and $\Phi>337.5*S$, then there is excess luminosity; scp_{81} – if *rlm=2* and *tr=2* and *chi=3* and $\Phi<337.5*S$, then the available luminosity is insufficient; scp_{82} – if *rlm=2* and *tr=2* and *chi=4* and $\Phi=450*S$, then the available luminosity is sufficient; scp_{83} – if *rlm=2* and *tr=2* and *chi=4* and $\Phi>450*S$, then there is excess luminosity; scp_{84} – if *rlm=2* and *tr=2* and *chi=4* and $\Phi<450*S$, then the available luminosity is insufficient; scp_{85} – if *rlm=2* and *tr=3* and *chi=1* and $\Phi=100*S$, then the available luminosity is sufficient; scp_{86} – if *rlm=2* and *tr=3* and *chi=1* and $\Phi>100*S$, then there is excess luminosity; scp_{87} – if *rlm=2* and *tr=3* and *chi=1* and $\Phi<100*S$, then the available luminosity is insufficient; scp_{88} – if *rlm=2* and *tr=3* and *chi=2* and $\Phi=120*S$, then the available luminosity is sufficient; scp_{89} – if *rlm=2* and *tr=3* and *chi=2* and $\Phi>120*S$, then there is excess luminosity; scp_{90} – if *rlm=2* and *tr=3* and *chi=2* and $\Phi<120*S$, then the available luminosity is insufficient; scp_{91} – if *rlm=2* and *tr=3* and *chi=3* and $\Phi=150*S$, then the available luminosity is sufficient; scp_{92} – if *rlm=2* and *tr=3* and *chi=3* and $\Phi>150*S$, then there is excess luminosity; scp_{93} – if *rlm=2* and *tr=3* and *chi=3* and $\Phi<150*S$, then the available luminosity is insufficient; scp_{94} – if *rlm=2* and *tr=3* and *chi=4* and $\Phi=200*S$, then the available luminosity is sufficient; scp_{95} – if *rlm=2* and *tr=3* and *chi=4* and $\Phi>200*S$, then there is excess luminosity; scp_{96} – if *rlm=2* and *tr=3* and *chi=4* and $\Phi<200*S$, then the available luminosity is insufficient; scp_{97} – if *rlm=2* and *tr=4* and *chi=1* and $\Phi=150*S$, then the available luminosity is sufficient; scp_{98} – if *rlm=2* and *tr=4* and *chi=1* and $\Phi>150*S$, then there is excess luminosity; scp_{99} – if *rlm=2* and *tr=4* and *chi=1* and $\Phi<150*S$, then the available luminosity is insufficient; scp_{100} – if *rlm=2* and *tr=4* and *chi=2* and $\Phi=180*S$, then the available luminosity is sufficient; scp_{101} – if *rlm=2* and *tr=4* and *chi=2* and $\Phi>180*S$, then there is excess luminosity; scp_{102} – if *rlm=2* and *tr=4* and *chi=2* and $\Phi<180*S$, then the available luminosity is insufficient; scp_{103} – if *rlm=2* and *tr=4* and *chi=3* and $\Phi=225*S$, then the available luminosity is sufficient; scp_{104} – if *rlm=2* and *tr=4* and *chi=3* and $\Phi>225*S$, then there is excess luminosity; scp_{105} – if *rlm=2* and *tr=4* and *chi=3* and $\Phi<225*S$, then the available luminosity is insufficient; scp_{106} – if *rlm=2* and *tr=4* and *chi=4* and $\Phi=300*S$, then the available luminosity is sufficient; scp_{107} – if *rlm=2* and *tr=4* and *chi=4* and $\Phi>300*S$, then there is excess luminosity; scp_{108} – if *rlm=2* and *tr=4* and *chi=4* and $\Phi<300*S$, then the available luminosity is insufficient; scp_{109} – if *rlm=2* and *tr=5* and *chi=1* and $\Phi=37.5*S$, then the available luminosity is sufficient; scp_{110} – if *rlm=2* and *tr=5* and *chi=1* and $\Phi>37.5*S$, then there is excess luminosity; scp_{111} – if *rlm=2* and *tr=5* and *chi=1* and $\Phi<37.5*S$, then the available luminosity is insufficient; scp_{112} – if *rlm=2* and *tr=5* and *chi=2* and $\Phi=45*S$, then the available luminosity is sufficient; scp_{113} – if *rlm=2* and *tr=5* and *chi=2* and $\Phi>45*S$, then there is excess luminosity; scp_{114} – if *rlm=2* and *tr=5* and *chi=2* and $\Phi<45*S$, then the available luminosity is insufficient; scp_{115} – if *rlm=2* and *tr=5* and *chi=3* and $\Phi=56.25*S$, then the available luminosity is sufficient; scp_{116} – if *rlm=2* and *tr=5* and *chi=3* and $\Phi>56.25*S$, then there is excess luminosity; scp_{117} – if *rlm=2* and *tr=5* and *chi=3* and $\Phi<56.25*S$, then the available luminosity is insufficient; scp_{118} – if *rlm=2* and *tr=5* and *chi=4* and $\Phi=75*S$, then the available luminosity is sufficient; scp_{119} – if *rlm=2* and *tr=5* and *chi=4* and $\Phi>75*S$, then there is excess luminosity; scp_{120} – if *rlm=2* and *tr=5* and *chi=4* and $\Phi<75*S$, then the available luminosity is insufficient; scp_{121} – if *rlm=3* and (*tr=1* or *tr=2* or *tr=3* or *tr=4* or *tr=5)* and (*chi=1* or *chi=2* or *chi=3* or *chi=4)* and $\Phi>0$, then there is excess luminosity.

The set of possible alternatives (scenarios) represented by formula (4) consists of three subsets:

$$SCP = \{SCPS, SCPE, SCPIS\}, \quad (5)$$

where $SCPS=\{scp_1, scp_4, scp_7, scp_{10}, scp_{13}, scp_{16}, scp_{19}, scp_{22}, scp_{25}, scp_{28}, scp_{31}, scp_{34}, scp_{37}, scp_{40}, scp_{43}, scp_{46}, scp_{49}, scp_{52}, scp_{55}, scp_{58}, scp_{61}, scp_{64}, scp_{67}, scp_{70}, scp_{73}, scp_{76}, scp_{79}, scp_{82}, scp_{85}, scp_{88}, scp_{91}, scp_{94}, scp_{97}, scp_{100}, scp_{103}, scp_{106}, scp_{109}, scp_{112}, scp_{115}, scp_{118}\}$ – subset of scenarios with sufficient luminosity level; $SCPE=\{scp_2, scp_5, scp_8, scp_{11}, scp_{14}, scp_{17}, scp_{20}, scp_{23}, scp_{26}, scp_{29}, scp_{32}, scp_{35}, scp_{38}, scp_{41}, scp_{44}, scp_{47}, scp_{50}, scp_{53}, scp_{56}, scp_{59}, scp_{62}, scp_{65}, scp_{68}, scp_{71}, scp_{74}, scp_{77}, scp_{80}, scp_{83}, scp_{86}, scp_{89}, scp_{92}, scp_{95}, scp_{98}, scp_{101}, scp_{104}, scp_{107}, scp_{110}, scp_{113}, scp_{116}, scp_{119}, scp_{121}\}$ – subset of scenarios with excessive luminosity level; $SCPIS=\{scp_3, scp_6, scp_9, scp_{12}, scp_{15}, scp_{18}, scp_{21}, scp_{24}, scp_{27}, scp_{30}, scp_{33}, scp_{36}, scp_{39}, scp_{42}, scp_{45}, scp_{48}, scp_{51}, scp_{54}, scp_{57}, scp_{60}, scp_{63}, scp_{66}, scp_{69}, scp_{72}, scp_{75}, scp_{78}, scp_{81}, scp_{84}, scp_{87}, scp_{90}, scp_{93}, scp_{96}, scp_{99}, scp_{102}, scp_{105}, scp_{108}, scp_{111}, scp_{114}, scp_{117}, scp_{120}\}$ – subset of scenarios with insufficient luminosity level.

The set of scenarios for calculating the number of additional lamps that must be turned on to ensure the required level of luminosity is formed according to Tables 3-6 and has the following form:

