BACKGROUND FOR DEVELOPING THE PARAMETER CONTROL SYSTEM OF THE COMFORT ZONE OF OFFICE PREMISES

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DOI: https://doi.org/10.30525/978-9934-26-151-0-35

Abstract. The results of the research related to the selection and justification of the parameters of office space comfort zones and sensors for their control have been presented. The parameters that determine the comfort zone of the premises have been divided into two groups. The first group includes microclimate parameters (temperature, humidity, and air quality). The second group includes the parameters due to the equipment operation (radiation, lighting, dust, atmospheric pressure, noise). It has been shown that the level of comfort depends on the class of office space. For classes A and B, the microclimate parameters can be controlled and maintained by built-in air conditioning systems. However, the parameters of the second group require the development and implementation of specific engineering solutions. Class C, D, E office premises require the development and implementation of control systems, both for the microclimate parameters and the parameters due to the equipment operation.

The paper presents a thorough analysis of standards and scientific publications on the object of research. Based on the results of the analysis, it has been concluded that existing publications, as a rule, provide mechanisms and tools for assessing individual parameters of the comfort zone and do not provide recommendations for their generalized (comprehensive) definition. Standards regulate either the normalized values of parameters or provide methods, principles, approaches to obtaining them.

A three-step algorithm has been developed to define the parameters that determine the comfort zone of office premises. The peculiarity of this

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algorithm is that it allows simultaneously taking into account both the level of employee satisfaction with the comfort zone and the actual values of the parameters obtained using instrumental measurement methods. This approach allows finding a correlation between the results obtained by the questionnaire survey and by measuring and selecting the optimal parameter values of the office space comfort zone.

To determine the configuration of the control system of office space comfort zone more than 50 sensors manufactured by different firms and companies have been analyzed. The selection and substantiation of sensors were carried out by the method of comparative analysis of their technical characteristics. According to the results of the analysis, seven sensors were selected. In particular, the SHT30 sensor manufactured by the Swiss company Sensirion was chosen to determine the temperature and humidity; for measuring air quality BME680 sensor from the German company Bosch was chosen; to determine the illuminance – a sensor type GY-302; for electric radiation – digital unipolar sensor A3144; for the dust parameter – the sensor of the Chinese company Waveshare; for noise level measurement – a sensor based on the MAX9814 amplifier manufactured by the American company Arduino and for atmospheric pressure – a BMP280 sensor.

The research results should be used at the stage of control system development, both the microclimate parameters and the parameters due to the equipment operation. They are especially relevant for office premises of C, D, E classes, which have a lower level of comfort zone compared to classes A and B.

1. Introduction

Today, one of the leading places in the structure of modern production is occupied by information technology. According to statistics, there are about 12 million so-called «white-collar workers» in Ukraine [15]. These are employees who are engaged in IT business, public administration, financial activities, and communications, etc. They work in offices of different comfort classes.

According to the international standard, office space is divided into five classes. Class A and B office space has air conditioning, central heating, and air traffic. That is, they are more comfortable compared to premises of C, D, E classes.

The modern workplace of the employee who works in the field of IT technologies is equipped with the system block, the power supply unit, the monitor like Apple. The work is sedentary. The set of functions depends on the type of professional orientation of the employee.

According to statistics, the incidence of office workers is not lower than that of other professions. This is because the health of office workers is exposed to both harmful and dangerous production factors, and specific. The latter is typical for enclosed spaces with artificially regulated microclimate. However, diagnosis and treatment are quite difficult. The main diseases of office workers include osteochondrosis, headache, tunnel syndrome (computer mouse syndrome), dry eye syndrome, burnout, drowse, chronic fatigue syndrome, etc. In addition, office workers dealing with personal computer equipment have thermal disorders with an increase in average body temperature by 0.2-0.7 °C. The latter requires the normalization of microclimatic working conditions.

Therefore, the safe and productive work of office workers requires the creation of a comfort zone, however, it is quite difficult for office premises. This is due to the fact that the comfort zone is determined by many parameters. During the study, the latter were divided into two groups. The first group – the microclimate parameters, which include temperature, relative humidity, air quality. The second group – the parameters stipulated by the equipment operation. These include electrical radiation, lighting, dusting, atmospheric pressure, noise.

Thus, the research related to the creation of a comfortable work area in office space through the development and implementation of modern engineering solutions is an urgent and timely task.

The object of research is to improve the process of controlling the parameters of the office space comfort zone.

The subject of the study is office space, comfort zone parameters, engineering, and technical solutions for building a control system.

