# Ergonomic Aspects of an Intelligent Building

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## ABSTRACT

The issue of intelligent building is one of the most important design challenges in today's world. The main factors that influence the development of an intelligent building are cultural, civilization, technical and economical conditioning. The development of information technology and control engineering has allowed the construction of a building that responds to the needs of people in an automatic and flexible way. Full integration of electronic systems allows a building to be categorised as smart objects and attest to its quality. Human factors are considered in the context of intelligent building design that is to adapt to the requirements of users in order to improve the quality of life. The purpose of this article is to show the ergonomic aspects of an intelligent building taking into account factors affecting the peace of mind and well-being of people in two environments: work environment and housing environment (work environment and housing environment are the primary spaces where people spend a major part of their life). These are not only technical factors, but also elements associated with the arrangement of space. The article discusses factors which also determine the quality of an intelligent building. It examines the ergonomic aspects within the interdisciplinary context taking into account, above all, convenience, comfort and safety of users.

**Keywords**: Intelligent building, ergonomic aspects, housing environment, working environment

## INTRODUCTION

Widespread access to consumer goods in the fifties and the sixties created demand for higher quality of life in affluent societies. On the other hand, the development of IT and automation has allowed to construct a building that responds to human needs in an automatic way at any given time. Since the beginning the idea behind developing an intelligent building has been to increase the comfort of use while reducing maintenance costs. Ergonomics, which explores the relationship between man and the elements of the environment, is developing in line with the direction set by technological progress and our civilization. This is of particular importance in an intelligent building. Human factors are considered in the context of intelligent building design that is to adapt to the requirements of users in order to improve the quality of life.

In this paper, ergonomic aspects of an intelligent building are explored against the backdrop of factors that affect mental comfort and well-being of people in two environments: work environment and housing environment. The aim of creating intelligent buildings is to create high-quality working environment but also in other aspect to create high-quality housing environment. It is worth pointing out that over the last twenty years intelligent buildings in most cases have developed into office buildings. In recent decades, with the development and popularization of information and communication technology, traditional ways of using space began to evolve. Nowadays, due to the ease of communication between people over the Internet, it is possible to work at home in many professions.



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An intelligent building is equipped with control systems that control almost everything. Thus, the building becomes more comfortable and better equipped with modern appliances. Such building, by offering a higher quality of both the physical environment and space, offers better conditions and better organization than conventional buildings, which in turn makes everyday life much easier. It is worth noting that all elements of a building that are controlled remotely offer great help for people with disabilities. What is more, intelligent building provides an opportunity to reduce maintenance costs while increasing user comfort.

## THE DEFINITION OF INTELLIGENT BUILDING

There is no single universal definition of an intelligent building. According to the definitions adopted internationally an intelligent building is a building that adapts to the changing conditions of its environment (Krainer, 1996), and is equipped with systems that provide comfortable living conditions. An intelligent building is a building that knows what is happening inside it and outside it and can decide the most effective way to create the right environment for users on time (Atkin, 1988). At the beginning the name intelligent building was assigned to objects that provided control over primary installations. Over time, more complex element of intelligent buildings appeared, namely the control and monitoring centre that had control over the entire building (Winnicka-Jasłowska, 2005). An intelligent building, which has an artificial intelligence and thus is able to understand the surrounding situation and find appropriate and targeted response, can adjust to users' needs better than ordinary buildings and has the ability to adapt.

However, the overall concept of comfort and the idea of adaptation to the changing environmental conditions may not be sufficient. It is well known that people also differ as far as individual perception of comfort conditions is concerned, which is influenced by the cultural element. Therefore, in order to ensure comfort in a building based on artificial intelligence one has to make it more flexible and adapt it to the needs of individual users. A building must be able to easily adapt to anticipated needs.

Indeed, most of the existing definitions of IBs in the world state that an intelligent building is an apartment building or an office building where you can live safely, comfortably and efficiently (So and Chan, 1999). An intelligent building offers us above average safety. It constantly monitors the environment through electronic sensors and reacts in an intelligent way to any irregularities; it warns us of impending danger and triggers adequate procedures to minimize potential losses (Niezabitowska, 2005). This basically means that it automatically activates the alarm, notifies a fire department, unlocks the doors on escape routes, activates smoke venting, etc.