$$SCAL = \{scal_1, \dots, scal_{160}\}, \quad (6)$$

where $scal_1$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=1* and $(\Phi/75)<(2*S)$, then $k = \left\lceil \frac{2*S-\Phi/75}{Pl} \right\rceil$; $scal_2$ – if *rlm=1* and *trl=1* and *tr=1* та *chi=2* and $(\Phi/75)<(2.4*S)$, then $k = \left\lceil \frac{2.4*S-\Phi/75}{Pl} \right\rceil$; $scal_3$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=3* and $(\Phi/75)<(3*S)$, then $k = \left\lceil \frac{3*S-\Phi/75}{Pl} \right\rceil$; $scal_4$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=4* and $(\Phi/75)<(4*S)$, then $k = \left\lceil \frac{4*S-\Phi/75}{Pl} \right\rceil$; $scal_5$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=1* and $(\Phi/75)<(6*S)$, then $k = \left\lceil \frac{6*S-\Phi/75}{Pl} \right\rceil$; $scal_6$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=2* and $(\Phi/75)<(7.2*S)$, then $k = \left\lceil \frac{7.2*S-\Phi/75}{Pl} \right\rceil$; $scal_7$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=3* and $(\Phi/75)<(9*S)$, then $k = \left\lceil \frac{9*S-\Phi/75}{Pl} \right\rceil$; $scal_8$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=4* and $(\Phi/75)<(12*S)$, then $k = \left\lceil \frac{12*S-\Phi/75}{Pl} \right\rceil$; $scal_9$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=1* and $(\Phi/75)<(2.67*S)$, then $k = \left\lceil \frac{2.67*S-\Phi/75}{Pl} \right\rceil$; $scal_{10}$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=2* and $(\Phi/75)<(3.2*S)$, then $k = \left\lceil \frac{3.2*S-\Phi/75}{Pl} \right\rceil$; $scal_{11}$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=3* and $(\Phi/75)<(4*S)$, then $k = \left\lceil \frac{4*S-\Phi/75}{Pl} \right\rceil$; $scal_{12}$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=4* and $(\Phi/75)<(5.33*S)$, then $k = \left\lceil \frac{5.33*S-\Phi/75}{Pl} \right\rceil$; $scal_{13}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=1* and $(\Phi/75)<(4*S)$, then $k = \left\lceil \frac{4*S-\Phi/75}{Pl} \right\rceil$; $scal_{14}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=2* and $(\Phi/75)<(4.8*S)$, then $k = \left\lceil \frac{4.8*S-\Phi/75}{Pl} \right\rceil$; $scal_{15}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=3* and $(\Phi/75)<(6*S)$, then $k = \left\lceil \frac{6*S-\Phi/75}{Pl} \right\rceil$; $scal_{16}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=4* and $(\Phi/75)<(8*S)$, then $k = \left\lceil \frac{8*S-\Phi/75}{Pl} \right\rceil$; $scal_{17}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=1* and $(\Phi/75)<(S)$, then $k = \left\lceil \frac{S-\Phi/75}{Pl} \right\rceil$; $scal_{18}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=2* and $(\Phi/75)<(1.2* S)$, then $k = \left\lceil \frac{1.2*S-\Phi/75}{Pl} \right\rceil$; $scal_{19}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=3* and $(\Phi/75)<(1.5* S)$, then $k = \left\lceil \frac{1.5*S-\Phi/75}{Pl} \right\rceil$; $scal_{20}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=4* and $(\Phi/75)<(2*S)$, then $k = \left\lceil \frac{2*S-\Phi/75}{Pl} \right\rceil$; $scal_{21}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=1* and $(\Phi/75)<(S)$, then $k = \left\lceil \frac{S-\Phi/75}{Pl} \right\rceil$; $scal_{22}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=2* and $(\Phi/75)<(1.2*S)$, then $k = \left\lceil \frac{1.2*S-\Phi/75}{Pl} \right\rceil$; $scal_{23}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=3* and $(\Phi/75)<(1.5*S)$, then $k = \left\lceil \frac{1.5*S-\Phi/75}{Pl} \right\rceil$; $scal_{24}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=4* та $(\Phi/75)<(2*S)$, then $k = \left\lceil \frac{2*S-\Phi/75}{Pl} \right\rceil$; $scal_{25}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=1* and $(\Phi/75)<(3*S)$, then $k = \left\lceil \frac{3*S-\Phi/75}{Pl} \right\rceil$; $scal_{26}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=2* and $(\Phi/75)<(3.6*S)$, then $k = \left\lceil \frac{3.6*S-\Phi/75}{Pl} \right\rceil$; $scal_{27}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=3* and $(\Phi/75)<(4.5*S)$, then $k = \left\lceil \frac{4.5*S-\Phi/75}{Pl} \right\rceil$; $scal_{28}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=4* and $(\Phi/75)<(6*S)$, then $k = \left\lceil \frac{6*S-\Phi/75}{Pl} \right\rceil$; $scal_{29}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=1* and $(\Phi/75)<(1.335*S)$, then $k = \left\lceil \frac{1.335*S-\Phi/75}{Pl} \right\rceil$; $scal_{30}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=2* and $(\Phi/75)<(1.6*S)$, then $k = \left\lceil \frac{1.6*S-\Phi/75}{Pl} \right\rceil$; $scal_{31}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=3*

and *(Φ/75)<(2*S)*, then $k = \left\lceil \frac{2*S-\Phi/75}{Pl} \right\rceil$; $scal_{32}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=4* and *(Φ/75)<(2.665*S)*, then $k = \left\lceil \frac{2.665*S-\Phi/75}{Pl} \right\rceil$; $scal_{33}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=1* and *(Φ/75)<(2*S)*, then $k = \left\lceil \frac{2*S-\Phi/75}{Pl} \right\rceil$; $scal_{34}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=2* and *(Φ/75)<(2.4*S)*, then $k = \left\lceil \frac{2.4*S-\Phi/75}{Pl} \right\rceil$; $scal_{35}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=3* and *(Φ/75)<(3*S)*, then $k = \left\lceil \frac{3*S-\Phi/75}{Pl} \right\rceil$; $scal_{36}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=4* and *(Φ/75)<(4*S)*, then $k = \left\lceil \frac{4*S-\Phi/75}{Pl} \right\rceil$; $scal_{37}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=1* and *(Φ/75)<(0.5*S)*, then $k = \left\lceil \frac{0.5*S-\Phi/75}{Pl} \right\rceil$; $scal_{38}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=2* and *(Φ/75)<(0.6*S)*, then $k = \left\lceil \frac{0.6*S-\Phi/75}{Pl} \right\rceil$; $scal_{39}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=3* and *(Φ/75)<(0.75*S)*, then $k = \left\lceil \frac{0.75*S-\Phi/75}{Pl} \right\rceil$; $scal_{40}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=4* and *(Φ/75)<(S)*, then $k = \left\lceil \frac{S-\Phi/75}{Pl} \right\rceil$; $scal_{41}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=1* and *(Φ/47)<(3.2*S)*, then $k = \left\lceil \frac{3.2*S-\Phi/47}{Pl} \right\rceil$; $scal_{42}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=2* and *(Φ/47)<(3.83*S)*, then $k = \left\lceil \frac{3.83*S-\Phi/47}{Pl} \right\rceil$; $scal_{43}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=3* and *(Φ/47)<(4.79*S)*, then $k = \left\lceil \frac{4.79*S-\Phi/47}{Pl} \right\rceil$; $scal_{44}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=4* and *(Φ/47)<(6.39*S)*, then $k = \left\lceil \frac{6.39*S-\Phi/47}{Pl} \right\rceil$; $scal_{45}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=1* and *(Φ/47)<(9.58*S)*, then $k = \left\lceil \frac{9.58*S-\Phi/47}{Pl} \right\rceil$; $scal_{46}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=2* and *(Φ/47)<(11.49*S)*, then $k = \left\lceil \frac{11.49*S-\Phi/47}{Pl} \right\rceil$; $scal_{47}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=3* and *(Φ/47)<(14.37*S)*, then $k = \left\lceil \frac{14.37*S-\Phi/47}{Pl} \right\rceil$; $scal_{48}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=4* and *(Φ/47)<(19.15*S)*, then $k = \left\lceil \frac{19.15*S-\Phi/47}{Pl} \right\rceil$; $scal_{49}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=1* and *(Φ/47)<(4.26*S)*, then $k = \left\lceil \frac{4.26*S-\Phi/47}{Pl} \right\rceil$; $scal_{50}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=2* and *(Φ/47)<(5.11*S)*, then $k = \left\lceil \frac{5.11*S-\Phi/47}{Pl} \right\rceil$; $scal_{51}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=3* and *(Φ/47)<(6.39*S)*, then $k = \left\lceil \frac{6.39*S-\Phi/47}{Pl} \right\rceil$; $scal_{52}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=4* and *(Φ/47)<(8.52*S)*, then $k = \left\lceil \frac{8.52*S-\Phi/47}{Pl} \right\rceil$; $scal_{53}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=1* and *(Φ/47)<(6.39*S)*, then $k = \left\lceil \frac{6.39*S-\Phi/47}{Pl} \right\rceil$; $scal_{54}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=2* and *(Φ/47)<(7.66*S)*, then $k = \left\lceil \frac{7.66*S-\Phi/47}{Pl} \right\rceil$; $scal_{55}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=3* and *(Φ/47)<(9.58*S)*, then $k = \left\lceil \frac{9.58*S-\Phi/47}{Pl} \right\rceil$; $scal_{56}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=4* and *(Φ/47)<(12.77*S)*, then $k = \left\lceil \frac{12.77*S-\Phi/47}{Pl} \right\rceil$; $scal_{57}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=1* and *(Φ/47)<(1.6*S)*, then $k = \left\lceil \frac{1.6*S-\Phi/47}{Pl} \right\rceil$; $scal_{58}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=2* and *(Φ/47)<(1.92*S)*, then $k = \left\lceil \frac{1.92*S-\Phi/47}{Pl} \right\rceil$; $scal_{59}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=3* and *(Φ/47)<(2.4*S)*, then $k = \left\lceil \frac{2.4*S-\Phi/47}{Pl} \right\rceil$; $scal_{60}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=4* and *(Φ/47)<(3.2*S)*, then $k = \left\lceil \frac{3.2*S-\Phi/47}{Pl} \right\rceil$; $scal_{61}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=1* and *(Φ/47)<(1.6*S)*, then $k = \left\lceil \frac{1.6*S-\Phi/47}{Pl} \right\rceil$; $scal_{62}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=2* and *(Φ/47)<(1.915*S)*, then $k = \left\lceil \frac{1.915*S-\Phi/47}{Pl} \right\rceil$; $scal_{63}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=3* and *(Φ/47)<(2.395*S)*, then $k = \left\lceil \frac{2.395*S-\Phi/47}{Pl} \right\rceil$; $scal_{64}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=4* and *(Φ/47)<(3.195*S)*, then $k = \left\lceil \frac{3.195*S-\Phi/47}{Pl} \right\rceil$; $scal_{65}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=1* and *(Φ/47)<(4.79*S)*, then $k = \left\lceil \frac{4.79*S-\Phi/47}{Pl} \right\rceil$; $scal_{66}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=2* and *(Φ/47)<(5.745*S)*, then $k = \left\lceil \frac{5.745*S-\Phi/47}{Pl} \right\rceil$; $scal_{67}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=3* and