Methodological basis. A systematic approach to the study of the object of the control parameters of office space comfort zone. To solve the tasks, the following methods have been used: questionnaires and systematic and comparative analysis.

The purpose of the study is to develop tools and engineering solutions for creating comfortable work areas in the office space.

The task of this study is:

– critical analysis of scientific works on this issue;

– selection and justification of the parameters that form the comfort zone of the office space;

– development of a step-by-step algorithm for determining the comfort zone of the office space;

– selection and substantiation of sensors for developing the control system of the office space comfort zone.

2. Analysis of recent publications on the problem

The paper [1] presents the results of studies on the satisfaction range of office workers with the microclimate parameters (air temperature and lighting). The authors propose to assess the comfortable level of lighting using expert methods. In particular, by a questionnaire survey of employees and simultaneous measurement of standardized characteristics of these parameters according to the requirements of ISO 7730 [1].

One of the most important parameters for office premises where the information technology is a working tool according to the standard [5] should be the lighting. In [15] the research of office space lighting is given. It is proved that the illumination in the range of 600 and 650 lux is the most suitable for a potential consumer. However, the data from these studies do not match the norms recommended by most standards. For example, the standard NS-EN 12464-1: 2021 [2] normalizes this parameter within 500 lux. According to the British standard BS 8206-2, the average daylight ratio must be at least 2% [4]. The latter requires the development of engineering measures to normalize this parameter in accordance with the approved requirements.

So, despite the large number of studies conducted on the parameters of comfortable lighting, today there is a big problem to determine its acceptable level.

In the field of research on microclimate problems, in our opinion, the most promising are the areas where the parameters that determine the microclimate are combined and presented in the form of complex criteria. Thus, the authors of [8] propose to use the «radiation temperature vector» as a criterion for microclimate comfort. This approach allows taking into account the air temperature and thermal radiation people are exposed to.

However, this does not take into account such important parameters of the microclimate as relative humidity, mobility, and air quality.

In [9] it is proposed to apply the concept of «operating temperature». It includes temperature, relative humidity, thermal radiation. However, the dependences proposed by the authors are suitable only for air mobility of 0.07-0.08 m/s.

In [10] the concept of «criterion of microclimate comfort» is used. It is more capacious and combines temperature, relative humidity, air mobility, and dust content. However, this concept can be applied only to production facilities with high dust emissions.

In [11] 28 diagrams of microclimatic conditions of comfort are given, which the authors propose to divide into three groups. The first group includes 12 diagrams built for the average radiation temperature of the room at different values of relative humidity and air mobility. The second group consists of four diagrams for different values of air mobility. These diagrams are based on the air temperature and the average radiation temperature of the room. The third group includes 12 diagrams constructed for different values of mobility and air temperature and relative humidity equal to 50%. The disadvantages of using the proposed diagrams include the inconvenience of graphical determination of the microclimate comfort parameters.

Thus, based on the results of research, we can conclude that a comprehensive assessment of the comfort zone of office space microclimate has a number of limitations. In particular, this applies to the simultaneous measurement of several microclimate parameters, the application of existing methods, and the availability of measuring equipment.

3. Selection and justification of parameters that form the comfort zone

The comfort level of office premises, as mentioned earlier, is determined by both the microclimate parameters and the equipment parameters. Table 1 shows a list of these parameters depending on the class of office space.

To create comfortable workplace areas, all these parameters must be constantly monitored and maintained in the normal range. However, the standards regulate the requirements for each of the parameters separately and do not provide methods, principles, approaches to obtaining their complex value.

Table 1

Parameters of the office space comfort zone depending on the class

№	Class of office space	Parameters							
		1 group			2 group				
		1	2	3	4	5	6	7	8
1	A	+	+	+	+	+	+	+	+
2	B	+	+	+	+	+	+	+	+
3	C	+	+	+					
4	D	+	+						
5	E	+	+						

Note: 1 – temperature; 2 – relative humidity; 3 – air quality; 4 – electrical radiation; 5 – lighting; 6 – dusting; 7 – atmospheric pressure; 8 – noise.

To determine the comfortable thermal conditions, it is advisable to use the comfort index, which consists of equivalent and effective temperature indices.

The use of equivalent and effective temperature indices allows determining the comfort zones taking into account the standard ISO 7730: 2005 [1]. The PDD and PMV indices are used. More detailed procedures for assessing the level of comfort concerning the office space microclimate are given in [13].

