The effectiveness of the Smart Office system

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Abstract. The capabilities of the Smart Office system allow you to control lighting, climate, safety in the building, as well as the work process as a whole. To assess the effectiveness of investments in the Smart Office system, the net present value, profitability index and payback period were calculated. The calculations showed that the implementation of the smart office system is an expensive, but justified in terms of energy efficiency and economy. As a result of the calculation, it was found that the cost of the system, taking into account the annual increase in utility tariffs by 7% and the increase in the discount rate by 9%, will pay off in 6 years, and the costs will begin to save money during the operation of the building.

1. Introduction

Smart Office system is a software and hardware complex for automatic control of systems and devices, which allows you to combine the entire engineering component of enterprises into a single management system, while reducing operating costs for maintenance (introducing unified monitoring and reducing the number of staff), water supply, heat and electricity, increasing safety and energy efficiency through the balanced operation of systems and the use of savings mechanisms.

Experts divide the concept of smart office into two components - technological and conceptual. Technologically, a Smart Office is not much different from a Smart Home, but it implies a wider application of technologies, providing great opportunities.

For example, a feature of a Smart Office is the creation of automated work scenarios with fixed preset lighting and microclimate settings for each room individually, taking into account the functional purpose of the room, working conditions, work schedule, number of employees in each individual room, etc. In addition, the Smart Office system is distinguished from the Smart Home by special design solutions aimed at organizing and optimizing the work process.

The principles of operation of any automated control system is reduced to the connection “sensor – actuator”. The sensor's tasks are to monitor the status of the parameters reporting to it and issue control signals. The tasks of executive devices are to receive control signals from sensors, process them and perform actions that correspond to the received signals.

The heart of the entire Smart Office system is the controller, a device that connects all the sensors, cameras, and bulbs in the office. Using the controller, you can fully control all the life support systems of the building, prescribe “scenarios” of interaction between devices. System requirements are determined by the customer and are programmed at the stage of system installation.

Features of the Smart Office system:
1. **Lighting control.** Using the “smart office” system, you can control any light source in all rooms, regardless of where the lamp is located and what type it is. Also, for the regulation of natural light, it is possible to control the electric drives of roller blinds and blinds. With the help of motion sensors it is possible to regulate the operation of lighting devices in rooms where workers are not on an ongoing basis, for example, in bathrooms or technical rooms. Intelligent lighting control reduces energy costs by an average of 30-40% and significantly saves energy, reducing peak load and increasing the life of the fixtures, which also reduces operating costs.

2. **Climate control.** Based on the readings of temperature, humidity and air sensors, an automatic control system allows you to maintain an optimal microclimate. Automatic mode helps to efficiently use ventilation, air conditioning and heating systems, increasing efficiency and reducing the cost of their operation. Such a system will not allow, for example, the operation of the air conditioning system when the heating is on. The climate control system can warn the owner of the object about precipitation, wind strength, temperature outdoors and indoors. The system manages the climate automatically, for example, in hot weather it will turn on air conditioners and lower the blinds. Upon reaching the optimum microclimate, the power of heaters or air conditioners automatically decreases. If the room temperature drops below comfortable, the heating will turn on.

3. **Security management.** The complex of security systems of Smart Office includes:
   - Organization of video surveillance via Wi-Fi cameras and control using motion sensors and door opening. In the event of an unauthorized access attempt, an automatic call is made to the security agency.
   - Access control (depending on the position held by the employee, it is possible to restrict access to certain premises).
   - Monitoring of malfunctions and accidents of the building's engineering networks (leakage, fire, smoke sensors, short circuits, gas leaks). If an emergency occurs in the building, the system will automatically call all the necessary services and carry out protective actions.