*(Ф/47)<(7.185*S)*, then $k = \left\lceil \frac{7.185*S-\Phi/47}{Pl} \right\rceil$; $scal_{68}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=4* and *(Ф/47)<(9.575*S)*, then $k = \left\lceil \frac{9.575*S-\Phi/47}{Pl} \right\rceil$; $scal_{69}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=1* and *(Ф/47)<(2.13*S)*, then $k = \left\lceil \frac{2.13*S-\Phi/47}{Pl} \right\rceil$; $scal_{70}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=2* and *(Ф/47)<(2.555*S)*, then $k = \left\lceil \frac{2.555*S-\Phi/47}{Pl} \right\rceil$; $scal_{71}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=3* and *(Ф/47)<(3.195*S)*, then $k = \left\lceil \frac{3.195*S-\Phi/47}{Pl} \right\rceil$; $scal_{72}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=4* and *(Ф/47)<(4.26*S)*, then $k = \left\lceil \frac{4.26*S-\Phi/47}{Pl} \right\rceil$; $scal_{73}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=1* and *(Ф/47)<(3.195*S)*, then $k = \left\lceil \frac{3.195*S-\Phi/47}{Pl} \right\rceil$; $scal_{74}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=2* and *(Ф/47)<(3.83*S)*, then $k = \left\lceil \frac{3.83*S-\Phi/47}{Pl} \right\rceil$; $scal_{75}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=3* and *(Ф/47)<(4.79*S)*, then $k = \left\lceil \frac{4.79*S-\Phi/47}{Pl} \right\rceil$; $scal_{76}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=4* and *(Ф/47)<(6.385*S)*, then $k = \left\lceil \frac{6.385*S-\Phi/47}{Pl} \right\rceil$; $scal_{77}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=1* and *(Ф/47)<(0.8*S)*, then $k = \left\lceil \frac{0.8*S-\Phi/47}{Pl} \right\rceil$; $scal_{78}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=2* and *(Ф/47)<(0.96*S)*, then $k = \left\lceil \frac{0.96*S-\Phi/47}{Pl} \right\rceil$; $scal_{79}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=3* and *(Ф/47)<(1.2*S)*, then $k = \left\lceil \frac{1.2*S-\Phi/47}{Pl} \right\rceil$; $scal_{80}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=4* and *(Ф/47)<(1.6*S)*, then $k = \left\lceil \frac{1.6*S-\Phi/47}{Pl} \right\rceil$; $scal_{81}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=1* and *(Ф/15)<(10*S)*, then $k = \left\lceil \frac{10*S-\Phi/15}{Pl} \right\rceil$; $scal_{82}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=2* and *(Ф/15)<(12*S)*, then $k = \left\lceil \frac{12*S-\Phi/15}{Pl} \right\rceil$; $scal_{83}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=3* and *(Ф/15)<(15*S)*, then $k = \left\lceil \frac{15*S-\Phi/15}{Pl} \right\rceil$; $scal_{84}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=4* and *(Ф/15)<(20*S)*, then $k = \left\lceil \frac{20*S-\Phi/15}{Pl} \right\rceil$; $scal_{85}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=1* and *(Ф/15)<(30*S)*, then $k = \left\lceil \frac{30*S-\Phi/15}{Pl} \right\rceil$; $scal_{86}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=2* and *(Ф/15)<(36*S)*, then $k = \left\lceil \frac{36*S-\Phi/15}{Pl} \right\rceil$; $scal_{87}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=3* and *(Ф/15)<(45*S)*, then $k = \left\lceil \frac{45*S-\Phi/15}{Pl} \right\rceil$; $scal_{88}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=4* and *(Ф/15)<(60*S)*, then $k = \left\lceil \frac{60*S-\Phi/15}{Pl} \right\rceil$; $scal_{89}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=1* and *(Ф/15)<(13.34*S)*, then $k = \left\lceil \frac{13.34*S-\Phi/15}{Pl} \right\rceil$; $scal_{90}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=2* and *(Ф/15)<(16*S)*, then $k = \left\lceil \frac{16*S-\Phi/15}{Pl} \right\rceil$; $scal_{91}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=3* and *(Ф/15)<(20*S)*, then $k = \left\lceil \frac{20*S-\Phi/15}{Pl} \right\rceil$; $scal_{92}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=4* and *(Ф/15)<(26.67*S)*, then $k = \left\lceil \frac{26.67*S-\Phi/15}{Pl} \right\rceil$; $scal_{93}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=1* and *(Ф/15)<(20*S)*, then $k = \left\lceil \frac{20*S-\Phi/15}{Pl} \right\rceil$; $scal_{94}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=2* and *(Ф/15)<(24*S)*, then $k = \left\lceil \frac{24*S-\Phi/15}{Pl} \right\rceil$; $scal_{95}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=3* and *(Ф/15)<(30*S)*, then $k = \left\lceil \frac{30*S-\Phi/15}{Pl} \right\rceil$; $scal_{96}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=4* and *(Ф/15)<(40*S)*, then $k = \left\lceil \frac{40*S-\Phi/15}{Pl} \right\rceil$; $scal_{97}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=1* and *(Ф/15)<(5*S)*, then $k = \left\lceil \frac{5*S-\Phi/15}{Pl} \right\rceil$; $scal_{98}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=2* and *(Ф/15)<(6*S)*, then $k = \left\lceil \frac{6*S-\Phi/15}{Pl} \right\rceil$; $scal_{99}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=3* and *(Ф/15)<(7.5*S)*, then $k = \left\lceil \frac{7.5*S-\Phi/15}{Pl} \right\rceil$; $scal_{100}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=4* and *(Ф/15)<(10*S)*, then $k = \left\lceil \frac{10*S-\Phi/15}{Pl} \right\rceil$; $scal_{101}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=1* and *(Ф/15)<(5*S)*, then $k = \left\lceil \frac{5*S-\Phi/15}{Pl} \right\rceil$; $scal_{102}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=2* and *(Ф/15)<(6*S)*, then $k = \left\lceil \frac{6*S-\Phi/15}{Pl} \right\rceil$; $scal_{103}$ – if *rlm=2* and *trl=3* and *tr=1* and

chi=3 and *(Φ/15)<(7.5*S)*, then $k = \left\lceil \frac{7.5*S-\Phi/15}{Pl} \right\rceil$; $scal_{104}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=4* and *(Φ/15)<(10*S)*, then $k = \left\lceil \frac{10*S-\Phi/15}{Pl} \right\rceil$; $scal_{105}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=1* and *(Φ/15)<(15*S)*, then $k = \left\lceil \frac{15*S-\Phi/15}{Pl} \right\rceil$; $scal_{106}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=2* and *(Φ/15)<(18*S)*, then $k = \left\lceil \frac{18*S-\Phi/15}{Pl} \right\rceil$; $scal_{107}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=3* and *(Φ/15)<(22.5*S)*, then $k = \left\lceil \frac{22.5*S-\Phi/15}{Pl} \right\rceil$; $scal_{108}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=4* and *(Φ/15)<(30*S)*, then $k = \left\lceil \frac{30*S-\Phi/15}{Pl} \right\rceil$; $scal_{109}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=1* and *(Φ/15)<(6.67*S)*, then $k = \left\lceil \frac{6.67*S-\Phi/15}{Pl} \right\rceil$; $scal_{110}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=2* and *(Φ/15)<(8*S)*, then $k = \left\lceil \frac{8*S-\Phi/15}{Pl} \right\rceil$; $scal_{111}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=3* and *(Φ/15)<(10*S)*, then $k = \left\lceil \frac{10*S-\Phi/15}{Pl} \right\rceil$; $scal_{112}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=4* and *(Φ/15)<(13.335*S)*, then $k = \left\lceil \frac{13.335*S-\Phi/15}{Pl} \right\rceil$; $scal_{113}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=1* and *(Φ/15)<(10*S)*, then $k = \left\lceil \frac{10*S-\Phi/15}{Pl} \right\rceil$; $scal_{114}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=2* and *(Φ/15)<(12*S)*, then $k = \left\lceil \frac{12*S-\Phi/15}{Pl} \right\rceil$; $scal_{115}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=3* and *(Φ/15)<(15*S)*, then $k = \left\lceil \frac{15*S-\Phi/15}{Pl} \right\rceil$; $scal_{116}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=4* and *(Φ/15)<(20*S)*, then $k = \left\lceil \frac{20*S-\Phi/15}{Pl} \right\rceil$; $scal_{117}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=1* and *(Φ/15)<(2.5*S)*, then $k = \left\lceil \frac{2.5*S-\Phi/15}{Pl} \right\rceil$; $scal_{118}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=2* and *(Φ/15)<(3*S)*, then $k = \left\lceil \frac{3*S-\Phi/15}{Pl} \right\rceil$; $scal_{119}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=3* and *(Φ/15)<(3.75*S)*, then $k = \left\lceil \frac{3.75*S-\Phi/15}{Pl} \right\rceil$; $scal_{120}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=4* and *(Φ/15)<(5*S)*, then $k = \left\lceil \frac{5*S-\Phi/15}{Pl} \right\rceil$; $scal_{121}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=1* and *(Φ/12)<(12.5*S)*, then $k = \left\lceil \frac{12.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{122}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=2* and *(Φ/12)<(15*S)*, then $k = \left\lceil \frac{15*S-\Phi/12}{Pl} \right\rceil$; $scal_{123}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=3* and *(Φ/12)<(18.75*S)*, then $k = \left\lceil \frac{18.75*S-\Phi/12}{Pl} \right\rceil$; $scal_{124}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=4* and *(Φ/12)<(25*S)*, then $k = \left\lceil \frac{25*S-\Phi/12}{Pl} \right\rceil$; $scal_{125}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=1* and *(Φ/12)<(37.5*S)*, then $k = \left\lceil \frac{37.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{126}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=2* and *(Φ/12)<(45*S)*, then $k = \left\lceil \frac{45*S-\Phi/12}{Pl} \right\rceil$; $scal_{127}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=3* and *(Φ/12)<(56.25*S)*, then $k = \left\lceil \frac{56.25*S-\Phi/12}{Pl} \right\rceil$; $scal_{128}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=4* and *(Φ/12)<(75*S)*, then $k = \left\lceil \frac{75*S-\Phi/12}{Pl} \right\rceil$; $scal_{129}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=1* and *(Φ/12)<(16.67*S)*, then $k = \left\lceil \frac{16.67*S-\Phi/12}{Pl} \right\rceil$; $scal_{130}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=2* and *(Φ/12)<(20*S)*, then $k = \left\lceil \frac{20*S-\Phi/12}{Pl} \right\rceil$; $scal_{131}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=3* and *(Φ/12)<(25*S)*, then $k = \left\lceil \frac{25*S-\Phi/12}{Pl} \right\rceil$; $scal_{132}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=4* and *(Φ/12)<(33.34*S)*, then $k = \left\lceil \frac{33.34*S-\Phi/12}{Pl} \right\rceil$; $scal_{133}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=1* and *(Φ/12)<(25*S)*, then $k = \left\lceil \frac{25*S-\Phi/12}{Pl} \right\rceil$; $scal_{134}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=2* and *(Φ/12)<(30*S)*, then $k = \left\lceil \frac{30*S-\Phi/12}{Pl} \right\rceil$; $scal_{135}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=3* and *(Φ/12)<(37.5*S)*, then $k = \left\lceil \frac{37.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{136}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=4* and *(Φ/12)<(50*S)*, then $k = \left\lceil \frac{50*S-\Phi/12}{Pl} \right\rceil$; $scal_{137}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=1* and *(Φ/12)<(6.25*S)*, then $k = \left\lceil \frac{6.25*S-\Phi/12}{Pl} \right\rceil$; $scal_{138}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=2* and *(Φ/12)<(7.5*S)*, then $k = \left\lceil \frac{7.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{139}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=3* and