A very important issue in intelligent buildings technology is related to energy saving policies. Optimization procedures regarding energy consumption are not only justified in terms of reducing operating costs, but also because of the environmental benefits. In order to accomplish optimization procedures, an expert system containing rules that perform energy saving strategies is set up in the central computer (Sierra et al., 2004). However, it is necessary to verify if the rules defined in the energy saving expert system may eventually alter the comfort conditions established by the control strategy expert system.

A definition of an intelligent environment is presented in a book by Cook and Das (2007): an intelligent environment is ‘one that is able to acquire and apply knowledge about the environment admits inhabitants in order to improve their experience in that environment’. Cook et al. (2009) have also clarified an intelligent environment as ‘an electronic butler, which senses features of the users and their environment, then reasons about the accumulated data, and finally selects actions to take that will benefit the users in the environment’.

Buildings are technology, they accommodate technology, and they use technology. Buildings as objects become intelligent in the moment of gaining computer ability (Sherbini and Krawczyk, 2004).

Therefore criteria by which the building needs to have to be considered as intelligent are:

- Input system that receives information by means of information receiver.
- Processing and information analysis.
- Output system that reacts to the input in form of a response.
- Time consideration that makes the response happen within the needed time.
- Learning ability.

The definition of intelligent architecture should therefore include all of these criteria and systems. Moreover, an intelligent building is therefore a building that has the ability to respond (output) on time according to processed information that is measured and received from exterior and interior environments by multi-input information detectors and sources to achieve users’ needs and with the ability to learn ( Sherbini and Krawczyk, 2004).

It is worth pointing out that intelligent architecture is a way of functional integration and developing sustainable combination of supporting material that assists in reducing environmental impact. The next step is an eco friendly or sustainable building together with its derivatives - green building, climatic-building or eco-building - which use alternative technical solutions (i.e. the use of geothermal energy, water basins, energy produced by solar panels or windmills) in order to decrease or stop energy consumption. Hybrid systems - that utilize traditional heating systems that are backed up by alternative sources - are also frequently used.

# FACTORS AFFECTING USER COMFORT

Elements that determine user comfort in intelligent buildings are multi-faceted. They consist of both the technical equipment as well as the interior design, interior equipment, quality of appliances and functional arrangement.

## Building equipment systems

The diverse requirements in an intelligent building can be met by using modern building maintenance systems. These are:

- HVAC (heating, ventilation, air condition), that is heating and cooling as well as mechanical ventilation of the rooms,
- Lighting the rooms with daylighting systems, also by refracting sunbeams and artificial adaptation to the conditions of residence,
- Modifying the intensity of light in rooms through the use of automatically controlled shutters,
- Installations (e.g. water) with consumption adjustment.

Automatic systems are controlled by artificial intelligence techniques.
There are integrated systems that operate in a facility, such as computer network, telephone network, power grid.

Safety is provided by technical and electronic systems:

- Fire detection system - fire protection
- Intruder alarm
- Access control system
- Cable and satellite television system
- Intercom system
- Sound and notification system
- Video surveillance system
- Emergency lighting system
- BMS - Building management system

Efficient operation of all these systems is not possible without providing the building with electricity and without equipping it with automatic control systems. This system allows for continuous monitoring of environmental parameters and helps keep them at a set level. What is more, these systems allow the exclusion of certain installations in the building when they are not needed. The systems can turn off the lights when there is nobody in the room (savings up to 50%), turn off the heating when there is nobody in the room (savings up to 30%) or when the room is too hot (Niezabitowska, 2005). Automatic monitoring devices and computer programs allow for the analysis of operation of these devices in search for more economical solutions.
Automatic control system determines the quality of an intelligent building. The priority, however, is full system integration. An intelligent system has the ability to learn from the environment.
An intelligent system makes a contribution as far as optimization of buildings is concerned by transforming them into dynamic space with a high standard of comfort and user satisfaction. So the ergonomic aspect of intelligent

buildings is of key importance in this respect.

It is worth pointing out that an intelligent installation is very universal; it is possible at any time to reprogram and adapt it to the individual needs of users. With the option of remote control it is possible to monitor the status of the alarm system, but also to manage other systems from outside.