4. **Workflow management.** Artificial intelligence will play a leading role in the work of a modern office, allowing to significantly increase the company's productivity. Office workflow management can be divided into the following categories:
   - IoT or Internet of things. In a simplified version, this can be described as a system of autonomous interaction between all devices in the office. This solution allows you to save a lot of time for office workers, removing from them the obligation to transfer data from one device to another.
   - Work in the cloud. Cloud computing will allow companies to do without the device and maintenance of powerful server rooms, which will significantly reduce the energy consumption in the building. All applications are stored and interact online.
   - Development of corporate instant messengers to integrate video chat, graphics sharing, voice chat and traditional messaging in one platform. This solution allows you to establish express communication between employees.
   - Organization of negotiations and meetings. The basic functionality of the control room management system includes: displaying the actual state of the meeting room: “free” or “busy”; automatic search for a suitable free space by the specified parameters; reservation of a free meeting room; active wiretap protection for meeting rooms.

5. **Other features.** The Smart Office system provides an opportunity to collect statistics on the occupancy of premises, the intensity of use of certain functional zones. This allows you to identify empty or congested areas of the office. All this helps to analyze and optimize the office space, increasing its efficiency and comfort. Also, the building provides for intelligent parking, which allows you to specify a free parking space, the availability of places for the disabled or places with chargers for electric cars.

To create a private atmosphere in meeting rooms, workrooms and other rooms, dynamic adjustment of the transparency of partitions made of smart window is used (figure 1).
2. Materials and methods
As the experience of domestic companies, as well as the experience of the USA and Western Europe, shows, an increase in the cost of equipping a building with modern automated building management systems during construction by 50% pays for itself in 2-4 years of operation. At the same time, the cost of operating an automated building for 20-30 years is 2.5 times less than that of a non-automated building; therefore, the total cost of owning a building equipped with automated building management systems is reduced by more than 1.5 times.

To assess the effectiveness of investing in the Smart Office system, we will calculate the net present value (NPV), profitability index (ID) and payback period.

First, we will calculate the cost of the purchase of devices and the installation of the system. By studying the market prices for the equipment of the Smart Office system, average values were obtained and the cost of installing and maintaining the system was calculated (Table 1).

Table 1. The list of devices of an automated building management system.

| Device                                              | Cost, USD | Quantity per floor | Quantity per building | Total cost, USD |
|-----------------------------------------------------|-----------|--------------------|-----------------------|-----------------|
| Ceiling motion sensor                               | 92        | 12                 | 312                   | 28,600          |
| Temperature, Light, and Humidity Sensor             | 112       | 24                 | 624                   | 69,680          |
| CO₂ level sensor                                    | 433       | 8                  | 208                   | 90,133          |
| Smoke detector                                      | 50        | 58                 | 1,508                 | 75,400          |
| Water leakage protection (sensor + damper mechanism) | 213       | -                  | 2                     | 427             |
| Smart lamp                                          | 25        | 100                | 2,600                 | 65,000          |
| Smart socket                                        | 25        | 200                | 5,200                 | 130,000         |
| Electric drive for curtains                         | 158       | 30                 | 780                   | 123,500         |
| Fan coil control unit                               | 163       | -                  | 5                     | 817             |
| Door lock system                                    | 207       | -                  | 2                     | 413             |
| 16 channel actuator                                 | 500       | 2                  | 52                    | 26,000          |
| Remote Control                                      | 17        | 72                 | 1,872                 | 31,200          |
| Control Panel                                       | 200       | 24                 | 624                   | 124,800         |
| Device and setup of notification system, web-interface and cloud work | 500       | -                  | 1                     | 500             |
| System Maintenance (per year)                       | -         | -                  | -                     | 500             |
| Use of virtual machines for cloud computing and cloud storage (subscription), per year | -         | -                  | -                     | 5,000           |
In total, the cost of installing an automation system for the entire business center building is 766,470 USD, and about 5,500 USD will be spent on annual maintenance.

Next, we will calculate the cost savings from using the system.

Using light sensors and smart lamps, it is possible to save. On average, from the maximum value, 75% of artificial light power is required in the morning, 50% in the afternoon. Accordingly, the average energy savings will be 37.5%.

Also, savings are due to the introduction of motion sensors in rarely used rooms. Due to this solution, a number of lamps (24 pieces located in technical and utility rooms) will work in a more economical mode. Energy saving in this case occurs due to the exclusion of the human factor (the employee forgot to turn off the light) and is about 33%. Then the total savings for these premises will be: 58.1%.