*(Φ/12)<(9.38*S)*, then $k = \left\lceil \frac{9.38*S-\Phi/12}{Pl} \right\rceil$; $scal_{140}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=4* and *(Φ/12)<(12.5*S)*, then $k = \left\lceil \frac{12.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{141}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=1* and *(Φ/12)<(6.25*S)*, then $k = \left\lceil \frac{6.25*S-\Phi/12}{Pl} \right\rceil$; $scal_{142}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=2* and *(Φ/12)<(7.5*S)*, then $k = \left\lceil \frac{7.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{143}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=3* and *(Φ/12)<(9.375*S)*, then $k = \left\lceil \frac{9.375*S-\Phi/12}{Pl} \right\rceil$; $scal_{144}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=4* and *(Φ/12)<(12.5*S)*, then $k = \left\lceil \frac{12.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{145}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=1* and *(Φ/12)<(18.75*S)*, then $k = \left\lceil \frac{18.75*S-\Phi/12}{Pl} \right\rceil$; $scal_{146}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=2* and *(Φ/12)<(22.5*S)*, then $k = \left\lceil \frac{22.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{147}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=3* and *(Φ/12)<(28.125*S)*, then $k = \left\lceil \frac{28.125*S-\Phi/12}{Pl} \right\rceil$; $scal_{148}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=4* and *(Φ/12)<(37.5*S)*, then $k = \left\lceil \frac{37.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{149}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=1* and *(Φ/12)<(8.335*S)*, then $k = \left\lceil \frac{8.335*S-\Phi/12}{Pl} \right\rceil$; $scal_{150}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=2* and *(Φ/12)<(10*S)*, then $k = \left\lceil \frac{10*S-\Phi/12}{Pl} \right\rceil$; $scal_{151}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=3* and *(Φ/12)<(12.5*S)*, then $k = \left\lceil \frac{12.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{152}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=4* and *(Φ/12)<(16.67*S)*, then $k = \left\lceil \frac{16.67*S-\Phi/12}{Pl} \right\rceil$; $scal_{153}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=1* and *(Φ/12)<(12.5*S)*, then $k = \left\lceil \frac{12.5*S-\Phi/12}{Pl} \right\rceil$; $scal_{154}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=2* and *(Φ/12)<(15*S)*, then $k = \left\lceil \frac{15*S-\Phi/12}{Pl} \right\rceil$; $scal_{155}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=3* and *(Φ/12)<(18.75*S)*, then $k = \left\lceil \frac{18.75*S-\Phi/12}{Pl} \right\rceil$; $scal_{156}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=4* and *(Φ/12)<(25*S)*, then $k = \left\lceil \frac{25*S-\Phi/12}{Pl} \right\rceil$; $scal_{157}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=1* and *(Φ/12)<(3.125*S)*, then $k = \left\lceil \frac{3.125*S-\Phi/12}{Pl} \right\rceil$; $scal_{158}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=2* and *(Φ/12)<(3.75*S)*, then $k = \left\lceil \frac{3.75*S-\Phi/12}{Pl} \right\rceil$; $scal_{159}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=3* and *(Φ/12)<(4.69*S)*, then $k = \left\lceil \frac{4.69*S-\Phi/12}{Pl} \right\rceil$; $scal_{160}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=4* and *(Φ/12)<(6.25*S)*, then $k = \left\lceil \frac{6.25*S-\Phi/12}{Pl} \right\rceil$.

The set of scenarios for calculating the number of additional lamps that must be turned on to ensure the required level of illuminosity, represented by formula (6), consists of four subsets:

$$SCAL = \{SCALLED, SCALES, SCALH, SCALI\}, \quad (7)$$

where $SCALLED=\{scal_1 \ldots scal_{40}\}$ – subset of scenarios for turning on LED lamps; $SCALES=\{scal_{41} \ldots scal_{80}\}$ – subset of scenarios for turning on energy-saving lamps; $SCALH=\{scal_{81} \ldots scal_{120}\}$ – subset of scenarios for turning on halogen lamps; $SCALI=\{scal_{121} \ldots scal_{160}\}$ – subset of scenarios for turning on incandescent lamps.

The set of scenarios for calculating the number of lamps that must be turned off to ensure the required level of luminosity is formed according to Tables 3-6 and has the following form:

$$SCOFFL = \{scoffl_1, \ldots, scoffl_{161}\}, \quad (8)$$

where $scoffl_1$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=1* and *(Φ/75)>(2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2*S}{Pl} \right\rfloor$; $scoffl_2$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=2* and *(Φ/75)>(2.4*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2.4*S}{Pl} \right\rfloor$; $scoffl_3$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=3* and *(Φ/75)>(3*S)*, then $k1 = \left\lfloor \frac{\Phi/75-3*S}{Pl} \right\rfloor$; $scoffl_4$ – if *rlm=1* and *trl=1* and *tr=1* and *chi=4* and *(Φ/75)>(4*S)*, then $k1 = \left\lfloor \frac{\Phi/75-4*S}{Pl} \right\rfloor$; $scoffl_5$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=1* and *(Φ/75)>(6*S)*, then $k1 = \left\lfloor \frac{\Phi/75-6*S}{Pl} \right\rfloor$; $scoffl_6$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=2* and *(Φ/75)>(7.2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-7.2*S}{Pl} \right\rfloor$; $scoffl_7$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=3* and *(Φ/75)>(9*S)*, then $k1 = \left\lfloor \frac{\Phi/75-9*S}{Pl} \right\rfloor$; $scoffl_8$ – if *rlm=1* and *trl=1* and *tr=2* and *chi=4* and *(Φ/75)>(12*S)*, then $k1 = \left\lfloor \frac{\Phi/75-12*S}{Pl} \right\rfloor$;