The benefits of integrated systems are as follows:

- increasing comfort of the facility
- increasing safety of people and property
- facilitating management of the building (visualization)
- lowering operating costs
- lowering upgrading and expansion costs
- flexibility when changing the purpose of the building

## Factors in housing environment

Buildings provide framework for human life. But people do not want to stay in a building only to feel safe. They have numerous needs and expectations regarding everyday life. This refers to, inter alia, activities such as sleeping, resting, eating and maintaining personal hygiene. These basic bodily functions require functional adaptation of spaces, specialized equipment and arrangement. It is here that the need for affiliation, recognition, self-realization - described by Maslow (2013) - is met. Intelligent technologies also affect the appearance of a place. It should be noted that with the advent of Internet technology, data can be sent to authorized users all over the world. They can perform the same monitoring and control functions at home and when they are thousands of miles from home.
All appliances can be controlled from a single panel thanks to the integration of all system components. Smart houses can also be controlled remotely: using a telephone, the Internet or even an iPad. We also expect intelligent buildings to make decisions regarding relevant changes of physical parameters, adapting them to our needs.
An intelligent system, based on readings from appropriate sensors that monitor in real time the conditions inside and outside the house, adjusts the temperature and humidity to a predetermined level. Turning on air quality control makes the windows open automatically as soon as the system detects contamination or smoke, caused for example by cooking. When the windows are opened, heating or air conditioning is of course shut off. This environmentally friendly feature minimizes energy consumption. Below we can analyze various rooms in a building as well as the equipment and arrangement that make life easier.

The kitchen is one of the most important rooms of an apartment or a house. Technological advances associated with the development of computerization in all areas of life created a new model of smart kitchen in an intelligent home. There are many factors that affect user comfort. The design of every kitchen should provide optimum comfort conditions for food preparation, and so the kitchen should be equipped with a set of technological appliances. The kitchen is for many people a kind of a laboratory where one creates recipes and then tests and improves them. Therefore, it is a place that combines many processes from different branches of science such as chemistry, biology, and sometimes even physics. The kitchen is a place where you can hold a conversation not only between family members at the table, but also using devices connected to a smartphone, for example. Systems used to connect home appliances to the Internet, allow to control and manage individual devices and program them, to remember settings, optimum parameters of microclimate etc. (Charytonowicz, 2012). Tactile steering panels are used to control the refrigerator from the distance, cookers etc, however some devices can be controlled by mobile phone (Dubrawski, 2009). Kitchen devices are able to inform the user about breakdown, need for supplies replenishment.
The tendency to equip the kitchen in an intelligent building in an environmentally friendly manner is very important. This applies to equipping the kitchen with appliances that can save energy and water. Dishwashers are connected with fast water heating systems and can use half of the load, whereas washing machines consume less energy and reduce water consumption by half. Advanced filtration systems ensure access to safe drinking water, and new methods of cooling in refrigerators allow storing products at the appropriate temperatures. In turn, water taps are able to control the flow of water. Modern appliances are smarter, faster, more elegant and more ecological. They are definitely more suited to the requirements of users and are often multipurpose. The entire kitchen technology can make everyday life easier. An intelligent kitchen - in addition to offering technical and ecological (and economic) improvements - must meet safety requirements. It is here that one has to deal with heat, hot dishes, gas and sharp knives. Safe kitchen is one in which users can easily use kitchen appliances without any dangerous situations that

may cause an accident.
Modern kitchen is open and is usually connected to the living room. It may form a common multipurpose area or be partially combined with the living room through a hole in the wall. The openness of the kitchen makes the introduction of interesting, modern and well-designed solutions and appliances more exposed. On top of that the hosts will have visual contact with other people sitting in the living room area.