Standard [1] provides for three classes of premises according to the thermal comfort level. They are:premises of comfort class A: – 0,2 <PMV <+ 0,2 (PPD <6%); premises of comfort class B: – 0.5 <PMV <+ 0.5 (PPD <10%); premises of comfort class C: – 0,7 <PMV <+ 0,7 (PPD <15%). Figure 1 shows the functional dependence of PDD on PMV for different classes of office space for cold and warm periods of the year.

It should be noted that the given level of parameters that determine the comfort zones of the office space is influenced by external and internal factors. For example, the level of the electromagnetic field of the office depends on its location. In [6] it was proved that in large industrial cities, where a lot of electricity is used, there is a risk of stronger electromagnetic fields. According to the same source, the average level of the electromagnetic field in the office varies from 0.01 to 0.2 μT, if the office is not near power lines or another external source.

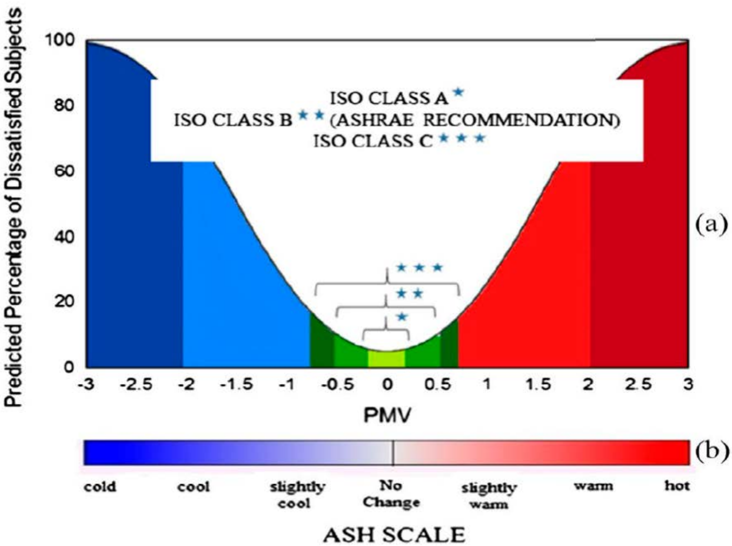

Figure 1. Functional dependence of PPD = f (PMV) [7]

Analysis of the results of sanitary and hygienic research proves that in many cases office work requires the normalization of microclimatic conditions, in terms of optimizing the aeroionic air composition and the introduction of rational operation modes. Standard DSTU ISO 9241: 2004 «Ergonomic requirements for working with video terminals in the office» provides methodological approaches to the organization of the workplace of office people [3].

Thus, to determine the parameters of the office space comfort zone, taking into account the conditions of potential consumers, it is required to have special tools that will work according to certain procedures.

4. Building an algorithm to determine the comfort zone

During the study to determine the office space comfort zone, a three-step algorithm was developed (Figure 2).

The first step is to choose the factors that affect the level of satisfaction of office workers with the comfort zone. To do this, the internal and external factors that affect the level of perception of the office space comfort