The total energy savings for lighting will be 42.5% (the average value per building).

According to the averaged data, the device of temperature regulators allows saving up to 35% on heat supply, and the leakage control system and water consumption allows saving up to 35% on water supply and sanitation.

Total, we take 35% for savings on all accounts.

We calculate the estimated monthly fee for utilities at current tariffs for enterprises (table 2).

| Table 2. Utility costs. |
|------------------------|
| **Type of service**    | **Cost, USD** | **Volume of consumption** | **Calculation** | **Total cost, USD** |
| Cold water supply      | 0.59 USD/m³  | 0.3 m³/person              | = 0.59 · 0.3 · 1,872 | 331 |
| Water disposal         | 0.7 USD/Gcal | 0.0095 Gcal/person         | = 0.7 · 0.0095 · 1,872 | 590 |
| Hot water supply       | 39.67 USD/m³| 0.45 m³/person             | = 39.67 · 0.45 · 1,872 | 705 |
| Heating                | 39.67 USD/Gcal | 0.994 Gcal/hour        | = 39.67 · 0.994 · 24 · 30 | 28,391 |
| Power supply           | 68.5 USD/(MW·hour) | 243 MW·hour | = 68.5 · 243 | 16,646 |

The average heating period for St. Petersburg is 7 months. Therefore, we accept expenses for 7 months with heating (46,663 USD per month), for 5 - without heating (18,272 USD per month). Correspondingly, total expenses for utilities for the year will amount to 418,000 USD.

According to the Federal State Statistics Service of the Russian Federation in recent years, the increase in the cost of utilities amounted to 7%. We accept this gain for calculation.

We calculate the savings from using the Smart Office system for 7 years (table 3).

| Table 3. Analysis of the effectiveness of the implementation of Smart Office system. |
|-------------------------------|
| **Type of service** | **1 year** | **2 year** | **3 year** | **4 year** | **5 year** | **6 year** | **7 year** |
| Without using a Smart Office system | | | | | | |
| Utility Payments, USD | -418,000 | -447,260 | -478,568 | -512,068 | -547,913 | -586,267 | -627,305 |
| Accumulated cash flow, USD | -865,267 | -1,343,850 | -1,855,933 | -2,403,867 | -2,990,150 | -3,617,467 | -3,617,467 |
| Using a Smart Office system | | | | | | |
| System Installation, USD | -766,483 | | | | | |
| Utility Payments, USD | -271,700 | -290,719 | -311,069 | -332,844 | -356,143 | -381,073 | -407,748 |
| Smart office costs, USD | -5,500 | -5,500 | -5,500 | -5,500 | -5,500 | -5,500 | -5,500 |
| Cash flow, USD | -1,043,683 | -296,217 | -316,583 | -338,350 | -361,650 | -386,583 | -413,250 |
| Savings / expense, USD | -625,183 | 151,050 | 162,000 | 173,733 | 186,283 | 199,700 | 214,067 |
| Accumulated cash flow, USD | -625,183 | -474,133 | -312,133 | -138,400 | 47,883 | 247,583 | 461,650 |
Based on table 3, a simplified table 4 was created. Here, the income is taken as savings on utility bills, and the costs of maintaining the system are taken as expenses.

**Table 4. Investment Project Indicators.**

| Index   | 0 year  | 1 year  | 2 year  | 3 year  | 4 year  | 5 year  | 6 year  | 7 year  | Total, USD |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|------------|
| Income, USD | 141,300 | 151,050 | 162,000 | 173,733 | 186,283 | 199,700 | 214,067 | 1,228,133|
| Expenses, USD | -766,483 | -5,500 | -5,500 | -5,500 | -5,500 | -5,500 | -5,500 | -804,983|
| Net income, USD | 135,800 | 145,550 | 156,500 | 168,233 | 180,783 | 194,200 | 208,567 | 423,150|

The discount rate is calculated by the formula 1:

\[ r = r_f + r_p + I \]  \hspace{1cm} (1)

where:
- \( r \) – discount rate;
- \( r_f \) – risk-free interest rate;
- \( r_p \) – risk premium;
- \( I \) – inflation rate.