Another important room in the house is the bathroom. An ergonomic bathroom is a comfortable interior designed in an optimal way, providing easy access to sanitation. When designing this room one must provide security through the use of appropriate materials. This applies mainly to the floor, which can form a slippery surface when it is wet. These guidelines apply to every bathroom in every house but the ease of use ought to be improved in an intelligent building. Intelligent fittings for kitchens and bathrooms are becoming more and more popular. Modern taps are equipped with the following features: automatic on and off switch, coloured light-signalling device, level of water consumption and filling the tub for bathing.
In our homes and apartments there are more and more appliances and devices that make it easier to perform daily duties. Intelligent systems can now also be used in the bathroom, which is why one can not only increase the functionality and usability of the space, but also save water and electricity. The bathroom is a place where you spend a lot of time and therefore it should be above all functional and comfortable, and preferably also economical. More and more innovative solutions that one can use apply to both the technical and the aesthetic area. The surface of tiling and sanitary fixtures is covered by special coatings that help keep them clean. While most of us are accustomed to white tubs and sinks, today we have wider range of colours and a wide variety of materials - stone (e.g. marble, granite), wood, steel, and even glass. More and more often they are also equipped with features such as massage, but also speakers and screens that we can connect to our smartphones or tablets, and by doing so listen to music in the shower, answer the phone or check email.
Faucets are ecological and aimed at reducing the amount of water consumed. We can choose from a contactless, electronically controlled taps that sense movement and automatically shut off water supply as soon as one withdraws his/her hand from the stream. There are also thermostatic taps that not only eliminate the risk of burning one’s skin, but also reduce the amount of water going down during temperature regulation. Also, faucet aerators become more and more popular. Aerators create a non-splashing stream by delivering a mixture of water and air and reduce water consumption by up to 60 percent. One of eco novelties is a technology that allows to connect a water basin to a lavatory - so that the water that we use for washing is reused for flushing. Bathroom interior design is largely dependent on the size of the room. The interior can be equipped with basic accessories, but can also act as big bathing zones with relaxation areas.
The living room and the bedroom are one of the most important parts of a house. The equipment and arrangement of those rooms have a direct impact on the quality of our sleep or rest. The living room, however, can fulfil an additional function, as required by a modern way of life. If a house does not have a separate study or a work area, the living room can combine work-leisure function.
Nowadays, due to the ease of communication between people over the Internet, it is possible to work at home in many professions. The combination of these two aspects of life (private and professional) means that the boundaries between work and leisure area tend to fade away in apartment buildings, and public and private zones slowly lose their meaning. Users often seek "multifunctional zones". Within the concept of intelligent buildings their adaptability of functioning plays more important role.

Each building should meet the needs of people. It is well known that the most important human needs are met in housing environment. The quality of a house depends on many factors, namely a good functional layout, the possibility of creating an interesting arrangement, originality of solution, ecology and finishing. In addition, in each building the well-being of people is affected by, amongst others, appropriate air temperature, air quality, acoustic quality, optical quality, appropriate intensity of natural and artificial light. Studies show that people are not indifferent to the above issues. It is a process of interaction in the environment-human relationship, although one should remember that man also affects the environment.
All functional zones in a residential building must meet individual needs of users - provide the right temperature in the rooms, good lighting, the right kind of artificial lighting, and the right interior colours and make it easy to change the solutions.

The modern working environment is gradually developing towards a more ‘intelligent’ one, which means remarkable technological, architectural, psychosocial and medical innovations. Important parameters of the intelligent office building design have been sought out from among a large number of parameters of the intelligent building concepts (Himanem, 2003).

Ergonomics in the work place and the requirements concerning the quality of the work place result from the need to ensure good organization but also from an employee's performance. A person who spends long hours at work and puts a lot of intellectual effort into their work should be provided with the best possible conditions. Research has shown that an employee’s engagement is closely related to working conditions. In relation to office environment - apart from the requirements connected with the need of technical and functional quality - organizational needs play a key role as well.

The possibility of designing and building an ‘intelligent’ work environment using current technology is far more than just a glimpse of the future. Widespread research work has been put into making this enticing vision a reality. As a result, a wide variety of technological devices, solutions and scenarios for an intelligent work environment currently exist (Röcker, 2010). At present, however, merely parts of a complete, working, intelligent environment have been developed: for example, a smart LED-lighting solution has been developed that adapts to user contexts and preferences (Bhardwaj et al., 2010).

Intelligent work environment have to be ergonomic, ecologic, user friendly or adaptive to users’ needs. Many workplaces offer comfortable office rooms that have useful devices to help increase work productivity. Designing a functional intelligent work environment requires a multi professional approach – not only architectural knowledge but also technical, medical and psychosocial insight. Users’ needs must be taken into account when designing intelligent buildings (Clements-Croome, 2004).