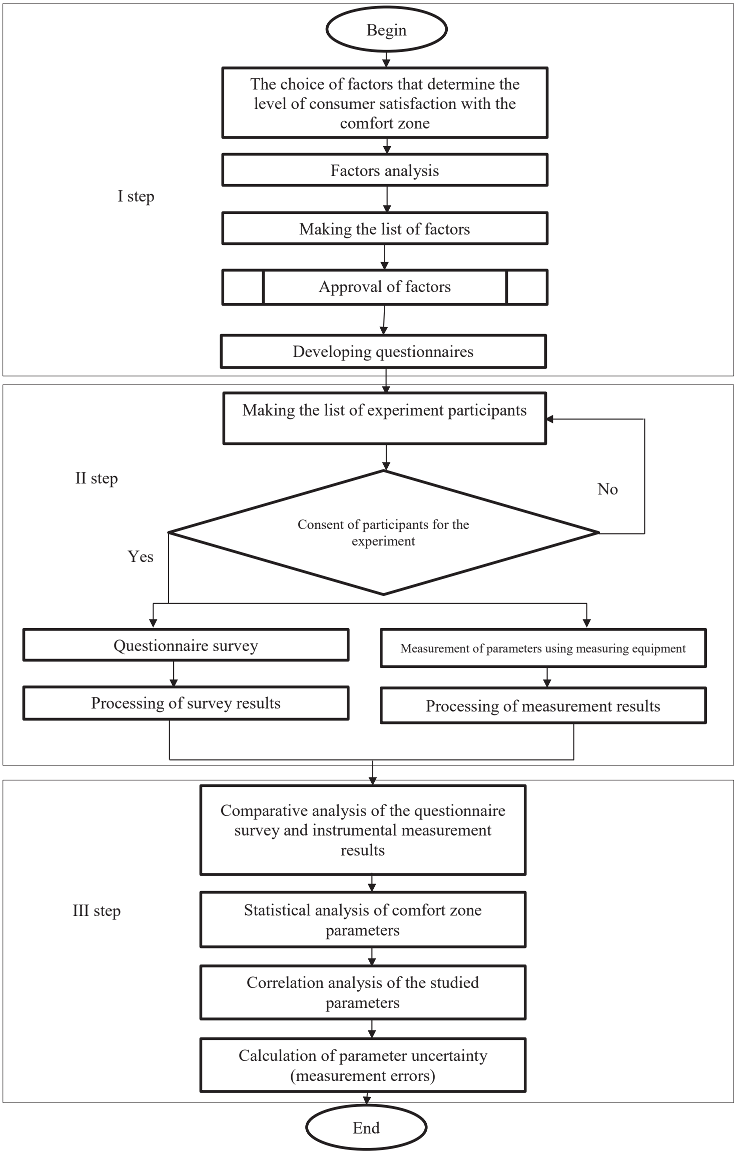

Figure 2. Algorithm for determining the office space comfort zone

parameters should be analyzed. In particular, on temperature, relative humidity, and air quality, electric radiation, lighting, dusting, atmospheric pressure, noise. Based on the results of the analysis, a list of factors is formed, which is then used to build a questionnaire. The questionnaire consists of two sections. The first section is general information (gender, age, type of office worker). The second section deals with the level of perception of comfort parameters by the office worker (senses satisfaction by physical and ecological parameters). Questionnaires are conducted for the warm and cold periods of the year. Figure 3 shows a fragment of the questionnaire.

As can be seen from the figure, when determining the comfort of the lighting parameter, such external factors as the perception of the lighting

Section A – Demography						
General information	General	age	sex	Right hand/left hand		
	Regarding work	Activity	Paper work	Working with a computer	Complex	Another activity
		Working hours	> 8 hours	7-8 hours	4-6 hours	< 4 hours
		How long have you been working in the office?				
	Problems with visual effects	Do you have pain when working with a computer? Do you have sensitivity to light? Do you use glasses?				
Section B – Perception of lighting						
Perceived lighting level	Please provide an overall assessment of the lighting level in your office:					
	Very little	Little	Average	Much	Too much	
	How do you assess the level of lighting at the height of your desk?					
	Very little	Little	Average	Much	Too much	
	Please rate your satisfaction with lighting when working with a computer:					
	Very little	Little	Average	Much	Too much	
	Please rate your satisfaction of lighting when writing/reading a paper:					
	Very little	Little	Average	Much	Too much	
The tendency to change the amount of light	What is your wish to increase the amount of light?					
	Very little	Little	Average	Much	Too much	
	What is your wish to reduce the amount of light?					
	Very little	Little	Average	Much	Too much	
Lighting distribution	Please rate your satisfaction with the distribution of lighting throughout the room:					
	Very little	Little	Average	Much	Too much	
Light sources	Which of these light sources do you prefer?					
	Daylight	Lamplight	Combination of both			

Figure 3. Fragment of the questionnaire for the lighting parameter

level, satisfaction with lighting, the need to change the amount of light, and light sources were taken into account. To evaluate the results of the questionnaire in [12], it is proposed to use a five-point Likert scale.

The **second step** of the algorithm involves an experiment to determine the values of the parameters of the comfort zone. The list of experiment participants is formed of office workers taking into account the age, gender, and profile of the employee. To obtain accurate and reliable results, the survey conditions must be the same for all participants in the experiment. In addition, in the office, the measurement of the first and second groups of parameters is carried out using measuring equipment at the same time as the survey. The results of the experiment are processed according to existing rules and regulations.

In **the third step**, a comparative analysis is performed to determine the correlation between the results of the questionnaire survey and the instrumental measurement. Based on the results of this analysis, engineering and technical solutions for the creation and maintenance of the office space comfort zone are further developed.

The application of this algorithm allows you to more reasonably choose the parameters to create an office space comfort zone and the types of sensors to build their control systems.

5. Selection of sensors for building a control system.

Some of the above parameters can be adjusted by engineering methods. For example, in office premises, A and B, the parameters of the microclimate, dusting, determination of the content of harmful chemicals in the air, etc. are regulated automatically.