scoffl$_9$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=1* and *(Φ/75)>(2.67*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2.67*S}{Pl} \right\rfloor$; *scoffl*$_{10}$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=2* and *(Φ/75)>(3.2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-3.2*S}{Pl} \right\rfloor$; *scoffl*$_{11}$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=3* and *(Φ/75)>(4*S)*, then $k1 = \left\lfloor \frac{\Phi/75-4*S}{Pl} \right\rfloor$; *scoffl*$_{12}$ – if *rlm=1* and *trl=1* and *tr=3* and *chi=4* and *(Φ/75)>(5.33*S)*, then $k1 = \left\lfloor \frac{\Phi/75-5.33*S}{Pl} \right\rfloor$; *scoffl*$_{13}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=1* and *(Φ/75)>(4*S)*, then $k1 = \left\lfloor \frac{\Phi/75-4*S}{Pl} \right\rfloor$; *scoffl*$_{14}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=2* and *(Φ/75)>(4.8*S)*, then $k1 = \left\lfloor \frac{\Phi/75-4.8*S}{Pl} \right\rfloor$; *scoffl*$_{15}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=3* and *(Φ/75)>(6*S)*, then $k1 = \left\lfloor \frac{\Phi/75-6*S}{Pl} \right\rfloor$; *scoffl*$_{16}$ – if *rlm=1* and *trl=1* and *tr=4* and *chi=4* and *(Φ/75)>(8*S)*, then $k1 = \left\lfloor \frac{\Phi/75-8*S}{Pl} \right\rfloor$; *scoffl*$_{17}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=1* and *(Φ/75)>(S)*, then $k1 = \left\lfloor \frac{\Phi/75-S}{Pl} \right\rfloor$; *scoffl*$_{18}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=2* and *(Φ/75)>(1.2* S)*, then $k1 = \left\lfloor \frac{\Phi/75-1.2*S}{Pl} \right\rfloor$; *scoffl*$_{19}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=3* and *(Φ/75)>(1.5* S)*, then $k1 = \left\lfloor \frac{\Phi/75-1.5*S}{Pl} \right\rfloor$; *scoffl*$_{20}$ – if *rlm=1* and *trl=1* and *tr=5* and *chi=4* and *(Φ/75)>(2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2*S}{Pl} \right\rfloor$; *scoffl*$_{21}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=1* and *(Φ/75)>(S)*, then $k1 = \left\lfloor \frac{\Phi/75-S}{Pl} \right\rfloor$; *scoffl*$_{22}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=2* and *(Φ/75)>(1.2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-1.2*S}{Pl} \right\rfloor$; *scoffl*$_{23}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=3* and *(Φ/75)>(1.5*S)*, then $k1 = \left\lfloor \frac{\Phi/75-1.5*S}{Pl} \right\rfloor$; *scoffl*$_{24}$ – if *rlm=2* and *trl=1* and *tr=1* and *chi=4* and *(Φ/75)>(2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2*S}{Pl} \right\rfloor$; *scoffl*$_{25}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=1* and *(Φ/75)>(3*S)*, then $k1 = \left\lfloor \frac{\Phi/75-3*S}{Pl} \right\rfloor$; *scoffl*$_{26}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=2* and *(Φ/75)>(3.6*S)*, then $k1 = \left\lfloor \frac{\Phi/75-3.6*S}{Pl} \right\rfloor$; *scoffl*$_{27}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=3* and *(Φ/75)>(4.5*S)*, then $k1 = \left\lfloor \frac{\Phi/75-4.5*S}{Pl} \right\rfloor$; *scoffl*$_{28}$ – if *rlm=2* and *trl=1* and *tr=2* and *chi=4* and *(Φ/75)>(6*S)*, then $k1 = \left\lfloor \frac{\Phi/75-6*S}{Pl} \right\rfloor$; *scoffl*$_{29}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=1* and *(Φ/75)>(1.335*S)*, then $k1 = \left\lfloor \frac{\Phi/75-1.335*S}{Pl} \right\rfloor$; *scoffl*$_{30}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=2* and *(Φ/75)>(1.6*S)*, then $k1 = \left\lfloor \frac{\Phi/75-1.6*S}{Pl} \right\rfloor$; *scoffl*$_{31}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=3* and *(Φ/75)>(2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2*S}{Pl} \right\rfloor$; *scoffl*$_{32}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=4* and *(Φ/75)>(2.665*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2.665*S}{Pl} \right\rfloor$; *scoffl*$_{33}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=1* and *(Φ/75)>(2*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2*S}{Pl} \right\rfloor$; *scoffl*$_{34}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=2* and *(Φ/75)>(2.4*S)*, then $k1 = \left\lfloor \frac{\Phi/75-2.4*S}{Pl} \right\rfloor$; *scoffl*$_{35}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=3* and *(Φ/75)>(3*S)*, then $k1 = \left\lfloor \frac{\Phi/75-3*S}{Pl} \right\rfloor$; *scoffl*$_{36}$ – if *rlm=2* and *trl=1* and *tr=4* and *chi=4* and *(Φ/75)>(4*S)*, then $k1 = \left\lfloor \frac{\Phi/75-4*S}{Pl} \right\rfloor$; *scoffl*$_{37}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=1* and *(Φ/75)>(0.5*S)*, then $k1 = \left\lfloor \frac{\Phi/75-0.5*S}{Pl} \right\rfloor$; *scoffl*$_{38}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=2* and *(Φ/75)>(0.6*S)*, then $k1 = \left\lfloor \frac{\Phi/75-0.6*S}{Pl} \right\rfloor$; *scoffl*$_{39}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=3* and *(Φ/75)>(0.75*S)*, then $k1 = \left\lfloor \frac{\Phi/75-0.75*S}{Pl} \right\rfloor$; *scoffl*$_{40}$ – if *rlm=2* and *trl=1* and *tr=5* and *chi=4* and *(Φ/75)>(S)*, then $k1 = \left\lfloor \frac{\Phi/75-S}{Pl} \right\rfloor$; *scoffl*$_{41}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=1* and *(Φ/47)>(3.2*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.2*S}{Pl} \right\rfloor$; *scoffl*$_{42}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=2* and *(Φ/47)>(3.83*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.83*S}{Pl} \right\rfloor$; *scoffl*$_{43}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=3* and *(Φ/47)>(4.79*S)*, then $k1 = \left\lfloor \frac{\Phi/47-4.79*S}{Pl} \right\rfloor$; *scoffl*$_{44}$ – if *rlm=1* and *trl=2* and *tr=1* and *chi=4* and *(Φ/47)>(6.39*S)*, then $k1 = \left\lfloor \frac{\Phi/47-6.39*S}{Pl} \right\rfloor$; *scoffl*$_{45}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=1* and *(Φ/47)>(9.58*S)*, then $k1 = \left\lfloor \frac{\Phi/47-9.58*S}{Pl} \right\rfloor$; *scoffl*$_{46}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=2* and *(Φ/47)>(11.49*S)*, then $k1 = \left\lfloor \frac{\Phi/47-11.49*S}{Pl} \right\rfloor$; *scoffl*$_{47}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=3* and

*(Φ/47)>(14.37*S)*, then $k1 = \left\lfloor \frac{\Phi/47-14.37*S}{Pl} \right\rfloor$; $scoffl_{48}$ – if *rlm=1* and *trl=2* and *tr=2* and *chi=4* and
*(Φ/47)>(19.15*S)*, then $k1 = \left\lfloor \frac{\Phi/47-19.15*S}{Pl} \right\rfloor$; $scoffl_{49}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=1* and
*(Φ/47)>(4.26*S)*, then $k1 = \left\lfloor \frac{\Phi/47-4.26*S}{Pl} \right\rfloor$; $scoffl_{50}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=2* and
*(Φ/47)>(5.11*S)*, then $k1 = \left\lfloor \frac{\Phi/47-5.11*S}{Pl} \right\rfloor$; $scoffl_{51}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=3* and
*(Φ/47)>(6.39*S)*, then $k1 = \left\lfloor \frac{\Phi/47-6.39*S}{Pl} \right\rfloor$; $scoffl_{52}$ – if *rlm=1* and *trl=2* and *tr=3* and *chi=4* and
*(Φ/47)>(8.52*S)*, then $k1 = \left\lfloor \frac{\Phi/47-8.52*S}{Pl} \right\rfloor$; $scoffl_{53}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=1* and
*(Φ/47)>(6.39*S)*, then $k1 = \left\lfloor \frac{\Phi/47-6.39*S}{Pl} \right\rfloor$; $scoffl_{54}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=2* and
*(Φ/47)>(7.66*S)*, then $k1 = \left\lfloor \frac{\Phi/47-7.66*S}{Pl} \right\rfloor$; $scoffl_{55}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=3* and
*(Φ/47)>(9.58*S)*, then $k1 = \left\lfloor \frac{\Phi/47-9.58*S}{Pl} \right\rfloor$; $scoffl_{56}$ – if *rlm=1* and *trl=2* and *tr=4* and *chi=4* and
*(Φ/47)>(12.77*S)*, then $k1 = \left\lfloor \frac{\Phi/47-12.77*S}{Pl} \right\rfloor$; $scoffl_{57}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=1* and
*(Φ/47)>(1.6*S)*, then $k1 = \left\lfloor \frac{\Phi/47-1.6*S}{Pl} \right\rfloor$; $scoffl_{58}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=2* and
*(Φ/47)>(1.92*S)*, then $k1 = \left\lfloor \frac{\Phi/47-1.92*S}{Pl} \right\rfloor$; $scoffl_{59}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=3* and
*(Φ/47)>(2.4*S)*, then $k1 = \left\lfloor \frac{\Phi/47-2.4*S}{Pl} \right\rfloor$; $scoffl_{60}$ – if *rlm=1* and *trl=2* and *tr=5* and *chi=4* and
*(Φ/47)>(3.2*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.2*S}{Pl} \right\rfloor$; $scoffl_{61}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=1* and
*(Φ/47)>(1.6*S)*, then $k1 = \left\lfloor \frac{\Phi/47-1.6*S}{Pl} \right\rfloor$; $scoffl_{62}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=2* and
*(Φ/47)>(1.915*S)*, then $k1 = \left\lfloor \frac{\Phi/47-1.915*S}{Pl} \right\rfloor$; $scoffl_{63}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=3* and
*(Φ/47)>(2.395*S)*, then $k1 = \left\lfloor \frac{\Phi/47-2.395*S}{Pl} \right\rfloor$; $scoffl_{64}$ – if *rlm=2* and *trl=2* and *tr=1* and *chi=4* and
*(Φ/47)>(3.195*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.195*S}{Pl} \right\rfloor$; $scoffl_{65}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=1* and
*(Φ/47)>(4.79*S)*, then $k1 = \left\lfloor \frac{\Phi/47-4.79*S}{Pl} \right\rfloor$; $scoffl_{66}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=2* and
*(Φ/47)>(5.745*S)*, then $k1 = \left\lfloor \frac{\Phi/47-5.745*S}{Pl} \right\rfloor$; $scoffl_{67}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=3* and
*(Φ/47)>(7.185*S)*, then $k1 = \left\lfloor \frac{\Phi/47-7.185*S}{Pl} \right\rfloor$; $scoffl_{68}$ – if *rlm=2* and *trl=2* and *tr=2* and *chi=4* and
*(Φ/47)>(9.575*S)*, then $k1 = \left\lfloor \frac{\Phi/47-9.575*S}{Pl} \right\rfloor$; $scoffl_{69}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=1* and
*(Φ/47)>(2.13*S)*, then $k1 = \left\lfloor \frac{\Phi/47-2.13*S}{Pl} \right\rfloor$; $scoffl_{70}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=2* and
*(Φ/47)>(2.555*S)*, then $k1 = \left\lfloor \frac{\Phi/47-2.555*S}{Pl} \right\rfloor$; $scoffl_{71}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=3* and
*(Φ/47)>(3.195*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.195*S}{Pl} \right\rfloor$; $scoffl_{72}$ – if *rlm=2* and *trl=2* and *tr=3* and *chi=4* and
*(Φ/47)>(4.26*S)*, then $k1 = \left\lfloor \frac{\Phi/47-4.26*S}{Pl} \right\rfloor$; $scoffl_{73}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=1* and
*(Φ/47)>(3.195*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.195*S}{Pl} \right\rfloor$; $scoffl_{74}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=2* and
*(Φ/47)>(3.83*S)*, then $k1 = \left\lfloor \frac{\Phi/47-3.83*S}{Pl} \right\rfloor$; $scoffl_{75}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=3* and
*(Φ/47)>(4.79*S)*, then $k1 = \left\lfloor \frac{\Phi/47-4.79*S}{Pl} \right\rfloor$; $scoffl_{76}$ – if *rlm=2* and *trl=2* and *tr=4* and *chi=4* and
*(Φ/47)>(6.385*S)*, then $k1 = \left\lfloor \frac{\Phi/47-6.385*S}{Pl} \right\rfloor$; $scoffl_{77}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=1* and
*(Φ/47)>(0.8*S)*, then $k1 = \left\lfloor \frac{\Phi/47-0.8*S}{Pl} \right\rfloor$; $scoffl_{78}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=2* and
*(Φ/47)>(0.96*S)*, then $k1 = \left\lfloor \frac{\Phi/47-0.96*S}{Pl} \right\rfloor$; $scoffl_{79}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=3* and
*(Φ/47)>(1.2*S)*, then $k1 = \left\lfloor \frac{\Phi/47-1.2*S}{Pl} \right\rfloor$; $scoffl_{80}$ – if *rlm=2* and *trl=2* and *tr=5* and *chi=4* and
*(Φ/47)>(1.6*S)*, then $k1 = \left\lfloor \frac{\Phi/47-1.6*S}{Pl} \right\rfloor$; $scoffl_{81}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=1* and
*(Φ/15)>(10*S)*, then $k1 = \left\lfloor \frac{\Phi/15-10*S}{Pl} \right\rfloor$; $scoffl_{82}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=2* and