\( r_f \) corresponds to the nominal discount rate and is equal to 2%. Risk premium (\( r_p \)):
- 1. Investments to intensify production: 3-5%.
- 2. Increase in sales of products: 8-10%.
- 3. The risk of market promotion of a new type of product: 13-15%.
- 4. Research and development costs: 18-20%.

We accept \( r_p = 4\% \), \( I = 3\% \) (inflation for 2019). Total, \( r = 2\% + 4\% + 3\% = 9\% \).

Calculation of net present value by the formula 2:

\[ NPV = \sum_{t=0}^{T} \frac{NCF_t}{(1 + r)^t} \]  \hspace{1cm} (2)

where:
- \( NCF \) – net cash flow;
- \( r \) – discount rate;
- \( T \) – project implementation period.

\[ NPV = \frac{135,800}{(1 + 0.09)^0} + \frac{145,550}{(1 + 0.09)^1} + \frac{156,500}{(1 + 0.09)^2} + \frac{168,233}{(1 + 0.09)^3} + \frac{180,783}{(1 + 0.09)^4} + \frac{194,200}{(1 + 0.09)^5} + \]

\[ + \frac{208,567}{(1 + 0.09)^6} = \frac{423,150}{(1 + 0.09)^6} = 411,356 \]

The project is effective because \( NPV > 0 \).

We will calculate the profitability index by formula 3. The higher the profitability index, the more profitable the project.

\[ PI = \frac{PV}{IC} = \frac{\sum_{t=0}^{T} CF_t}{IC} \]  \hspace{1cm} (3)

where:
- \( PV \) – total cash flow from the project;
- \( CF_t \) – cash receipts in the period \( t \) (Cash flow);
- \( r \) – discount rate;
IC – invested capital;
T – project implementation period.

\[ PI = \sum_{n=0}^{T} \frac{IC}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=1}^{T} \frac{\text{Discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=2}^{T} \frac{\text{Net discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=3}^{T} \frac{\text{Net discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=4}^{T} \frac{\text{Net discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=5}^{T} \frac{\text{Net discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=6}^{T} \frac{\text{Net discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + \sum_{n=7}^{T} \frac{\text{Net discounted cash flow}}{(1 + 0.09)\text{\textsuperscript{n}}} + 1 = 1.97 \]

Conclusion: the project is effective, because index is greater than one. Finally, we calculate the payback period (table 5).

**Table 5. Payback period calculation.**

| Indicators | 0 year | 1 year | 2 year | 3 year | 4 year | 5 year | 6 year | 7 year |
|------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Investments, USD | -766,483 |        |        |        |        |        |        |        |
| Discounted cash flow, USD | 124,583 | 122,500 | 120,850 | 119,183 | 117,500 | 115,800 | 114,100 |        |
| Net discounted cash flow, USD | -641,900 | -519,400 | -398,550 | -279,367 | -161,867 | -46,067 | 68,033 |        |

3. Results and discussion
Implementation of an automation system is an expensive but energy-efficient solution.

In this work, for the business center, the introduction of the Smart Office automation system is proposed, the cost of the device of which is 766,470 USD. In addition, the system requires maintenance: the total cost of maintaining the life support of the system per year will be 5,500 USD.

Due to the relatively high cost of implementing and maintaining the system, in this work it was decided to calculate the economic efficiency of its application.

As a result of the calculation, it was found that the cost of the system, taking into account the annual increase in tariffs of 7% and the discount rate of 9%, will pay off in 6 years, and the investment will begin to bring net savings in cash during the operation of the building. It is believed that the period of “moral aging” of equipment is 10-15 years, which is much more than the payback period obtained. At the same time, the service life of the equipment can be much longer.

In addition, if you take into account possible unforeseen incidents, for example, fire, flooding or theft, which can be avoided by using this building automation system, the benefits of its use will increase many times.

All of the above allows us to conclude that the introduction of the Smart Office automation system into the project is a profitable and effective investment, despite its high cost.

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