In the premises of other classes (C, D, E) deviations of these parameters from hygienic standards are quite often observed. That is, the level of the comfort zone decreases. Therefore, for these premises, it is necessary to develop and implement special control systems and automatic maintenance of comfort parameters. The most promising, in our opinion, are systems that provide control of the comfort zone by determining its complex parameter. However, this requires the use of special controls. In particular, various types of sensors for monitoring and improving the quality of the office space comfort zone.

The sensors developed and manufactured by different countries for building parameter control systems have been analyzed. When choosing sensors, it was taken into account that the system must give a result on a complex parameter. That is, special attention was paid to such requirements as the level of automation of the system, feedback, the ability to self-configure and connect to the microcontroller, simultaneous control of several parameters, the implementation of data transmission over the LAN.

By conducting a comparative analysis of the metrological characteristics of existing sensors to build parameter control of the production space comfort zone, including office space, a number of modules developed by companies and firms from different countries were selected. Let's analyze each of them in more detail.

The basic sensor model of the Swiss company Sensirion SHT30 was chosen to determine such parameters as temperature and humidity. This sensor opens a new level in measurement technology. It is available in two versions: with analog voltage output and with digital I2C output. The functional diagram of the sensor includes a signal processing and amplification circuit, a signal linearization circuit, a calibration memory unit, an analog-to-digital converter, and a voltage output circuit. The I2C digital data interface has a baud rate of up to 1 MHz and two selectable address cells. Technical characteristics of the sensor are given in table 2.

Table 2

Technical characteristics of the SHT30 sensor

№	**Characteristics**	**Value**
1	**2**	**3**
1	Manufacturer	Sensirion
2	Relative humidity range	from 0% to 100%
3	Accuracy of relative humidity range	+/- 3%
4	Installation type	SMD/SMT
5	Output type	digital
6	Interface type	I2C
7	Operating current of the power supply	800 mA
8	Temperature measurement range	-40...125 C
9	Body type	DFN-8
10	Supply voltage	2,4...5,5 B.
11	Size	2.5x2.5x0.9 mm

The BME680 digital sensor, developed by the German company Bosch, was chosen to measure air quality parameters. The principle of operation of the digital module is to read data from the BME680 sensor. The latter is placed on the microcontroller board. Data on air quality are obtained by applying a special algorithm that comprehensively takes into account the values of temperature, humidity, and atmospheric pressure. The module can be connected to any type of microcontroller or minicomputer. The data is read via the I2C interface, which has two modes of data output (continuous output and output on request). Technical characteristics of the sensor are given in table 3.

Table 3

Technical characteristics of the BME680 sensor

№	**Characteristics**	**Value**
1	**2**	**3**
1	Manufacturer	Bosch
2	Temperature measurement range	from -40 °C to + 85 °C
3	Humidity measurement range	from 0% to 100%
4	Air pressure measuring range	from 300 to 1100 hPa
5	Frequency of measurements	in default 3 sec
6	Operating voltage	from 3 V to 5 V
7	Operating current	up to 12 mA
8	Operating temperature	from -40 °C to + 85 °C
9	Size	12 x 30 mm

A digital light sensor type GY-302 was selected to measure the backlight. It is built on the BH1750 chip. The latter is a 16-bit light sensor with an I2C interface. The use of photodiode BH1750 allows determining the intensity of light that is converted into output voltage using an operational amplifier. Digital data is received in suites through the built-in analog-to-digital converter. The advantages of this sensor include direct digital output without additional complex calculations, transformations, and calibration. Technical characteristics of the sensor are given in table 4.

In practice, the A3144 digital unipolar sensor is typically used to measure electromagnetic radiation. It is based on the Hall effect. The sensor has an analog output and a digital output of the LM393 comparator. The advantages of the sensor are high reliability and small size. The characteristics of the sensor A3144 are shown in table 5.