*(Φ/15)>(12*S)*, then $k1 = \left\lfloor \frac{\Phi/15-12*S}{Pl} \right\rfloor$; $scoffl_{83}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=3* and *(Φ/15)>(15*S)*, then $k1 = \left\lfloor \frac{\Phi/15-15*S}{Pl} \right\rfloor$; $scoffl_{84}$ – if *rlm=1* and *trl=3* and *tr=1* and *chi=4* and *(Φ/15)>(20*S)*, then $k1 = \left\lfloor \frac{\Phi/15-20*S}{Pl} \right\rfloor$; $scoffl_{85}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=1* and *(Φ/15)>(30*S)*, then $k1 = \left\lfloor \frac{\Phi/15-30*S}{Pl} \right\rfloor$; $scoffl_{86}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=2* and *(Φ/15)>(36*S)*, then $k1 = \left\lfloor \frac{\Phi/15-36*S}{Pl} \right\rfloor$; $scoffl_{87}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=3* and *(Φ/15)>(45*S)*, then $k1 = \left\lfloor \frac{\Phi/15-45*S}{Pl} \right\rfloor$; $scoffl_{88}$ – if *rlm=1* and *trl=3* and *tr=2* and *chi=4* and *(Φ/15)>(60*S)*, then $k1 = \left\lfloor \frac{\Phi/15-60*S}{Pl} \right\rfloor$; $scoffl_{89}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=1* and *(Φ/15)>(13.34*S)*, then $k1 = \left\lfloor \frac{\Phi/15-13.34*S}{Pl} \right\rfloor$; $scoffl_{90}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=2* and *(Φ/15)>(16*S)*, then $k1 = \left\lfloor \frac{\Phi/15-16*S}{Pl} \right\rfloor$; $scoffl_{91}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=3* and *(Φ/15)>(20*S)*, then $k1 = \left\lfloor \frac{\Phi/15-20*S}{Pl} \right\rfloor$; $scoffl_{92}$ – if *rlm=1* and *trl=3* and *tr=3* and *chi=4* and *(Φ/15)>(26.67*S)*, then $k1 = \left\lfloor \frac{\Phi/15-26.67*S}{Pl} \right\rfloor$; $scoffl_{93}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=1* and *(Φ/15)>(20*S)*, then $k1 = \left\lfloor \frac{\Phi/15-20*S}{Pl} \right\rfloor$; $scoffl_{94}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=2* and *(Φ/15)>(24*S)*, then $k1 = \left\lfloor \frac{\Phi/15-24*S}{Pl} \right\rfloor$; $scoffl_{95}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=3* and *(Φ/15)>(30*S)*, then $k1 = \left\lfloor \frac{\Phi/15-30*S}{Pl} \right\rfloor$; $scoffl_{96}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=4* and *(Φ/15)>(40*S)*, then $k1 = \left\lfloor \frac{\Phi/15-40*S}{Pl} \right\rfloor$; $scoffl_{97}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=1* and *(Φ/15)>(5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-5*S}{Pl} \right\rfloor$; $scoffl_{98}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=2* and *(Φ/15)>(6*S)*, then $k1 = \left\lfloor \frac{\Phi/15-6*S}{Pl} \right\rfloor$; $scoffl_{99}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=3* and *(Φ/15)>(7.5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-7.5*S}{Pl} \right\rfloor$; $scoffl_{100}$ – if *rlm=1* and *trl=3* and *tr=5* and *chi=4* and *(Φ/15)>(10*S)*, then $k1 = \left\lfloor \frac{\Phi/15-10*S}{Pl} \right\rfloor$; $scoffl_{101}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=1* and *(Φ/15)>(5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-5*S}{Pl} \right\rfloor$; $scoffl_{102}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=2* and *(Φ/15)>(6*S)*, then $k1 = \left\lfloor \frac{\Phi/15-6*S}{Pl} \right\rfloor$; $scoffl_{103}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=3* and *(Φ/15)>(7.5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-7.5*S}{Pl} \right\rfloor$; $scoffl_{104}$ – if *rlm=2* and *trl=3* and *tr=1* and *chi=4* and *(Φ/15)>(10*S)*, then $k1 = \left\lfloor \frac{\Phi/15-10*S}{Pl} \right\rfloor$; $scoffl_{105}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=1* and *(Φ/15)>(15*S)*, then $k1 = \left\lfloor \frac{\Phi/15-15*S}{Pl} \right\rfloor$; $scoffl_{106}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=2* and *(Φ/15)>(18*S)*, then $k1 = \left\lfloor \frac{\Phi/15-18*S}{Pl} \right\rfloor$; $scoffl_{107}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=3* and *(Φ/15)>(22.5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-22.5*S}{Pl} \right\rfloor$; $scoffl_{108}$ – if *rlm=2* and *trl=3* and *tr=2* and *chi=4* and *(Φ/15)>(30*S)*, then $k1 = \left\lfloor \frac{\Phi/15-30*S}{Pl} \right\rfloor$; $scoffl_{109}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=1* and *(Φ/15)>(6.67*S)*, then $k1 = \left\lfloor \frac{\Phi/15-6.67*S}{Pl} \right\rfloor$; $scoffl_{110}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=2* and *(Φ/15)>(8*S)*, then $k1 = \left\lfloor \frac{\Phi/15-8*S}{Pl} \right\rfloor$; $scoffl_{111}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=3* and *(Φ/15)>(10*S)*, then $k1 = \left\lfloor \frac{\Phi/15-10*S}{Pl} \right\rfloor$; $scoffl_{112}$ – if *rlm=2* and *trl=3* and *tr=3* and *chi=4* and *(Φ/15)>(13.335*S)*, then $k1 = \left\lfloor \frac{\Phi/15-13.335*S}{Pl} \right\rfloor$; $scoffl_{113}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=1* and *(Φ/15)>(10*S)*, then $k1 = \left\lfloor \frac{\Phi/15-10*S}{Pl} \right\rfloor$; $scoffl_{114}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=2* and *(Φ/15)>(12*S)*, then $k1 = \left\lfloor \frac{\Phi/15-12*S}{Pl} \right\rfloor$; $scoffl_{115}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=3* and *(Φ/15)>(15*S)*, then $k1 = \left\lfloor \frac{\Phi/15-15*S}{Pl} \right\rfloor$; $scoffl_{116}$ – if *rlm=2* and *trl=3* and *tr=4* and *chi=4* and *(Φ/15)>(20*S)*, then $k1 = \left\lfloor \frac{\Phi/15-20*S}{Pl} \right\rfloor$; $scoffl_{117}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=1* and *(Φ/15)>(2.5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-2.5*S}{Pl} \right\rfloor$; $scoffl_{118}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=2* and *(Φ/15)>(3*S)*, then $k1 = \left\lfloor \frac{\Phi/15-3*S}{Pl} \right\rfloor$; $scoffl_{119}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=3*