An employee needs an individual, comfortable work environment that is well designed, well equipped with working tools and - depending on the type of work - completely or partially isolated from other areas. The place of work, for example an office building, should have a proper organizational quality that on the one hand facilitates communication, but also presents the possibility to concentrate. In a word, it should have functional qualities that will affect the creativity and productivity of an employee. An important element associated with an intelligent building is the peace of mind of a user. While the adjustment of space in an apartment building depends on the user herself or himself, it is more complex in the workplace. There is a need to create the right conditions for a number of people in different positions that require individual arrangements. It was stated that offices with various spatial arrangements affect the quality of work environment.

The sophisticated spatial solutions and the new ways of using space can influence the productivity of the workers and their spatial experience (comfort or discomfort) (Himanen, 2003). Functional connections with other rooms and areas of the building are very important in this respect. As in the domestic environment, it is important to set the right temperature, create the right microclimate, provide good lighting and use proper interior colours. One of the challenges is creating a comfortable computer terminal that is adjusted for a specific person, where the computer screen is positioned at a comfortable distance and at the proper height and glare is minimized. This is important especially for those who spend long hours in a constrained posture. Free zone in office spaces is also important for employees who - while crossing the zone - can not only change their position but also create new ideas.

Functional solutions in office spaces in intelligent buildings are very important. Office space can be divided into enclosed areas and open areas - the former include offices, conference rooms or archives, and the latter include spaces with no defined boundaries. The layout depends on the type of work and has a direct impact on the comfort of work. Each type has its advantages and disadvantages, nonetheless, each type is equally important in every office.

When designing an office one should bear in mind the essential role of team work which is important as far as the proper functioning and growth of any organization. Meetings and conferences are often organized in every office. In this context, the appropriate design becomes a necessity. This is where contemporary furniture systems that can be combined in any way come into play. What matters are flexible solutions allowing you to make quick changes. In modern offices many different functional areas are combined: work area, meeting room and lounge area. If there is enough space one might want to create an area with comfortable sofas where you can discuss interesting ideas. This system is an answer to the need of organizing short meetings or individual workplaces in a dedicated space. Thus, the concept of an intelligent building should take into account and combine the possibility to model space in a flexible and multi-functional way.

Large automated and well-furnished office spaces are to provide better physical comfort (quality of air conditioning equipment, lighting) to employees. The level of quality of the environment in an office depends primarily on the

perceived air quality. A feature that makes it difficult to shape a proper comfort zone in an office is an individual, diversified reaction to air quality. This in turn calls for individualized control of environmental parameters in the workplace.
What matters most in office buildings is the quality of both the organizational and the physical environment. A building can further work processes or impede them causing a decrease in productivity. An intelligent building offers higher quality and better conditions than a traditional building. It must not be forgotten that one of the most important elements of the quality of a building is microclimate, which has a direct impact on our mood and health.

## CATEGORIES OF QUALITY IN AN INTELLIGENT BUILDING

There are two general categories of quality in an intelligent building: the quality of the physical environment and the quality of space (Niezabitowski, 2005). Each of these categories contains elements of technical quality, functional quality, behavioural quality, organizational quality and economic quality. Building technology creates the quality of the physical environment in which an individual resides. The physical environment is shaped by the following elements: microclimate, lighting as well as the efficiency of IT and telecommunication network, automatic systems and other media. The quality of the physical environment is responsible for the physical comfort which to a large extent also translates into our peace of mind, whereas the quality of space mainly affects our psychological comfort.

The overall assessment of the quality of an intelligent building can be determined using methods and quality assessment tools for buildings. Buildings can then be classified into three groups A, B and C. One can also determine how the building fulfils user needs.

## CONCLUSIONS

Ergonomic aspects of an intelligent building are multi-faceted solutions that facilitate the use of a given facility. These are elements that are used to equip a building with adequate facilities, fittings and interior design features and the right functional solutions. They not only influence the quality of an intelligent building but also user comfort. In both the housing and office environment they depend on users' individual needs. A modern intelligent building must be ecological, and therefore environmentally friendly and sustainable. There is a close relationship between man and his environment, which has a direct impact on his psyche, emotions, mood and health. As a result, human needs result from personality traits and physiology. The desire to stay at a certain place depends on our mood.
The aim of an intelligent building is to create a friendly, comfortable housing/work environment while striving to achieve considerable cost savings.
A key issue in the case of both the residential and office buildings is the flexibility of solutions and, therefore, adaptability and the ability to adapt to changing environmental conditions.

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