Table 4

Technical characteristics of the GY-302 sensor

№	Characteristics	Value
1	**2**	**3**
1	Type	GY-302.
2	The original chip	BH1750
3	Measurement accuracy	1 lux
4	Supply voltage	3-5 V
5	Illumination range	0-65535 lx
6	Interface type	I2C
7	Size	13.9 x 18.5 mm

Table 5

Technical characteristics of the A3144 sensor

№	Characteristics	Value
1	**2**	**3**
1	Sensor type	unipolar
2	Interface	digital
3	Response time	2 ms
4	Magnetic range	from ± 20 G to ± 450 G
5	Output voltage	0,4 V
6	Output current	up to 10 μA
7	Operating voltage	4,5 – 24 V
8	Current	up to 9 mA
9	Permissible temperature	from -65 to +170 ° C
10	Body	TO-94
11	Weight	less than 1 gr

To determine such a parameter as dusting, a universal sensor based on Sharp GP2Y1010AU0F, developed by the Chinese company Waveshare, was chosen. This sensor allows detecting dust particles from 0.8 μm. In addition, it can detect the presence of cigarette smoke, which is a very important problem for the office. The sensor has high energy efficiency. It is used as a sensitive element in air purifiers, air conditioners, air quality detectors. Its design is based on infrared LEDs. This allows the detection of fairly small dust particles. The technical characteristics of the sensor are shown in table 6.

Table 6

Technical characteristics of the dust sensor based on Sharp GP2Y1010AU0F

№	Characteristics	Value
1	**2**	**3**
1	Manufacturer	Waveshare
2	Supply voltage	2.5B – 5.5V
3	Sensitivity	0.5V / (100 μg/m³)
4	Measuring range	500 μg/m³
5	Operating current	20mA (max.)
6	Operating temperature	-10 °C – 65 °C
7	Size	63.2 x 41.3 x 21.1 mm

The American company Arduino has developed a sound sensor module, which should be used to detect noise in the office. The sensor has a built-in amplifier MAX9814 with a programmable gain of 40, 50 or 60 dB. The technical characteristics of the sensor are shown in table 7.

Table 7

Technical characteristics of the sensor module with built-in amplifier MAX9814

№	Characteristics	Value
1	**2**	**3**
1	Manufacturer	Arduino
2	Operating voltage	2.7...5.5 V
3	Current	3 mA
4	Amplifier	MAX9814
5	Microphone type	electret
6	Temperature range	-40°C..+85°C
7	Size	23x14 mm

The BMP280 barometer was selected for atmospheric pressure. It is controlled by the I2C bus (TWI). The atmospheric pressure module is based on the BMP280 sensor. Its advantages are rather low power consumption, high accuracy, and the presence of two interfaces. The module can work in three modes: SLEEP, FORCED, NORMAL. The first mode is the mode of reduced power consumption. In FORCED mode, the sensor on the command of the microcontroller performs procedures for measuring, transmitting the result, and switching to low power mode. For NORMAL mode, the sensor is programmed as follows: exit standby mode, perform pressure measurement, and switch to low power mode. Technical characteristics of the BMP280 sensor are shown in table 8.

Table 8

Technical characteristics of the BMP-280 sensor

№	Characteristics	Value
1	**2**	**3**
1	Supply voltage	From 1.71 V to 3.6 B
2	Max speed of I2C interface	3.4 MHz
3	Current	2.7μA at a sampling frequency of 1 Hz
4	Interface type	I2C
5	Measured pressure range	from 300hPa to 1100hPa
6	Size	21 mm x 18 mm

Thus, to create a configuration of the parameter control system of the production space comfort zone, including and office space, it is advisable to use the above sensors as primary transducers. The use of these sensors will create a comfort zone taking into account the wishes of potential consumers.

6. Conclusions

1. It has been proved that the level of comfort of office space is influenced by two groups of parameters. The first group is the microclimate parameters (temperature, relative humidity, air quality). The second group – the parameters stipulated by the equipment operation (radiation, lighting, dusting, atmospheric pressure, noise).

2. It has been proposed to determine the level of the office space comfort zone by a complex parameter taking into account the satisfaction of the potential consumer (in our case, the office worker).

3. To determine the complex parameter of the office space comfort zone, a three-step algorithm has been developed. The application of this algorithm allows us to compare the results of the questionnaire and instrumental measurement, to find a correlation between them and the results of the latter to calculate the optimal value of the complex parameter.

4. The developments of various companies and firms engaged in the manufacture of sensors have been analyzed to determine the parameters of office space comfort, on their basis, the seven most suitable models have been selected. In particular, the following sensors have been chosen: the SHT30 sensor manufactured by the Swiss company Sensirion has been chosen to determine the temperature and humidity; for measuring air quality – BME680 sensor from the German company Bosch; to determine the illuminance – a sensor type GY-302; for electric radiation – digital unipolar sensor A3144; for the dusting parameter – the sensor of the Chinese company Waveshare; for noise level measurement – a sensor based on the MAX9814 amplifier manufactured by the American company Arduino and for atmospheric pressure – a BMP280 sensor.

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