and *(Φ/15)>(3.75*S)*, then $k1 = \left\lfloor \frac{\Phi/15-3.75*S}{Pl} \right\rfloor$; $scoffl_{120}$ – if *rlm=2* and *trl=3* and *tr=5* and *chi=4* and *(Φ/15)>(5*S)*, then $k1 = \left\lfloor \frac{\Phi/15-5*S}{Pl} \right\rfloor$; $scoffl_{121}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=1* and *(Φ/12)>(12.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-12.5*S}{Pl} \right\rfloor$; $scoffl_{122}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=2* and *(Φ/12)>(15*S)*, then $k1 = \left\lfloor \frac{\Phi/12-15*S}{Pl} \right\rfloor$; $scoffl_{123}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=3* and *(Φ/12)>(18.75*S)*, then $k1 = \left\lfloor \frac{\Phi/12-18.75*S}{Pl} \right\rfloor$; $scoffl_{124}$ – if *rlm=1* and *trl=4* and *tr=1* and *chi=4* and *(Φ/12)>(25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-25*S}{Pl} \right\rfloor$; $scoffl_{125}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=1* and *(Φ/12)>(37.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-37.5*S}{Pl} \right\rfloor$; $scoffl_{126}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=2* and *(Φ/12)>(45*S)*, then $k1 = \left\lfloor \frac{\Phi/12-45*S}{Pl} \right\rfloor$; $scoffl_{127}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=3* and *(Φ/12)>(56.25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-56.25*S}{Pl} \right\rfloor$; $scoffl_{128}$ – if *rlm=1* and *trl=4* and *tr=2* and *chi=4* and *(Φ/12)>(75*S)*, then $k1 = \left\lfloor \frac{\Phi/12-75*S}{Pl} \right\rfloor$; $scoffl_{129}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=1* and *(Φ/12)>(16.67*S)*, then $k1 = \left\lfloor \frac{\Phi/12-16.67*S}{Pl} \right\rfloor$; $scoffl_{130}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=2* and *(Φ/12)>(20*S)*, then $k1 = \left\lfloor \frac{\Phi/12-20*S}{Pl} \right\rfloor$; $scoffl_{131}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=3* and *(Φ/12)>(25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-25*S}{Pl} \right\rfloor$; $scoffl_{132}$ – if *rlm=1* and *trl=4* and *tr=3* and *chi=4* and *(Φ/12)>(33.34*S)*, then $k1 = \left\lfloor \frac{\Phi/12-33.34*S}{Pl} \right\rfloor$; $scoffl_{133}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=1* and *(Φ/12)>(25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-25*S}{Pl} \right\rfloor$; $scoffl_{134}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=2* and *(Φ/12)>(30*S)*, then $k1 = \left\lfloor \frac{\Phi/12-30*S}{Pl} \right\rfloor$; $scoffl_{135}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=3* and *(Φ/12)>(37.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-37.5*S}{Pl} \right\rfloor$; $scoffl_{136}$ – if *rlm=1* and *trl=4* and *tr=4* and *chi=4* and *(Φ/12)>(50*S)*, then $k1 = \left\lfloor \frac{\Phi/12-50*S}{Pl} \right\rfloor$; $scoffl_{137}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=1* and *(Φ/12)>(6.25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-6.25*S}{Pl} \right\rfloor$; $scoffl_{138}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=2* and *(Φ/12)>(7.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-7.5*S}{Pl} \right\rfloor$; $scoffl_{139}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=3* and *(Φ/12)>(9.38*S)*, then $k1 = \left\lfloor \frac{\Phi/12-9.38*S}{Pl} \right\rfloor$; $scoffl_{140}$ – if *rlm=1* and *trl=4* and *tr=5* and *chi=4* and *(Φ/12)>(12.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-12.5*S}{Pl} \right\rfloor$; $scoffl_{141}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=1* and *(Φ/12)>(6.25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-6.25*S}{Pl} \right\rfloor$; $scoffl_{142}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=2* and *(Φ/12)>(7.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-7.5*S}{Pl} \right\rfloor$; $scoffl_{143}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=3* and *(Φ/12)>(9.375*S)*, then $k1 = \left\lfloor \frac{\Phi/12-9.375*S}{Pl} \right\rfloor$; $scoffl_{144}$ – if *rlm=2* and *trl=4* and *tr=1* and *chi=4* and *(Φ/12)>(12.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-12.5*S}{Pl} \right\rfloor$; $scoffl_{145}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=1* and *(Φ/12)>(18.75*S)*, then $k1 = \left\lfloor \frac{\Phi/12-18.75*S}{Pl} \right\rfloor$; $scoffl_{146}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=2* and *(Φ/12)>(22.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-22.5*S}{Pl} \right\rfloor$; $scoffl_{147}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=3* and *(Φ/12)>(28.125*S)*, then $k1 = \left\lfloor \frac{\Phi/12-28.125*S}{Pl} \right\rfloor$; $scoffl_{148}$ – if *rlm=2* and *trl=4* and *tr=2* and *chi=4* and *(Φ/12)>(37.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-37.5*S}{Pl} \right\rfloor$; $scoffl_{149}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=1* and *(Φ/12)>(8.335*S)*, then $k1 = \left\lfloor \frac{\Phi/12-8.335*S}{Pl} \right\rfloor$; $scoffl_{150}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=2* and *(Φ/12)>(10*S)*, then $k1 = \left\lfloor \frac{\Phi/12-10*S}{Pl} \right\rfloor$; $scoffl_{151}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=3* and *(Φ/12)>(12.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-12.5*S}{Pl} \right\rfloor$; $scoffl_{152}$ – if *rlm=2* and *trl=4* and *tr=3* and *chi=4* and *(Φ/12)>(16.67*S)*, then $k1 = \left\lfloor \frac{\Phi/12-16.67*S}{Pl} \right\rfloor$; $scoffl_{153}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=1* and *(Φ/12)>(12.5*S)*, then $k1 = \left\lfloor \frac{\Phi/12-12.5*S}{Pl} \right\rfloor$; $scoffl_{154}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=2* and

*(Φ/12)>(15*S)*, then $k1 = \left\lfloor \frac{\Phi/12-15*S}{Pl} \right\rfloor$; *scoffl*$_{155}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=3* and *(Φ/12)>(18.75*S)*, then $k1 = \left\lfloor \frac{\Phi/12-18.75*S}{Pl} \right\rfloor$; *scoffl*$_{156}$ – if *rlm=2* and *trl=4* and *tr=4* and *chi=4* and *(Φ/12)>(25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-25*S}{Pl} \right\rfloor$; *scoffl*$_{157}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=1* and *(Φ/12)>(3.125*S)*, then $k1 = \left\lfloor \frac{\Phi/12-3.125*S}{Pl} \right\rfloor$; *scoffl*$_{158}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=2* and *(Φ/12)>(3.75*S)*, then $k1 = \left\lfloor \frac{\Phi/12-3.75*S}{Pl} \right\rfloor$; *scoffl*$_{159}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=3* and *(Φ/12)>(4.69*S)*, then $k1 = \left\lfloor \frac{\Phi/12-4.69*S}{Pl} \right\rfloor$; *scoffl*$_{160}$ – if *rlm=2* and *trl=4* and *tr=5* and *chi=4* and *(Φ/12)>(6.25*S)*, then $k1 = \left\lfloor \frac{\Phi/12-6.25*S}{Pl} \right\rfloor$; *scoffl*$_{161}$ – if *rlm=3* and (*trl=1* or *trl=2* or *trl=3* or *trl=4*) and (*tr=1* or *tr=2* or *tr=3* or *tr=4* or *tr=5)* and (*chi=1* or *chi=2* or *chi=3* or *chi*=4) and *(Φ/75)>0*, then turn off all the lamps that are on.

The set of scenarios for calculating the number of lamps that must be turned off to ensure the required level of luminosity, represented by formula (8), consists of four subsets:

$$SCOFFL = \{SCOFFLLED, SCOFFLES, SCOFFLH, SCOFFLI\}, \quad (9)$$

where *SCOFFLLED={scoffl*$_1$*…scoffl*$_{40}$*, scoffl*$_{161}$*}* – subset of scenarios for turning off LED lamps; *SCOFFLES={scoffl*$_{41}$*…scoffl*$_{80}$*, scoffl*$_{161}$*}* – subset of scenarios for turning off energy-saving lamps; *SCOFFLH={scoffl*$_{81}$*…scoffl*$_{120}$*, scoffl*$_{161}$*}* – subset of scenarios for turning off halogen lamps; *SCOFFLI={scoffl*$_{121}$*…scoffl*$_{160}$*, scoffl*$_{161}$*}* – subset of scenarios for turning off incandescent lamps.

After forming the set of alternatives, the residential luminosity control subsystem of «Smart House» cyber-physical system must evaluate all available scenarios in order to choose the best alternative(s) – for example, to give priority to the scenario with the maximum use of natural lighting and the minimum use of artificial lighting to ensure maximum energy efficiency.

Then *method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system* (starts to execute or every 5 minutes, if the user does not change the lighting mode, since the subsystem must constantly respond to changes in lighting, or immediately when the lighting mode is changed by the user) will consist of the following steps:

1. measurement by the sensors of the residential luminosity control subsystem of «Smart House» cyber-physical system of the luminous flux with available lighting (for the first iteration after changing the lighting mode, the subsystem turns off all artificial lighting and measures the luminous flux only for natural lighting; measurements are performed either every 5 minutes or immediately when the lighting mode is changed by the user) – the measured value is assigned to variable *Φ*
2. if *asd=1*, then check the position of the blinds (if the blinds are fully open, then the variable *bp* is assigned 0; if the blinds are completely closed, then the variable *bp* is assigned 1), else, if *asd=2*, then check the position of the roller shutters (if roller shutters are fully open, then the variable *rsp* is assigned 0; if the roller shutters are completely closed, then the variable *rsp* is assigned 1), else, if *asd=3*, then check the position of the curtains (if the curtains are fully open, then the variable *cp* is assigned 0; if the curtains are completely closed, then the variable *cp* is assigned 1)
3. search of the scenario according to the values of the variables *rlm, tr, chi, S* and *Φ* in the subsets *SCPS, SCPE, SCPIS*
4. if according to the values of the variables *rlm, tr, chi, S* and *Φ* the residential luminosity control subsystem of «Smart House» cyber-physical system» found a scenario in *SCPS* subset, then at this moment in time the luminosity corresponds to the norm, so the subsystem does not perform any actions
5. if according to the values of the variables *rlm, tr, chi, S* and *Φ* the residential luminosity control subsystem of «Smart House» cyber-physical system found a scenario in *SCPIS* subset, then:
   5.1. at this moment of time, the luminosity is insufficient, so the subsystem must perform the addition of luminous flux
   5.2. if *asd=0*, then proceed to step 5.5
   5.3. if *asd=1* and *bp=0*, then proceed to step 5.5, else, if *asd=2* and *rsp=0*, then proceed to step 5.5, else, if *asd=3* and *cp=0*, then proceed to step 5.5

5.4. if *asd=1* and *bp≠0*, then turn on the blinds by 1 degree and go to step 1, else, if *asd=2* and *rsp≠0*, then raise the roller shutters to open by 1 cm and go to step 1, else, if *asd=3* and *cp≠0*, hen move the curtains to open by 1 cm each and go to step 1

5.5. turning on additional lamps: the scenario is searched according to the values of the variables *rlm, trl, tr, chi, S, Pl* and *Φ* in the set *SCAL* (if *trl=1*, then the scenario is searched in *SCALLED* subset; if *trl=2*, then the scenario is searched in *SCALES* subset; if *trl=3*, then the scenario is searched in *SCALH* subset; if *trl=4*, then the scenario is searched in *SCALI* subset); if the number of additional lamps (*k*) calculated according to the found scenario is available (*k≤ak*), then the subsystem turns on *k* lamps, else it issues a message about the impossibility of providing the required level of luminosity with the existing lamps and a recommendation to add (*k-ak*) lamps in this room

6. if according to the values of the variables *rlm, tr, chi, S* and *Φ* the residential luminosity control subsystem of «Smart House» cyber-physical system found a scenario in *SCPE* subset, then:

6.1. at this moment in time, there is excess luminosity, so the subsystem must perform a reduction of the luminous flux

6.2. if *asd=0*, then proceed to step 6.5

6.3. if *asd=1* and *bp=1*, then then proceed to step 6.5, else, if *asd=2* and *rsp=1*, then proceed to step 6.5, else, if *asd=3* and *cp=1*, then proceed to step 6.5

6.4. if *asd=1* and *bp≠1*, then turn off the blinds by 1 degree and go to step 1, else, if *asd=2* and *rsp≠1*, then lower the roller shutters to close by 1 cm and go to step 1, else, if *asd=3* and *cp≠1*, then move the curtains to close by 1 cm each and go to step 1

6.5. turning off extra lamps: the scenario is searched according to the values of the variables *rlm, trl, tr, chi, S, Pl* and *Φ* in the set *SCOFFL* (if *trl=1*, then the scenario is searched in *SCOFFLLED* subset; if *trl=2*, then the scenario is searched in *SCOFFLES* subset; if *trl=3*, then the scenario is searched in *SCOFFLH* subset; if *trl=4*, then the scenario is searched in *SCOFFLI* subset); if the number of lamps that must be turned off (*k1*), calculated according to the found scenario, is available (*k1≤ak*), then the subsystem turns off *k1* lamps, else it issues a message about the impossibility of providing the required level of luminosity with the available means and a recommendation to add additional shading devices in this room

The developed method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system provides the user of the subsystem with the ability to quickly and conveniently configure the necessary lighting mode.

4. Results & Discussion

Let's consider the operation of the proposed method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room and method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system.

For *experiment 1*, the user configured the residential luminosity control subsystem of «Smart House» cyber-physical system for the room "working cabinet" according to the method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room. For this purpose, the user selected the type of room - "working cabinet" (*tr=4*), selected the ceiling height interval of the room - "2.5-2.7 m" (*chi=1*), entered the value of the area of the room - "18 m^2" (*S=18*), selected type of lamps used in the room - "halogen" (*trl=3*), entered the power value of one used lamp - "50 W" (*Pl=50*), entered the number of lamps used in the room - "8" (*ak=8*), selected the availadle in the room shading device - "no shading devices are used" (*asd=0*), selected the start room lighting mode - "activity" (*rlm=1*).

Then, in accordance with step 1 of the method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system, measurements of the luminous flux were made with the sensors of the subsystem with available natural lighting (*Φ=1900* lumens). Since *asd*=0, no action is taken in step 2 of the method. According to step 3 of the method, the scenario is searched – since *rlm=1, tr=4, chi=1, S=18* and *Φ=1900*, the scenario from *SCPIS* subset is chosen: scp_{39} – if *rlm=1* and *tr=4* and *chi=1* and *Φ<300*S (1900<5400)*, then the

available luminosity is insufficient. There is a transition to step 5 of the method. According to 5.1, a decision is made that at the moment the available luminosity is insufficient, so the subsystem must perform the addition of luminous flux. According to 5.2, since *asd=0*, the transition to step 5.5 is performed. According to 5.5, additional lamps are turned on: the scenario is searched – since *rlm=1, trl=3, tr=4, chi=1, S=18, Pl=50* and *Ф=1900*, the scenario from *SCALH* subset is selected: $scal_{93}$ – if *rlm=1* and *trl=3* and *tr=4* and *chi=1* and *(Ф/15)<(20*S) (126.67<360)*, then $k = \left\lceil \frac{20*S-\Phi/15}{Pl} \right\rceil$. So, $k = \left\lceil \frac{20*18-1900/15}{50} \right\rceil = 5$. Since the number of additional lamps calculated according to the found scenario (*k=5*) is available (*5<8*), then subsystem turned on 5 lamps.

For experiment 2, the user configured the residential luminosity control subsystem of «Smart House» cyber-physical system for the room "bedroom" according to the method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room. For this purpose, the user selected the type of room - "bedroom" (*tr=3*), selected the ceiling height interval of the room - "2.5-2.7 m" (*chi=1*), entered the value of the area of the room - «25 m^2» (*S=25*), selected type of lamps used in the room - «LED» (*trl=1*), entered the power value of one used lamp - «10 W» (*Pl=10*), entered the number of lamps used in the room - «10» (*ak=10*), selected the availadle in the room shading device - "blinds" (*asd=1*), selected the start room lighting mode - "relax" (*rlm=2*).

Then, in accordance with step 1 of the method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system, measurements of the luminous flux were made with the sensors of the subsystem with available natural lighting (*Ф=300* lumens). At the step2, since *asd=1*, then the position of the blinds is checked (since the blinds are completely closed, then *bp=1*). According to step 3 of the method, the scenario is searched – since *rlm=2, tr=3, chi=1, S=25* and *Ф=300*, the scenario from *SCPIS* subset is chosen: scp_{87} – if *rlm=2* and *tr=3* and *chi=1* and *Ф<100*S (300<2500)*, then the available luminosity is insufficient. There is a transition to step 5 of the method. According to 5.1, a decision is made that at the moment the available luminosity is insufficient, so the subsystem must perform the addition of luminous flux. According to 5.4, since *asd=1* та *bp≠0,* then turn on the blinds by 1 degree and go to step 1. The subsystem performed this cycle (steps 1-2-3-5.1-5.4 of the method) until the blinds were fully opened.

When the blinds are fully opened (*bp=0*) luminous flux measured in step 1 of the method is 2300 lumens (*Ф=2300* lumens). At the step2, since *asd=1*, then the position of the blinds is checked (since the blinds are fully open, then *bp=0*). According to step 3 of the method, the scenario is searched – since *rlm=2, tr=3, chi=1, S=25* and *Ф=300*, the scenario from *SCPIS* suset is chosen: scp_{87} – if *rlm=2* and *tr=3* and *chi=1* and *Ф<100*S (2300<2500)*, then the available luminosity is insufficient. There is a transition to step 5 of the method. According to 5.1, a decision is made that at the moment the available luminosity is insufficient, so the subsystem must perform the addition of luminous flux. Since *asd≠0*, then no action occurs in step 5.2 of the method. According to 5.3, since *asd=1* and *bp=0*, the transition to step 5.5 is performed. According to 5.5, additional lamps are turned on: the scenario is searched – since *rlm=2, trl=1, tr=3, chi=1, S=25, Pl=10* and *Ф=2300*, the scenario from *SCALLED* subset is selected: $scal_{29}$ – if *rlm=2* and *trl=1* and *tr=3* and *chi=1* and *(Ф/75)<(1.335*S) (30.67<33.38)*, then $k = \left\lceil \frac{1.335*S-\Phi/75}{Pl} \right\rceil$. So $k = \left\lceil \frac{1.335*25-2300/75}{10} \right\rceil = 1$. Since the number of additional lamps calculated according to the found scenario (*k=1*) is available (*1<10*), then subsystem turned on 1 lamp.

The conducted experiments proved, that the developed method provides for the recognition of various situations in the lighting scenario (sufficient light flow, insufficient light flow, excess light flow – according to the current lighting standards) and support for decision-making regarding the lighting of the home according to the lighting mode set by the user (reflecting/closing shading devices, turning on/off the lamps – depending on the recognized situation).

5. Conclusions

Currently, the urgent problem is to ensure the ability of recognizing the situations and supporting the decision-making in the «Smart House» cyber-physical system.

The conducted survey of research showed that: known solutions provide for situation recognition and decision-making support only, as a rule, for one or two subsystems of the "Smart House" cyber-physical

system, and also do not provide for the possibility of assessing the sufficiency of information for decision-making in the "Smart House" cyber-physical system house". Therefore, the goal of our overall research is recognizing the situations and supporting the decision-making for all 5 subsystems of the «Smart House» cyber-physical system, with an assessment of the sufficiency of information for all decisions by developing a comprehensive situation recognition and decision support system in the «Smart House» cyber-physical system, and the purpose of this study is recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system.

The developed in this paper method for setting up the residential luminosity control subsystem of «Smart House» cyber-physical system for each room allows to enter the necessary parameters for further automatic operation of the residential luminosity control subsystem of «Smart House» cyber-physical system.

The developed method of recognizing the situations and supporting the decision-making in the residential luminosity control subsystem of «Smart House» cyber-physical system provides the user of the subsystem with the ability to quickly and conveniently configure the necessary lighting mode. In addition, the developed method provides for the recognition of various situations in the lighting scenario (sufficient light flow, insufficient light flow, excess light flow – according to the current lighting standards) and support for decision-making regarding the lighting of the home according to the lighting mode set by the user (reflecting/closing shading devices, turning on/off the lamps – depending on the recognized situation).

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